DISSERTATION

Gary Andrew O'Dell

The Graduate School

University of Kentucky

2003

ECO-EFFICIENCY AND LEAN PRODUCTION: ENVIRONMENTAL PERFORMANCE OF JAPANESE TRANSPLANTS IN THE UNITED STATES

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A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
Gary Andrew O'Dell

Morehead, Kentucky

Director: Dr. John Pickles, Professor of Geography

Lexington, Kentucky

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To Carol, who never doubted.

ABSTRACT OF DISSERTATION

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Until recently, Japanese direct investment in U.S. manufacturing has been been one of the most significant components of total foreign investment. A greater impact may have been achieved by the diffusion and hybridization of Japanese management methods, commonly known as "lean production." Attributes of these systems such as a focus upon efficiency and continuous improvement provided a competitive advantage that allowed Japanese corporations to penetrate and capture technology markets formerly dominated by Western industry. A number of writers, supported by empirical research, have also observed that these same characteristics provide a potential for environmental benefits in terms of resource productivity and pollution prevention. These concerns are central to an emerging perspective, known as ecological modernization, that represents an evolutionary change in industry's and government's approach to environmental issues from reactive to proactive.

This study is grounded within the theoretical framework of ecological modernization, and explores the role of three key features of this movement, eco-efficiency, industrial ecology, and environmental management systems, as part of a strategy to compare the environmental performance of Japanese transplants to non-Japanese facilities in the United States. The study area consists of the four states, Indiana, Ohio, Kentucky and Tennessee, which represent a dense concentration of Japanese manufacturing investment. The study employs both quantitative and qualitative methodologies, and has three primary objectives: (1) to construct an eco-efficiency indicator that uses readily available data and is applicable to a broad range of firms; (2) to compare the performance of Japanese and non-Japanese firms using the eco-efficiency and other appropriate indicators, and through survey techniques and case studies to develop an understanding of environmental policies and practices at the firm level; and (3) to provide a comprehensive account of the geographical distribution and characteristics of Japanese investment in the region.

KEYWORDS: Japanese Transplants, Lean Production, Eco-Efficiency, Environmental Performance, Environmental Management Systems

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I cannot begin to measure the support I received from my wife, Carol Sue O'Dell, whose emotional commitment and clear thinking contributed in many ways large and small to the completion of this project. Carol was both my inspiration and my foundation, who allowed my mind to soar while keeping my feet firmly planted. I must also acknowledge my mother, M. Elizabeth O'Dell, who from the moment I first learned the alphabet diligently cultivated in me a love for science and the natural world. At the Kentucky Department for Environmental Protection, training coordinator Elizabeth Shelby went far beyond the call of duty to assist me in navigating the bureaucratic hurdles involved in pursuing a graduate degree during the decade I was employed by the Division of Water. My colleagues at Morehead State University provided much needed emotional and technical support during the writing process. Last, but not least, I would like to thank the plant personnel who hosted my visits for the case studies, and the many confidential respondents to my survey.

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1.1. Industrial restructuring in the United States: Implications for the environment

Since the beginning of the Industrial Revolution, American industry has generally regarded the natural environment in limited terms, as a endless source of raw materials for production processes and as an unlimited sink for wastes generated through those processes. This simplistic view was first challenged during the 1960s and 1970s, when perception of widespread environmental degradation became an important public and political issue. Although the roots of the environmental crisis are many and include American lifestyles based on mass consumption, the perceived role of manufacturing industries in terms of resource depletion and pollution was highly visible and thus attracted criticism.

For four decades, American industry has faced considerable pressure to alter manufacturing practices and lessen its impact upon the environment. These pressures were focused initially upon industry from external sources including activist environmental organizations, increasingly complex environmental laws and regulations, and consumer responses favoring “green” products and corporate reputations. More recently, such developments as shareholder activism and industry group peer pressure have been complemented by the rise of internal pressures that may prove equally significant in modifying corporate behavior.

While a sense of corporate social responsibility has increasingly become a part of corporate culture, internal motivations for improved environmental performance are primarily economic in nature. These internal motivations include a desire to avoid the costs of compliance with prescriptive regulations and to simultaneously improve the overall efficiency of production processes and thereby increase profitability. Changes in the regulatory environment are providing greater support for these objectives, tending more to encourage innovation in the search for “win-win” solutions to environmental problems that benefit both business goals and environmental quality. This process of evolutionary change in industry’s and government’s approach to environmental issues has been the focus of an emerging perspective known as ecological modernization.

At about the same time, during the mid-to-late 1980s, that these developments were beginning to have a significant impact upon government policy and business practice, another phenomenon was attracting attention. The trend toward globalization of markets had stimulated an expansive growth in foreign direct investment by and in the United States. While the bulk of manufacturing investment from abroad came to the U.S. from Western Europe, there was at this time an extraordinary acceleration in the magnitude of investment by the island nation of Japan. Previously, Japanese investment in U.S. manufacturing had been relatively insignificant, but now rose to third place just behind Germany and the United Kingdom.

These Japanese transplant factories, most newly constructed or “greenfield,” brought with them an industrial management system and business philosophy that differed in many important ways from traditional, Fordist mass production. Japanese production management emphasized, was in fact obsessed by, an attention to efficiency whereby no product, no process, no system was ever considered as good as it could be. Concepts of continuous incremental improvement and elimination of all waste were at the core of a system that also featured a revolutionary mode of labor relations remarkably effective at harnessing the collective knowledge of the work force.

In the opinion of alarmed Western observers, it was these very attributes that had provided such a competitive advantage to Japanese corporations allowing penetration and capture of technology markets formerly dominated by Western industry. Accordingly, many companies in North America, and to a lesser degree, Europe, began to experiment with adoption of key features of the Japanese production system. In the new overseas environment, the Japanese system became a hybridized version of the original, with transplants borrowing or substituting additional elements from traditional Fordism even as Western corporations began restructuring operations to practice Japanese-style management.

The Japanese focus upon waste elimination and efficiency resonated with the emerging policy focus upon resource productivity and pollution prevention central to the ecological modernization movement. The potential of Japanese management systems to improve the environmental performance of manufacturing facilities thereby became a question for debate in government and academic circles and among mainstream and radical environmental organizations, although this aspect occupied far less attention than potential improvements in economic performance. During the 1990s, as investment inflows from Japan dwindled to a trickle following the collapse of the Japanese economic bubble, and industrial innovations once perceived as radical were incorporated into Western management orthodoxy, interest in the Japanese transplant phenomena also generally diminished.

In the United States, exceptions to this overall fading of public and academic concern were regions where Japanese automakers had established major assembly plants and created networks of dependent supplier firms, both domestic and transplant companies, which had become significant to local economies. Commonly, in such areas, regional universities had established programs, frequently with the automakers as benefactors and collaborators, to conduct research, advise and instruct in Japanese manufacturing methods. One such locale was the Bluegrass region of Kentucky. There, in 1986, Toyota Motor Manufacturing began construction of their largest global manufacturing plant, today employing more than 7,000 workers, and simultaneously the University of Kentucky in nearby Lexington established the Center for Robotics and Manufacturing Systems which features a Lean Manufacturing Program.

It was into this context that, in 1998, the author of this report entered and began research on an earlier project concerning Japanese transplant corporations. This project was undertaken at the instigation of Dr. P. P. Karan of the University's Department of Geography, who invited me to present a paper at a forthcoming conference addressing the local and regional impact of Japanese investment in Kentucky, sponsored by the Japan Studies Program at the University of Kentucky. My previous experience with Japanese culture and industry was limited to a graduate-level course on Japan, taken some years before and taught by Dr. Karan, however, sought to tap my professional expertise in an area where direct knowledge of Japan would not constitute a handicap, drawing instead upon my experience as a long-term employee of the Kentucky Department for Environmental Protection and my continuing interest in environmental issues. The topic he therefore asked me to investigate and present for the conference was: "What has been the environmental impact of Japanese investment in Kentucky?"

A simple question, indeed, but more challenging than I believe either of us anticipated. After considering this proposition for some time, I concluded that assessing the cumulative environmental impact of a group of widely-dispersed facilities was a task beyond my capabilities to achieve with reasonably limitations of time and resources. Two primary obstacles blocked pursuit of this particular inquiry: (1) Determining an impact requires that one be able to measure the condition of some environmental quality characteristic both before and after the event or circumstances that produces an effect. This is a complex, time-consuming, and expensive undertaking in regard to even a single facility, let alone nearly a hundred. One must also make a choice as to which environmental condition will be measured, and what may be appropriate for one facility may not be appropriate or even applicable for another. (2) Different pollutants are transported by and have effects upon different, or sometimes multiple media, and these effects are often geographically diffused over a wide area. Consequently, it is difficult and often impossible to disaggregate effects resulting from general industrial activity in a region.

This evaluation indicated that the investigation of environmental issues concerning Japanese transplant facilities would require a different approach. Instead of focusing upon the effects of pollutants, it would be far more practical to examine the origin and management of pollutants. Since information about a wide range of industrial pollutants is readily available through federal public-domain databases for a large population of manufacturers, it would be possible to compare one facility against another. Thus, instead of assessing environmental impacts directly, this can be accomplished through the proxy of environmental performance.

This was the tactic chosen, and the results were presented at the "Japan in the Bluegrass" conference in April 1999 and subsequently published in the volume of the same title issued by the University Press of Kentucky in 2001. Details of the research findings are discussed in Chapter 5 and will not be presented here other than to introduce a few summary points that provide the context for the larger, subsequent research project. The major finding of the pilot study was that Japanese facilities appeared to demonstrate superior environmental performance when that performance is measured on the basis of pollutant releases per worker. This is a somewhat unconventional way to measure performance, but provides some information about the efficiency of waste management that can be used as a basis of comparison for *firms of a similar size operating in similar industries*.

This last observation, italicized, is a distinction that was not made in the conclusions for the pilot study. In a number of ways, the pilot study was overly simplistic and did not take into account several factors that are included in the present research; e.g., the relative toxicity of the pollutants involved. Secondly, the earlier study had an entirely different theoretical basis because an important potential explanatory variable, the distinctive production system of Japanese transplants, was not evaluated as a contextual factor. Instead, the pilot study was premised on the concept of home-country, host-country differences, where an unfamiliar environment may pose operational difficulties for a transplant firm.[1] In the current work, differences in the nature of production systems are central to the framing of research questions.

The present research project is intended to investigate terrain that is similar in nature to the pilot study; i.e., the environmental performance of Japanese transplant firms compared to non-Japanese firms, but employs a more sophisticated methodology and a larger sample population based on firms located in four contiguous states: Indiana, Ohio, Kentucky, and Tennessee. A second goal of the project is to provide a more general analysis of the characteristics of Japanese presence in the United States, again focusing upon the four-state region. This analysis brings much of the excellent but widely scattered academic literature on the subject together with some original contributions to fill an existing gap for a comprehensive and integrated work on the transplant phenomenon. This gap has, to my knowledge, existed since the publication of Kenney and Florida's 1993 volume, *Beyond mass production*. Further, it is hoped that the fairly extensive list of citations will be of value to future researchers.

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[1] See, for example, Pearson, C.S. (1985), *Down to business: Multinational corporations, the environment,*

The remainder of this introductory chapter presents a general overview of topics that will be discussed at some length in the chapters that follow; specifically, concerning the scale of Japanese investment in the United States, the nature of the Japanese production system, and the context of U.S. environmental regulation. These topics are followed by a more detailed outline of the objectives of the study and the methodology employed.

1.2. Japanese transplants in the United States

1.2.1. The growth of Japanese direct investment in the United States

From relatively modest levels prior to 1980, foreign direct investment in the United States (FDIUS) has dramatically increased until transplant firms today represent a major segment of the American economy. By 1998, the Japanese position represented more than $132 billion in equity and net outstanding loans to their U.S. affiliates, second only to the United Kingdom and 16 percent of total FDIUS (Bargas and Troia 1999). In manufacturing, Japan ranked behind only the United Kingdom and Germany, having invested nearly $50 billion to acquire existing or establish new ("greenfield") manufacturing facilities in the United States. Following the collapse of Japan's so-called "bubble economy" in 1990 and subsequent recession, capital inflows plunged dramatically, briefly resurrected in the mid-90s, and dropped into negative numbers as disinvestment began to exceed inflows (Figure 1.1).

Japanese greenfield investment has concentrated primarily in two geographic regions, along the Pacific coast and along a corridor extending from southern Michigan through

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and development. Washington: World Resources Institute.

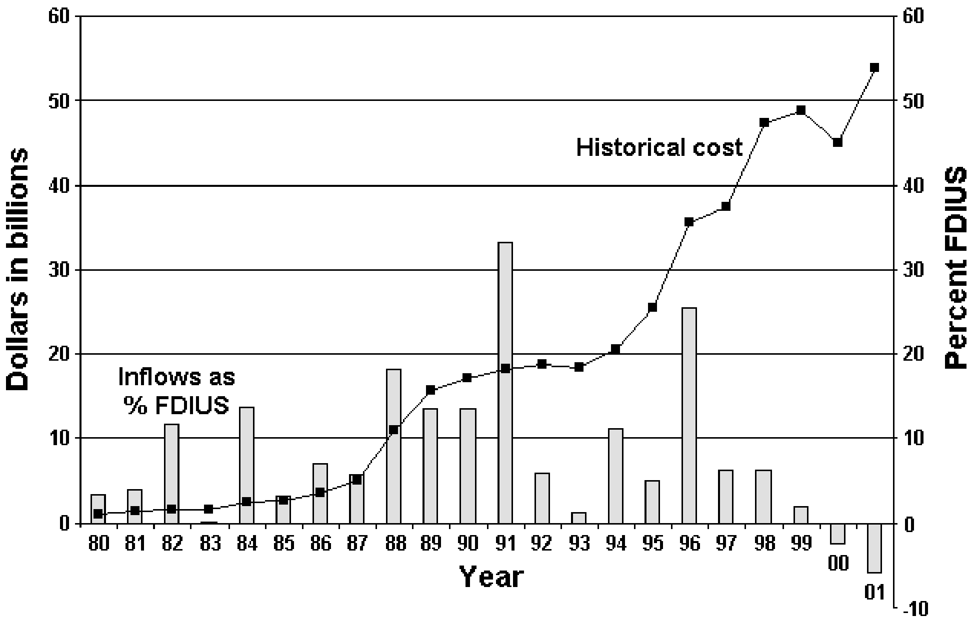

Table 1.1. Japanese Foreign Direct Investment in the United States (FDIUS), manufacturing sector

Source: U.S. Department of Commerce 1999.

Columns represent Japanese capital inflows as percentage of total foreign manufacturing investment.

Georgia. The nature of the investment differs between these two regions. Most Japanese facilities on the West Coast are associated with the electronics industries, whereas production of motor vehicles and components dominates the interior corridor. Furthermore, new Japanese facilities tend to be constructed in less populous areas, generally avoiding established industrial centers where other foreign-owned manufacturing plants are located (Shannon *et. al*., 1999).

1.2.2. Japan's growing challenge to U.S. industry

During the 1980s and 1990s, Japanese corporations began increasingly to dominate world markets formerly considered secure territory by U.S. manufacturers, achieving global leadership in numerous industries including consumer electronics, automobiles, semiconductor equipment and machine tools (Giffi, Roth and Seal 1990; National

Research Council 1997). In consequence, Japanese industrial production systems have come to be widely regarded as representing models of industrial efficiency and economy. Initially, most U.S. corporations took a defensive market maintenance position, failing to study the methods of other countries or to make fundamental changes in management and production strategies.

The Japanese "economic miracle," contrasting so sharply with the sluggish U.S. economy and shrinking markets for U.S. goods, combined with the entrance of numerous Japanese transplants into the U.S., forced many American corporations to take a closer look at Japanese industrial management. During the 1950s and 1960s, according to Gordon (1988), the U.S. viewed Japan's economic success as an appropriate role-model for developing countries that would prevent them from succumbing to communism. By the mid 1980s, however, the "audience" perceived to be in need of the Japanese role-model had shifted to target the United States. A host of works by U.S. authors stressed the theme of "learn from Japan," projecting Japanese management practices as a model and catalyst which would stimulate a resurgence of American industrial initiative. The debate in the management literature concerned "the appropriateness of appropriating management techniques and systems from Japan and redeploying them effectively in an American industrial context" (p. 173).

Many Western companies have, in recent years, sought to emulate the Japanese production style but most have achieved only limited degrees of success if any, since attempts to implement Japanese methods are often piecemeal and overlook the basic differences in corporate culture and philosophy that are the foundation of Japanese economic achievement (Giffi, Roth and Seal 1990). Despite this difficulty, a growing number of companies including General Motors and Ford have been able to adopt Japanese systems, either by individual plants or on a company-wide basis. Despite continuing differences between U.S. and Japanese industrial systems, the overall trend is toward convergence in innovation strategies and practices between U.S. and Japanese corporations, producing hybrid production systems in both Japanese transplant and domestic firms (Kenney and Florida 1993). A report released by the U.S. Office of International Affairs noted that:

> Companies in each country are focused on attaining innovation-related capabilities associated with firms in the other nation. For example, Japanese firms are putting greater emphasis on inventiveness, while U.S. firms are focusing more on being responsive to market needs, improving existing products, shortening product cycles, and *improving manufacturing processes and quality* (National Research Council 1999,2, emphasis added).

The distinctive manufacturing management practices that are often referred to as "lean production" were developed in Japan after World War Two by Toyota and freely disseminated to other Japanese manufacturers, including competitors, during the 1970s (Ohno 1988). The English-speaking world received its first introduction to "just-in-time" and other aspects of lean production through an article in a management journal in 1977 describing the Toyota system of production (Sugimori, Kusunoki, Cho and Uchikawa).

1.2.3. Japanese production methods

The Toyota system was largely predicated upon the elimination of all forms of waste for economic reasons, and the company's financial stability following the 1973 oil crisis and subsequent recession led to considerable interest by Japanese industry in the methods that had allowed their continuing success (Ohno 1988).

Basic to the global success of Japanese multinationals have been innovative strategies in the organization, processes, and management of industrial systems (Cusumano 1985). Japanese manufacturers are generally characterized by highly integrated organizations – keiretsu - that emphasize control over suppliers of raw materials and components and over distribution channels to a far greater extent than American corporations. In terms of technology, Japanese companies tend to invest relatively more in research and development, reflecting a strategic direction that focuses upon gaining leadership in innovation and new product introductions (National Research Council 1997, 1999).

Development of manufacturing systems that are both flexible and cost effective allows Japanese companies to readily deal with volume changes, product mixture changes, and to swiftly introduce new products (Giffi, Roth and Seal 1990). Innovations in management techniques, however, are perhaps the most distinctive characteristics of Japanese manufacturing operations. The core concepts that today underpin most Japanese production systems are those of continuous improvement and just-in-time (JIT). Together these methods constitute so-called "lean production" systems.

Continuous improvement, or "kaizen", is aimed at both enhancement of product quality and operations efficiency, involving a close interaction between the work force and management and between internal and external customers. Continuous improvement focuses on small incremental changes that flow out of the daily experience of the production process. Traditional mass production operates on the limited premise of "good enough," under which a certain number of product defects are considered acceptable, and under which certain material wastes in the production process are considered unavoidable. In contrast, the goal of continuous improvement is perfection, seeking a constant decrease in production costs along with zero defects, zero inventories, and an endless product variety (Womack 1990). This philosophy is intimately tied to the concept of just-in-time production, aimed at the elimination of waste throughout all operational functions and improving materials throughput. JIT, according to Voss and Clutterbuck (1989,8), is “The cost effective production and delivery of only the necessary quality parts in the right quantity, at the right time and place, while using a minimum of facilities, equipment, materials, and human resources.” JIT is the elimination of anything that is unnecessary, any form of waste, and thus addresses not only physical waste but also processual waste, as in wasted time or wasted motions.

Through the elimination of many forms of waste, Japanese manufacturers seek to maximize economic efficiency. Because one important aspect of economic efficiency is reflected by the efficiency with which raw materials are conserved and physical waste by-products are minimized, economic efficiency can be said to be in part analogous to ecological efficiency. Waste management practices of Japanese transplants in the United States can thus be compared with those of non-Japanese corporations to determine whether an improved environmental performance also derives from the assumed greater efficiency of Japanese production systems. If so, then successful adaptation of Japanese industrial best management practices (BMPs) may have significant implications for improving environmental performance of American firms. Conversely, lessons derived from Japanese environmental policies and practices may have distinct economic benefits, as has been the case with management and production practices.

1.3. New perspectives on the environment

Prior to 1969, air and water pollution were considered as strictly local matters, and so the federal government played little part in environmental policy-making. By the late 1960s, however, environmental policy was catapulted onto the national agenda. The widespread perception of environmental crisis was motivated by the developing science of ecology and by a series of books, such as Carson's *Silent Spring*, that alarmed the public and created a national environmental movement. The National Environmental Policy Act was passed in 1969, and the decade of the 1970s witnessed a flurry of landmark legislation intended to protect environmental quality. Over the next twenty-five years, legislation of particular relevance to industrial pollution were the Resources Recovery Act (1970), the Clean Air Act Amendments (1970, 1977, original Act 1963), Federal Water Pollution Control Act (1972, amended 1977, 1987), Toxic Substances Control Act (1976), Resource Conservation and Recovery Act (1976, amended 1984), Comprehensive Environmental Response, Compensation, and Liability Act (1980, a.k.a. "Superfund," amended 1986), Emergency Planning and Community Right-to-Know Act (established the Toxic Release Inventory 1986, amended 1991, 1994, 1996). Environmental legislation tended to be enacted for single media, separately targeting air, land or water pollution with a "react and cure" strategy that did not address the source of pollution. The failure to develop integrative policies created agency divisions from the federal level down to the local, each concerned only with their particular medium, and led to overlapping jurisdictions, conflicting goals, and duplicate reporting requirements (Wallace 1995, 122).

Federal environmental legislation set limits to the amounts of pollutants that could be released into the environment by facilities. Industrial pollution management under the environmental protection paradigm thus attempted to shift wastes from places where they are potentially harmful to places where this potential can be controlled, or to alter the wastes into forms less damaging to the environment. Thus end-of-the-pipe "pollution control" is hardly *control* at all; it is, rather, diversion or mitigation of the environmental effects of polluting waste products (Lynn 1989). Such approaches do not usually reduce the actual volume of waste, and diversions, as Tarr (1996) noted, often had the effect simply of transferring pollutants to another media or another place.

Furthermore, the requirements set for industry turned into moving targets, because the initial goals were unrealistic and required constant revision. Vague and inconsistent directives stimulated litigation to clarify interpretation, so that environmental policy was frequently set by judges untrained in environmental science. These legalistic determinations often forced inflexible and often inappropriate procedures, and reduced the scope for negotiation on the most cost-effective procedures (Wallace 1995, 119-120). Confusion and frustration were only heightened by the alternate fluctuations in the potency of regulatory provisions and enforcement as political administrations and agendas changed. The net effect of command-and-control environmental protection was to create an institutionalized adversarial relationship among government agencies, regulated industries, and environmental organizations (Petulla 1997; Wallace 1995).

By the mid-1980s, the weaknesses in the approach of environmental protection by direct regulation were evident even to policy makers, though this had long been apparent to both environmentalists and the business community. From an economic viewpoint, as noted by Freeman (1990):

> The pattern of pollution control activities required by the regulations is likely to be excessively costly. In other words, the activities are not likely to be cost-effective. Second, the incentive structure created for firms and individuals is inappropriate. Since compliance with the regulations is costly, there is no positive incentive to control pollution, only the negative incentive to avoid penalties. Not only is there no incentive to do better than the regulations require, but the incentives to comply with the regulations themselves may be too weak to overcome the disincentive of bearing the costs (pp. 152-153).

From the viewpoint of environmentalists, environmental protection is a failed paradigm, an approach that despite some modest success has been unable to halt the increasing and globalized degradation of the natural environment. In 1990, Hilary French wrote: "The approaches to date...have tended to be technological Band-Aids rather than efforts to address the roots of the problem: inappropriate energy, transportation, and industrial systems" (p. 110). Barry Commoner (1992, 43-46) noted that any form of pollution control technology always allows some pollution, so that increases in overall production negate the effects of pollution control. Reliance on control devices is self-defeating; prevention of pollution during the production process is the only real solution: "We now know that environmental pollution is an incurable disease; it can only be prevented."

Despite the evident limitations of the environmental protection paradigm, the application of technology-based regulations and national standards has brought about a cleaner environment. The existing structures of this regime, however, are inadequate to meet the environmental challenges of the present and future. In 1998, Pamela Hill of the U.S. Environmental Protection Agency expressed agency sentiment when she wrote: "It is clear to the EPA that the tools used for the first thirty years are no longer sufficient" (p. 626). Karl Hausker (1999) of the Center for Strategic and International Studies (CSIS)), in a synthesis of reports by presidential and congressional commissions, consensus-building forums, expert panels and individual authors, notes that there is a general agreement on the need for an evolutionary change in the nation's environmental protection system. The consensus is that continued growth in the economy will only worsen pollution problems. Resonating Commoner's (1992) statement that pollution cannot be cured but only prevented, Hausker observes that the current environmental protection system does a poor job of promoting pollution prevention and process redesign, doing little to encourage innovation. If the system fails to evolve, "further environmental and economic progress will be limited" (p. 8). The directions that such evolution should take, according to his synthesis of expert opinion, would be:

- Toward a more performance-based, information-rich, technology-spurring, flexible, accountable regulatory system;
- Toward a broader array of policy tools that promote continuous environmental improvement;
- Toward stronger private sector management systems that internalize the same stewardship ethics embodied in environmental statutes (p. 4).

The increasingly apparent failure of the tools and methods of the environmental protection paradigm to offer more than temporary, narrowly-focused quick-fix solutions to continuing environmental degradation was the driving force prompting a search for a new paradigm. By 1990 the long-entrenched paradigm of environmental protection had begun to shift toward an approach that was termed "ecological modernization." Ecological modernization holds that industrial capitalism and environmental quality are not mutually exclusive. In this view, businesses that seek to minimize the environmental impact of their operations by increasing resource productivity and minimizing or eliminating pollution achieve efficiency gains and thereby become more competitive and profitable. Under ecological modernization, the role of government is enabling, establishing the imperative for improvement through innovative but strict regulations while improving the capacity of industry to respond (Murphy 2001).

Many environmentalists find the term "sustainable development" to be unpalatable in its automatic association of unlimited economic growth and environmental quality. Decoupling the growth element, they prefer, instead, to conceptualize in terms of "sustainability," "sustainable economies" or a "sustainable society." Among the leading proponents of this viewpoint are economist Herman Daly, who has long advocated the "steady-state" economy (Daly 1974, 1991), and Lester R. Brown, founder of the Worldwatch Institute, who downplays "sustainable development" in favor of an approach he terms the "eco-economy."

Perspectives such as those of Daly and Brown do not argue for a stagnant economy or an end to human progress, but rather the restructuring of current institutions to seek an equilibrium within the carrying capacity of the planet. As Brown (2001, 21) notes, "The preeminent challenge for our generation is to design an eco-economy, one that respects the principles of ecology. A redesigned economy can be integrated into the ecosystem in a way that will stabilize the relationship between the two, enabling economic progress to continue." Daly's steady-state economy and Brown's eco-economy represent perspectives very similar to ecological modernization.

The environmental protection paradigm evolved at a time when technological and remedial approaches appeared, at least initially, to offer solutions to a narrowly defined environmental problematic, chiefly industrial pollution. These approaches served to reduce the most excessive releases into the environment, but at the cost of erecting a massive environmental bureaucracy, equipped with a vast and bewildering array of *ad hoc* regulations. This agency and regulatory structure has proved not only incapable of coping with widespread environmental degradation but has stifled innovation that may well have proved more capable of producing concrete results. Many of the inadequacies of the end-of-pipe environmental protection approach were apparent even during the late 1970s.

A decade later, it had clearly become evident that environmental problems were no longer local, no longer relatively simple, but had evolved to become global threats of vast complexity. Tools and methods poorly suited for dealing with problems of limited scale were wholly inadequate for dealing with both the intensification and globalization of environmental hazards. Accordingly, just as the narrow, reductionist mind-set defined by environmental protection has evolved paradigmatically toward the more holistic perspective of sustainability, the practical methodology of the paradigm has evolved from the rigid presciptive approach to ecological modernization, one that encompasses multiple approaches and encourages participation and innovation within the regulated industrial community.

1.4. The objectives of the study

This study is intended to assess the environmental performance of Japanese industrial firms in a study area comprised of the states of Indiana, Ohio, Kentucky, and Tennessee, which represents one of the densest concentrations of Japanese investment in the United States. Because this concentration in large part, though not exclusively, consists of networks of supplier firms operating in connection with major automobile assembly plants distributed throughout the study area, special attention will be given to the automotive industry. The research strategy compares Japanese firms against non-Japanese firms, which, depending upon context, may separate U.S. firms from those of other, non-Japanese ownership or may aggregate all non-Japanese firms.

Superior environmental performance is considered to be proportionately lesser rates of generation and uncontrolled (not recovered) releases of wastes that are considered hazardous or toxic. The research will be focused on three concepts related to hazardous waste management: eco-efficiency, industrial ecosystems, and environmental management systems. These are all key features representing the ecological modernization movement, and are defined and described in Chapter 2. Of these three, only the investigation of eco-efficiency produces quantifiable results indicative of environmental performance. In one sense, eco-efficiency refers to strategies that reduce environmental impact while simultaneously generating cost savings, thus improving firm efficiency. More specifically, eco-efficiency is the ratio of some economic variable, such as net value added or units of production, compared to one or more variables related to environmental influence, such as resources consumed or toxic chemicals released to the environment. The other two concepts, industrial ecosystems and environmental management systems, are investigated in terms of their roles in waste management strategies rather than for specific outcomes.

The issues involved concern the efficacy of Japanese management systems as regards pollution prevention. Although many of the key features of Japanese systems have been absorbed by non-Japanese firms in the United States, the underlying assumption in this study, derived from the literature, is that Japanese transplant firms have transferred more complete, and presumably more effective, versions of the original systems from Japan than can be implemented by non-Japanese imitators. A number of other studies, described in Chapter 4, have assessed environmental performance for firms in the United States, comparing those who employ Japanese methods against those who do not, but these studies have not specifically separated Japanese firms from non-Japanese. Other studies have compared environmental performance of foreign firms against U.S.-based firms, but again have not separated Japanese from other nationalities. Thus, a key issue in this study is how nationality affects environmental performance, rather than the "lean production" system per se.

Other issues are also involved in performance assessment. Some industries are considered to be "dirtier," than others, producing more total pollution or pollution of a more hazardous character. If industrial sector is controlled, the size of the firm is also anticipated to be of possible significance; logically, if two firms are engaged in the same type of production, the larger one should generate more waste. It may be, however, that economies of scale could negate this assumption.

From these observations and assumptions, the following hypothesis is proposed:

> Japanese firms will exhibit superior environmental performance, measured using various indicators, than non-Japanese firms of equivalent size and located within the same industrial sector, regardless of the production systems employed by the non-Japanese firms.

Based on this central hypothesis, the following research questions will be investigated, making comparisons based on various characteristics and potentially significant factors:

- How do Japanese and non-Japanese firms compare in the magnitude of generated and released waste?

- How do Japanese and non-Japanese firms compare in the toxicity of generated and released waste?

- How do Japanese and non-Japanese firms compare in the proportional magnitude of generated waste that becomes released waste?

- How do Japanese and non-Japanese firms compare in the proportional toxicity of generated waste that becomes released waste?

- How do Japanese and non-Japanese firms compare in magnitude and toxicity for generated and released waste in terms of the industry sector distribution?

- How do Japanese and non-Japanese firms compare in magnitude and toxicity for generated and released waste in terms of firm size?

- How do Japanese and non-Japanese firms compare in the number of federal waste programs under which they are regulated, and does this have significance in terms of waste magnitude or toxicity?

- How do Japanese firms vary among themselves in terms of magnitude and toxicity of generated and released waste, according to size or industrial sector?

- How do non-Japanese firms vary among themselves in terms of magnitude and toxicity of generated and released waste according to size or industrial sector?

- How do Japanese and non-Japanese firms compare using eco-efficiency indicators?

- Which eco-efficiency indicator appears to have the greatest utility?

Related to these questions, but not directly pertinent to environmental issues:

- How do Japanese and non-Japanese firms compare in terms of industrial structure (distribution within industrial sectors)?

- How do Japanese and non-Japanese firms compare in terms of the distribution of firm sizes?

- What is the spatial pattern of Japanese investment within the study area, and what factors influence this?

In addition, the following areas will be investigated using qualitative methodologies:

- What are some examples of specific waste management strategies, such as process modifications or alternative technologies, are used by

Japanese transplants within lean production systems to maximize resource productivity or minimize pollution?

- What is the role of Environmental Management Systems (EMSs) such as ISO 14000 in Japanese transplants and how are these integrated with lean production?

1.5. Methodology

I propose to examine the environmental performance of Japanese industrial affiliates in the United States by focusing on the regional concentration of firms along the Indiana-Georgia corridor, using waste management practices as a basis and comparing performance of Japanese-owned companies to those of American or other national ownership. The research questions will be addressed using the following methodologies:

- Analysis of toxic waste generation and management data collected by the U.S. Environmental Protection Agency and available through the Toxic Release Inventory (TRI) and Biennial Reporting System (BRS) databases.

- Preparation of a mail survey instrument regarding environmental policies and waste management practices, sent to all Japanese affiliates in the study area.

- Case studies of individual firms, focusing on strategies used to reduce resource consumption and waste production.

Accordingly, the research program will use both quantitative and qualitative methodologies, applied respectively to different aspects of the study. A detailed discussion of the methodologies employed is provided in Chapter 5.

1.6. Significance of the study

This study contributes to the growing literature on ecological modernization and eco-efficiency, in the context of a specific system of production that is attributed with a greater efficiency than traditional Fordist systems and hence is potentially more eco-efficient. Because ecological modernization is concerned with the restructuring of industry into forms that are more ecologically sustainable, Japanese systems may thus represent a model to be encouraged through government's enabling role in ecological modernization.

Second, an effort is made to construct an eco-efficiency indicator that has wider application than many of the firm-specific indicators now in use. An indicator such as "Factor X," described in the following chapter, is one of the best efforts yet obtained to accurately represent eco-efficiency, yet, like most such constructions, requires detailed information that is specific to the company. According, such eco-efficiency measures are of little value to investigators interested in comparing environmental performance among different firms. While the derived indicator also has limitations, it may assist other investigators in developing a more suitable metric for eco-efficiency.

Third, this study helps to fill a gap in the literature concerning Japanese transplants and lean production systems by assembling and interpreting widely scattered articles, and by providing some original insights into the pattern and characteristics of Japanese investment in the United States and the environmental practices and policies of these transplant firms.

Chapter Two

The ecological modernization of production

2.1. Concepts of ecological modernization

The production system devised and employed by Japanese corporations, according to most analysts, represents an evolutionary development that, through diffusion, is transforming Western industrial capitalism (e.g., Fujimoto 1999; Nakamura *et. al*. 1999; Kenney and Florida 1993; Womack 1990). Japanese management systems are commonly referred to as "lean production" in recognition of their central focus upon efficiency and elimination of all forms of waste, and, accordingly, there is a growing perception that these lean systems may be more environmentally benign than traditional production methods (e.g., Romm 1994; Florida 1996). These characteristics position lean production as one of the elements of an emerging body of environmental social theory known as ecological modernization.

Ecological modernization theory is today the dominant form of discourse concerning how modern industrial societies are dealing with environmental problems through transformations in social practices and the restructuring of institutions (Mol 2000). This body of theory acknowledges that industrialization has led to severe environmental degradation, but holds that the same institutions responsible for creating environmental problems possess the capability to solve them. This can be accomplished through innovative transformation of industrial and regulatory systems from an approach that has historically been reactive and curative to one that is environmentally proactive and based on prevention (Simonis 1989; Mol 1995). For industry, through a process of innovation and change, ecological concerns are integrated and embedded within the production function. Government's role is enabling, establishing the imperative for improvement through innovative but strict regulations while improving the capacity of industry to respond (Murphy 2001).

The basic concepts within ecological modernization theory were first developed in political science and sociology and spread to other disciplines including geography, beginning in Germany and the Netherlands with the work of Huber (1985) and Jänicke (1985) and, in North America and Britain, significant contributions jointly and separately from Arthur Mol and Gert Spaargaren (Spaargaren and Mol 1992; Mol and Spaargaren 1993; Mol 1995, 1996, 1997; Spaargaren 1996). Ecological modernization theory in the 1980s was not a derivative from pre-existing social theory but was instead driven by contemporary challenges and concerns; as a critical response to the countermodernity focus of radical environmentalism and as a way to conceptualize new developments in environmental management and environmental policy (Buttel 2000). Accordingly, ecological modernization theory has two primary dimensions: analytical and descriptive, on the one hand (e.g., Hajer 1995), and as a prescriptive for implementing a program of policy reform to stimulate innovation (e.g., Huber 1985; Jänicke *et. al*. 1989; Simonis 1989; Weale 1992; Gouldson and Murphy 1997).

Ecological modernization assumes that industrialization rather than capitalism is the source of environmental problems, and that, since capitalism is flexible enough to accommodate change, solutions to the environmental problematic do not require that society be dismantled and rebuilt (Dryzek 1997; Mol and Spaargaren 2000). The radical approach, calling for fundamental structural and cultural change, alienated the corporate and political world, so that ecological modernization's potential to align the interests of both capitalism and ecologism has been perceived as far more palatable (Hajer 1995; Curran 2001). As Hajer (1995, 31) notes, "ecological modernization suggests a positive-sum solution to what had until then been seen as a zero-sum problem." As conceptualized, environmental degradation is a consequence of poor resource utilization; businesses that improve their environmental performance receive simultaneous improvements in efficiency. Ecological modernization is therefore attractive because it offers hope, rather than the relentless pessimism of radical environmentalism (Buttel 2000).

Although ecological modernization is in many ways informed by concepts of sustainability and sustainable development – in fact, as Blowers (1997, 853) observes, "The Brundtland report [1987] exudes ecological modernization" – ecological modernization is only a partial interpretation and appropriation of these principles to suit different objectives (Curran 2001). Sustainable development had been developed to address policy issues in regard to the global South, concerned in particular with the primary-renewable sectors in nonmetropolitan or rural areas. Ecological modernization is based on experience in the global North, with a national rather than an international context, and an exclusive focus upon the environmental problems faced by metropolitan regions of advanced industrial nations (Murphy 2001; Buttel 2000; Murphy and Gouldson 2000; Blowers 1997). These are the nations which, today, have the largest industrial base and impose the most concentrated burden upon the environment (Murphy 2001). From the perspective of the developed world, then, it may be more useful to regard ecological modernization as "a new improved synonym for sustainable development" (Buttel 2000), or, as conceived by Anthony Giddens (1998), to subsume sustainable development within a broader concept of ecological modernization.

Like sustainable development, ecological modernization is characterized by a "fundamental belief in progress" (Hajer 1995). According to Murphy (2001, 9), "Innovation is central to the ecological modernisation of production because it is through innovation and change that environmental concerns can begin to be integrated into production." The earliest formulations of ecological modernization took the perspective that environmental problems could be solved by what Huber (1985) termed "superindustrialization," transforming the mode of industrial production through the development and application of advanced technologies. This concept is related to the idea of "reflexive modernity" developed by Beck (1992), in which modernity can be turned back on itself to address the problems of its own creation. Along with Beck, leading proponents of a prescriptive ecological modernization such as Arthur Mol and Gert Spaargaren, in the words of Buttel (2000, 62), agree that "solutions to the problems caused by modernization, industrialization, and science can only be solved through more modernization, industrialization and science."

This favorable view of the role of technology is, according to Fisher and Freudenburg (2001), "sharply different" from the majority of perspectives on human-environment relationships, which almost universally regard technological development and economic growth as irreconcilable with environmental quality. More recent conceptualizations of ecological modernization have noted that "technological change is essential but innovation is not just about technology" (Murphy 2001). Innovative transformations can take place at the process level, at the plant level, or at the level of industry, but involve changes in the structure and management of institutions as well as technological advances.

Ecological modernization thus addresses restructuring at the macroeconomic as well as firm level, emphasizing technological change and shift away from heavy polluting industries (Jänicke 1985; Murphy 2001). Transformation is likely to occur through both incremental and radical changes. The amount of incremental change that can take place is limited by diminishing returns, at which point more radical transformations are required that in turn permit further incremental improvements to be made (Murphy 2001). In this process of restructuring, some industries are more likely to accommodate transformation than others. Heavy industries in the most polluting sectors are least likely to be able to facilitate significant changes in their core processes and technology. Accordingly, the transformation is not likely to be within those industries dominant today but instead constitute a displacement of existing production, processes and technology by newer, more agile and efficient firms (Ashford 2002). Progress is therefore made in stages both evolutionary and revolutionary.

As the discussion above implied, considerable barriers to innovation within firms can exist. Murphy and Gouldson (2000, 43) note that "standard operating conditions in industry often promote control technologies, limited organisational change, and a focus on operational issues." The role of the state within ecological modernization is conceived as both forcing and facilitating change, through the application of innovative but strict regulations that set an imperative for change, and by building capacity to respond to that imperative. Porter (1991) and Porter and van der Linde (1995a,b) have advanced the idea that properly designed environmental regulations stimulate innovation and improve competitiveness, which is supported by empirical research in several areas. Actions by government to aid in capacity building might include public investment in R&D programs with environmental goals, facilitation of private sector R&D consortia and best practice programs, and building networks, nationally and internationally to encourage technology transfer (Murphy 2001).

Two strategic options are identified by Mol (1995, 46-47) for the government's role in ecological modernization. First, a transformation in basic environmental policy is necessary, "from curative and reactive to preventative, from exclusionary to participatory policy-making, from centralized to decentralized wherever possible, and from domineering, over-regulated environmental policy that creates favourable conditions and contexts for environmentally sound practices and behavior on the part of producers and consumers." Related to this is a greater dependence upon market incentives and economic instruments.

Ecological modernization has been criticized on several fronts, including its utilitarian world-view, faith in the ultimate adaptability of capitalism, its technological optimism and commitment to progress, the potential for corruption and "capture" of both the environmental agenda and government regulators by industry (Ashford 2002; Murphy 2001; Curran 2001; Blowers 1997). Geographer David Harvey writes, on the strengths and weaknesses of ecological modernization:

> As a discourse, ecological modernization internalizes conflict. It has a radical populist edge, paying serious attention to environmental-ecological issues and most particularly to the accumulation of scientific evidence of environmental impacts on human populations, without challenging the capitalist system head on….It can be appropriated by multinational corporations to legitimize a global grab to manage all of the world's resources. Indeed, it is not impossible to imagine a world in which big industry (certain segments), big governments (including the World Bank)

> and establishment, high-tech big science can get to dominate the world even more than they currently do in the name of "sustainability," ecological modernization and appropriate global management of the supposedly fragile health of planet earth (pp. 382-383).

These are all valid concerns, and rather than take the considerable space it would take to address each, the reader is referred to the discussion of these issues in Murphy (2001). Even many advocates of the ecological modernization approach have concerns as to its utility as a guide for the long term: "[T]here may in the end be structural limits which make it impossible to continually realise combined economic and environmental improvements as a result of innovation" (Murphy and Gouldson 2000, 43).

Over the short term, however, the perspective offered by ecological modernization provides a way to address many of the environmental problems associated with industrialization. It offers incentives, in the form of cost-savings and improved competitiveness, to industry use cleaner technologies and more efficient processes. Ecological modernization represents, possibly, an economically viable interim step on the path to an ecologically viable cultural change.

The research undertaken and presented here is grounded within the ecological modernization perspective, and therefore appreciates its strengths while recognizing its weaknesses. Only popular self-improvement manuals are likely to claim to solve all problems; the present research limits itself to a consideration of one small segment of the environmental problematic, the generation of hazardous waste and whether a particular mode of production – the Japanese method – is more effective in dealing with this material. Ecological modernization is concerned with innovation, both incremental and radical, that leads to environmental improvements. The Japanese production system is considered by many to be an advanced, more efficient, and cleaner form of production, and so fits squarely within the theoretical context of ecological modernization. Fisher and Freudenburg (2001, 706) observe that, judging by a number of indicators, Japan is “much closer to matching the predictions of ecological modernization than does the United States."

The analysis of the Japanese production system, as transferred and hybridized within North America, is conducted in a framework that examines three concrete expressions of trends in ecological modernization that are also highly significant to the Japanese system: eco-efficiency, industrial ecology, and the environmental management system. Eco-efficiency may be conceived as the overarching philosophy, industrial ecology as the (largely theoretical and yet-to-be-realized) structure, and the environmental management system as a tool employed to help achieve environmental goals. The remainder of this chapter explores each of these concepts, in turn.

2.2. Eco-efficiency

Ecological efficiency, more commonly shortened to “eco-efficiency,” has been referred to as “the business link to sustainable development” (Schmidheiny 1992; Simone and Popoff 1997). Eco-efficiency, a voluntary business strategy intended to reduce resource consumption and pollution beyond regulatory requirements, represents an approach to environmentally sustainable operations that has been implemented by many corporations. As a guiding principle, eco-efficiency is conceived as integrating economic and environmental concerns, two of the three so-called pillars of sustainable development. This approach was first introduced by the World Business Council for Sustainable Development (WBCSD) at the 1992 UN Conference on Environment and

Development at Rio,[1] and subsequently endorsed by the United Nations Environment Programme (UNEP) in 1997; the Organization for Economic Co-operation and Development (OECD) in 1998; the Clinton administration in 1999; and the Commission of the European Union in 2001. As a key concept emerging from the discourse on ecological modernization, eco-efficiency remains embroiled in the debate between the poles of sustainable development and sustainability, of continuous growth and steady-state economies.

Two different but complimentary dimensions of eco-efficiency are evident from both the critical and popular literature. In the more general sense, eco-efficiency refers to a company perspective based on developing strategies to improve environmental performance. The broad definition of eco-efficiency has evolved to a present formulation that states: "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity, through the life cycle, to a level at least in line with the Earth's carrying capacity" (WBCSD 1995). Business strategies developed in accord with the philosophy of eco-efficiency seek so-called "win-win" solutions to environmental problems associated with business activities. Under a win-win strategy, costs imposed by improving resource conservation and pollution prevention are offset by measurable efficiency gains. Thus, at one level eco-efficiency represents a specific methodology; on another level, a comprehensive approach.

[1] Stephan Schmidheiny, a prominent Swiss industrialist, was requested by the secretary-general of the 1992 UNED conference to provide a global business perspective on sustainable development. Schmidheiny recruited other business leaders to form the Business Council for Sustainable Development (later the World Business Council for Sustainable Development), which collectively prepared an advisory report, *Changing course* (1992). This book was responsible for popularizing the concept of eco-efficiency.

As envisioned by the WBCSD (1995), the drive for corporate eco-efficiency is defined by seven broad goals: reducing the material requirements for goods and services; reducing the energy intensity of goods and services; reducing toxic dispersion; enhancing material recyclability; maximizing sustainable use of renewable resources; extending product durability; and increasing the service intensity of goods and services. Hertwich (1997) refines these goals into five categories which can be linked to specific forms of contemporary research and practice: pollution prevention; cleaner technology; design for environment; loop closing; and environmental management systems.

Pollution prevention (P2) is focused on improvements to technology, processes and products that reduce the generation of pollutants at the source. Pollution prevention includes input substitutions and in-process recycling as well as modernization and modification of equipment or processes.   Cleaner technology is the attempt to develop manufacturing technologies that are inherently clean, in contrast to traditional "end-of-pipe" abatement technologies that address pollutants that have already been generated.

Design for the environment (DFE) is a complex concept that involves many differing approaches to "environmentally friendly" that range from a consideration only of the product's impact upon manufacturing processes to the entire life-cycle of the product. One strand of DFE that is currently receiving considerable attention is the design of products for durability, ease of disassembly, recycling and remanufacture from recovered assets. Considerable progress has been made in this area for high-value products such as appliances and automobiles; Toyota Motor Corporation, for example, has achieved recyclability of 75-80 percent for currently produced vehicles and has set a goal of 95 percent by 2015 (TMNA 2002). Similar goals have been set by other manufacturers, particularly those who market to Europe where "take-back" legislation is under consideration for several industries (Ayres *et. al*. 1997). In Japan, the Diet enacted a tough recycling law in May of 2001 that prohibits discarding of household appliances; disassembly costs borne by consumers provide a strong incentive to design products that can be easily taken apart (Burt 2001).

"Closing the loop" is a reference to the linearity of the economic process whereby resources are extracted, converted into goods, and ultimately discarded; a closed loop results when waste materials are recovered and recycled back into the production system. A limited amount of loop closure, or recycling, is a common feature within many industrial facilities today, particularly as regards metals. For example, at Madison Precision Products, a firm which die-casts aluminum automotive components and is profiled as a case study in Chapter 11, aluminum scrap left over from casting is recycled immediately back into the melt furnaces to be reused, or if dirtied, returned to the supplier for off-site recycling. In a larger sense, loop closure refers to the concept of extended and cooperative inter-firm waste recycling known as industrial ecology. Industrial ecologies involve devising industrial systems in which almost total recycling of materials takes place so that waste materials from one process become raw materials for another. Complete industrial ecologies do not as yet exist except in experimental stages, although many firms have been forging partial linkages of the sort necessary to create and industrial ecology. Industrial ecologies, along with environmental management systems, are discussed at some length later in this chapter. Each of these five categories of activity identified by Hertwich represents a separate arena of research and discourse concerned with reducing the environmental impacts of manufacturing, yet is fully embedded within the overarching philosophy of eco-efficiency.

Promoters claim that corporations can realize many benefits from adoption of eco-efficiency as a basic strategy. According to Brady et. al. (1999), such benefits may include cost reductions, product and process improvements, reduced liability and risk, better employee morale and customer relations, and opportunities for innovation and revenue generation by opening new markets and commanding premium prices for products. Cramer (1999), noting many of the same benefits, observes that eco-efficiency may be necessary for a company's long-term survival. Schmidheiny (1992,10) stated that "It is the more competitive and successful companies that are at the forefront of what we call eco-efficiency." Environmental performance enhancement is perceived as an integral part of operational efficiency, functioning in a bidirectional linkage; an improvement in either area generates improvements in the other. Accordingly, enhanced eco-efficiency equates to enhanced firm competitiveness (Kiernan 2001; Rondinelli 2001; Clelland *et. al*. 2000; Porter and van der Linde 1995a, 1995b).

In one sense, eco-efficiency represents a company strategy or philosophy premised on proactive, rather than reactive, improvement of environmental performance, eco-efficiency can also be applied as an operational tool to measure that performance (e.g. Schaltegger and Sturm 1990; Verfaillie and Bidwell 2000; Müller and Sturm 2001; Montgomery and Sanches 2002). Schaltegger and Sturm (1990), who originated the concept, defined eco-efficiency as the ratio between an environmental and a financial variable, noting that the aim of environmentally sound management is to increase eco-efficiency by reducing environmental impact added while increasing the value of an enterprise.

As a specific operational tool, eco-efficiency is a refinement of the concept of technical efficiency, a form of economic efficiency, derived from the neoclassical theory of the firm. Technical efficiency refers to the ability of the firm to minimize the costs of inputs to production – capital, resources and labor – required for a given output. As Bain (1968, 376) observes, internal efficiency "reflects the degree of managerial wisdom in selecting and using productive techniques and methods, in selecting cost-minimizing combinations of productive factors or agents, in designing administrative organizations, and in administering operations." Technical efficiency can thus be represented as the ratio of the value of output to the value of input (alternatively, as material output to material input):

$$\text{Technical efficiency} = \frac{\text{value of output}}{\text{value of input}}.$$

Technical efficiency increases whenever units of output increase or units of input decrease; the greater the resulting value, the more efficient are the production processes.

Ecological efficiency is derived from the concept of technical efficiency, but is grounded within ecological economics rather than neoclassical economics. Ecological economics is concerned with sustainability and recognizes that economic growth is constrained by the natural limits on resources and the environment's assimilative capacity for wastes. Resource inputs and waste outputs incur costs which are not directly reflected by the market mechanism but are borne by society through depletion of resource capital stocks and reduced environmental quality. Eco-efficiency attempts to address this situation by including resource inputs and pollution outputs to revise the technical efficiency equation.

Eco-efficiency may therefore be expressed using a variety of parameters which are generally intended to express the relation of some measure of production to some measure of environmental influence:

$$\text{Eco-efficiency} = \frac{\text{economic indicator}}{\text{environmental indicator.}}$$

The economic indicator may represent value added, or may be a unit of production; the environmental indicator may represent a combination of resource inputs and waste outputs indicating "environmental impact." This equation may also be inverted to represent the amount of environmental impact per unit or value measure. Determining a valid measure of environmental impact is, however, problematic:

The fundamental problem with the eco-efficiency concept, according to Sturm *et. al*. (2002, 12) is that there are "no agreed rules or standards for recognition, measurement and disclosure of environmental information either within the same industry or across industries." More importantly, in their view, as yet no techniques have been developed to consolidate various measures of a firm's environmental impacts in such a way as to be used with established financial indicators. Numerous individual eco-efficiency indicators have been devised that measure specific aspects of a firm's operations, but there has been considerable difficulty associated with developing a measure to include the entire range of environmental influences.

Environmental indicators, according to Button (2002) should be understandable and simple to use. They should be relatively few in number, sensitive to the condition they are designed to measure, easy to measure and readily quantifiable. Environmental indicators can generally be classed as either process measurements, or results or product measurements largely based on measurable amounts or flows. Water or energy consumption per unit of production are indicators commonly reported by manufacturing companies. Ideally, indicators should reflect the combined efficiencies of both resource use and pollutant releases for plant operations rather than specific products; for example, emissions of NO_x per ton of steel consumed (Tam 2002).

Verfaillie and Bidwell (2000) proposed a system in which eco-efficiency indicators are divided into three groups, related to (1) product or service value; (2) environmental influence in product or service creation; and (3) environmental influence in product or service use. According to this system, some environmental indicators associated with product or service creation would be generally applicable to all business operations and would include consumption of energy, materials, or water and releases of greenhouse gases or ozone depleters. If international agreement on measurement methods can be obtained, additional outputs such as acidification emissions to air and total waste can be added to this basic list. Other indicators may be business-specific and require definition according to business type or industrial sector. Upstream, eco-efficiency can be improved through the supplier network in regard to material or product specifications. Downstream, eco-efficiency can reduce impacts from consumer use and disposal by addressing product characteristics such as packaging, recyclability, and energy consumption.

Many multinational corporations are now using eco-efficiency indicators in public reports concerning their environmental performance. Among U.S.-based corporations that have adopted the eco-efficiency approach are General Motors, Proctor and Gamble, and Monsanto. All three worked with the WBCSD on a pilot project to develop indicators derived from the system presented in Verfaillie and Bidwell (2000). GM, for example, used four environmental indicators – energy and water consumed, greenhouse gas emissions, and non-product output (waste) – measured separately against two economic indicators – vehicles produced and net sales.[2] Toyota Motor Corporation, whose former corporate chair Shoichiro Toyoda is currently vice-chair of the WBCSD, uses two primary eco-efficiency indexes, separately comparing emissions of CO_2 (the most significant greenhouse gas) and waste volume to net sales.[3]

Mitsubishi Electric devoted considerable effort to develop an eco-efficiency index that combined several environmental variables, and the company's "Factor X" calculation has received considerable attention at international sustainability conferences. The company had noted a problem with eco-efficiency calculations: "If innovative improvements are made in a product's performance while the reduction of negative environmental impact is minimal or remains unchanged, the value given for eco-efficiency may rise, but in appearance only" (MELCO 2002, 16). To address this, the company developed Factor X with the assistance of Dr. Ryoichi Yamamoto of the University of Tokyo. The Factor X approach combines indexes for three environmental indicators representing Materials use, Energy use, and use of Toxic materials. These three parameters are tracked by the company as part of its M-E-T environmental initiative.[4]

For a given Mitsubishi product, eco-efficiency is computed in two steps by determining the proportional reduction in these three indicators against those used to

[2] http://www.gm.com.
[3] http://www.toyota.co.jp.
[4] See Chapter 11 for a discussion of Mitsubishi's environmental policies and the MET concept.

manufacture a standard product during a specific year in the past. In their 2002 environmental report, Mitsubishi gives the example of a room air conditioner, where improvements had been made so that resource, energy and toxics use were, respectively, 0.96, 0.48 and 0.54 of the levels for that product in 1990. These values are combined in the format: $\sqrt{0.96^2 + 0.48^2 + 0.54^2} = 1.20$ where the derivative is the eco-efficiency of the present product. The eco-efficiency derived for the present product is divided by the eco-efficiency of the standard product to create an index value, allowing assessment of environmental performance over time. The Factor X concept is a significant step toward development of standardized eco-efficiency indicators.

Other, more generalized indicators have been proposed to measure eco-efficiency, such as ecological rucksack, ecological footprint, or MIPS (material input per unit of service). The concepts of ecological rucksack and MIPS were both introduced in 1993 by Friedrich Schmidt-Bleek. Ecological rucksack refers to the total mass of materials (in kg.) displaced to produce a good or service; MIPS is the ratio of the ecological rucksack value per unit of product or service provided. Originally published in German, these concepts were popularized in the 1998 book Factor Four (Von Weizsaecker 1998). Factor Four, and its later reconceptualization as Factor Ten, asserts that existing technology and management systems can increase resource productivity by as much as tenfold, reducing materials usage accordingly (Schmidt-Bleek et. al. 1998). The concept of ecological footprint is related to the ecological rucksack and refers to the amount of land required to provide resources for a product or service through its life-cycle (Wackernagel and Rees 1996).

The adoption of eco-efficiency as a basic corporate philosophy has been both lauded and criticized. Leaders in business and industry view eco-efficiency as an economically valid rationale for improving environmental performance. Opinion among environmentalists is divided; many are willing to commend any strategy through which industry actively seeks to reduce its overall environmental impact, but others perceive only a smoke-screen for business-as-usual. Even the most ardent critics, however, acknowledge that improved efficiency is both necessary and desirable; the main issue of contention is that eco-efficiency in itself does nothing to address the root cause of the environmental problematic, a philosophy of continued economic growth inherent to the concept of sustainable development.

The critique, therefore, is not of eco-efficiency *per se*, but rather of the perception that this strategy is the ultimate environmental panacea for business operations. The primary thrust of most criticism is that, while eco-efficiency alone is insufficient to address the magnitude of the environmental problematic, its relative simplicity and quantifiability will tend to build a dependency that obscures the need for more fundamental change. A second and related strand of discourse centers around the startling proposition that eco-efficiency may at best produce no substantive environmental benefits and possibly lead to increased pressures on the environment. Together, these observations represent the critique offered by environmental writers. At the opposite pole, philosophically speaking, a conservative criticism of eco-efficiency holds that opportunities to capitalize upon such benefits are far more limited than anticipated, so that corporations who set high priorities for “win-win” environmental goals are likely to damage their market value.

Critics such as Welford (1997), McDonough and Braungart (1998) and Dyllick and Hockerts (2002) argue that eco-efficiency is not eco-effectiveness, since it does not address the root cause of environmental problems, an economic system based upon continued growth and consumption. An eco-efficiency strategy would seek to manufacture cars with improved gasoline mileage, but would not be eco-effective if total pollution rises because increased numbers of vehicles are produced. Under the current economic system, eco-efficiency might be capable of reducing the relative environmental impact for any given company but fail to reduce the cumulative impact of increased consumption.

McDonough and Braungart (1998) thus refer to eco-efficiency as "admirable" but note that it provides only the "illusion of change" and does not constitute a strategy for long term success: "Relying on eco-efficiency to save the environment will in fact achieve the opposite – it will let industry finish off everything quietly, persistently, and completely" (p. 67). Eco-efficiency, in this view, is a self-serving rationale allowing business to be conducted much as usual without the need for radical change, while providing business with a greener public image. Managers like simple solutions, observes Welford (1997), and opt for eco-efficiency rather than complex or radical alternatives. Dyllick and Hockerts (2002) note that managerial acceptance of environmental and social responsibility is commendable, but "In their quest to find a single concept, perhaps a single word to sum up the business end of sustainable development, most firms have opted for eco-efficiency as their guiding principle."

Eco-efficiency is an inherently positivist doctrine; it stresses quantification, technological development, and predictable linear solutions. "Business embraces positivism," write Richardson and Welford (1997, 61), because "it consists of a relatively simple set of ideas, it is operational and manageable, and it protects the status quo. Businesses resist other ways of looking at the world…because they tend to be more critical and challenge the traditional roles and structures of business." According to the authors, solutions for the environmental problematic will require "changing the basic values of society, the culture of organizations and the behavior of individuals rather than manipulating the physical world with technology" (p. 44).

Reviewing the literature, Figge and Hahn (2002) note that eco-efficiency may not lead to eco-effectiveness because of two potential "perverse effects" that may overcompensate for improved environmental performance. One such perverse effect has already been noted; that individual corporate improvements in eco-efficiency may tend to encourage growth from the perception that environmental problems can be managed by efficiency alone. In such a case, the net effect of growth in production and consumption may outweigh gains made by conservation and pollution prevention. The second perverse effect is a consequence of performance variations among companies, so that resources saved by an eco-efficient company are utilized by other firms with lower efficiency.

In a 1994 article in the *Harvard Business Review* titled "It's not easy being green," authors Walley and Whitehead claim that nearly all of the easily accomplished "win-win" situations for environmental improvement have already been exploited by companies. In their view, the gains from such opportunities have now become insignificant when measured against the enormous costs entailed in making further environmental improvements. Walley and Whitehead argue that environmental regulations are destroying the market values of corporations and, therefore, managers should "seek to minimize the destruction of shareholder value that is likely to be caused by environmental costs rather than attempt to create value through environmental enhancements" (p. 47). This perspective is directly in opposition to many other writers, such as Porter and van der Linde (1995), who argue that properly designed environmental regulations stimulate innovation and improve competitiveness, and Florida, Atlas and Cline (2001), who demonstrated an empirical linkage between environmental performance and competitiveness. The case studies reported in O'Dell (2001) and in the present research further illustrate that companies are continuing to find solutions to environmental problems that result in substantial cost savings.

Efficiency and effectiveness are not mutually exclusive. Architect William McDonough, perhaps the best-known critic of eco-efficiency as a single cure-all and champion of eco-effectiveness, was recently given the rare opportunity to express his ideas in, literally, concrete form. Proprietor of a small architectural firm in Charlottesville, Virginia, McDonough was hired by Ford Motor Company to work on the first phase of a planned two-decade effort to completely redesign their original River Rouge assembly plant in Michigan. McDonough, who has worked on numerous smaller projects, is not a conventional environmentalist, because he is a firm believer in economic growth; it is how that growth is achieved that is most significant. Among other environmental innovations, the ten-acre flat roof of the plant is to be covered with grass, which in combination with a porous parking lot pavement, provides natural stormwater filtering that eliminates the need for wastewater treatment and will save the company millions of dollars above the installation cost. Although McDonough has received criticism from environmentalists for associating with "the enemy," meaning large corporations such as Ford, he responded, “Who are we supposed to work with? At least they’re leading and trying to go forward. People need to recognize the need of industry to transform –to move as quickly as possible toward the positive alternatives. Our job is to provide those alternatives” (Curry 2003).

2.3. Building industrial ecosystems

Conventional industrial systems are primarily linear in nature. Virgin materials are extracted from the earth, processed into manufactured goods, and discarded either as leftover waste during the production process or after use by consumers. Many writers, concerned with the long-term implications of resource depletion and an increasing burden of pollution, have suggested the goal of transformation of the traditional industrial model into one that more closely emulates cyclic flows of matter and energy in natural ecosystems. In a biological ecosystem, a community of organisms is linked by transfers of matter and energy which are continually recycled among members. In similar fashion, an industrial ecosystem would consist of a symbiotic community of manufacturers, where the waste products of each component firm serve as the raw material - food - for another. In a perfect industrial ecosystem, there is no such thing as waste, in the sense of a material without value; all residues are absorbed within the industrial system and do not impact natural systems.

The theoretical development of industrial ecology has proceeded in slow and halting steps since the late 1960s, remaining largely invisible outside academic and engineering circles until the early 1990s. Industrial ecology is closely related to the study of industrial metabolism, an application of materials-balance principles to the movement of materials and energy as a consequence of human activity, that was pioneered by Robert U. Ayres (Ayres and Kneese 1969; Ayres 1989). The concept of industrial ecology was first popularized in a seminal 1989 paper by Frosch and Gallopoulos in *Scientific American*. According to Erkman (1997), this paper served as an initial catalyst to stimulate a strong general interest in industrial ecology, particularly in the context of the recently published report of the Brundtland Commission (1987) urging a movement toward sustainable development. Equally influential was a short brochure by Hardin Tibbs initially published in 1991, and since widely circulated by various means, that summarized and translated the ideas contained in the Frosch and Gallopoulos article into the language of business (Tibbs 1993).

The primary goal of industrial ecology, according to Garner and Keoleian (1995), is to promote sustainable development at the global, regional, and local levels through the sustainable use of renewable resources and minimal use of those that are non-renewable. Development of an effective industrial ecosystem will require not only changes in manufacturing but also changes in consumption, in demand patterns and the way materials are treated after purchase (Frosch and Gallopoulos 1989). For the firm, economic advantage is achieved through reduced costs associated with obtaining raw materials and energy, waste disposal, and compliance with environmental regulations (Korhonen 2002). Within an industrial ecosystem, waste attains value and becomes a commodity for exchange, rather than something to be discarded.

Conventional economic theory defines a waste residual as a non-product that has a market value less than the costs of collecting, processing, and transporting it for use (Kneese and Bower 1979). The market value of a waste material is a function of the relative costs of alternative inputs; however, there are also costs associated with waste disposal similar in kind to those associated with waste recovery plus destination charges such as landfill fees. As disposal costs increase relative to recovery costs or the cost of alternative inputs, the value of the waste product likewise increases. This relationship will influence the choice of waste management options. As the relative cost of waste increases, this is likely to promote waste minimization through the application of technology and strategies to enhance operational efficiency, and the commodification of waste that cannot be eliminated through the production process.

In present-day industrial facilities, relatively small percentages of waste residuals are transformed into commodities by recycling back into the production system on-site or through off-site recycling by materials processors. Industrial ecology is concerned with broad-scale waste commodification. The major focus of industrial ecology, according to Ayres and Ayres (1996), "is to identify opportunities for reducing wastes and pollution in the materials-intensive sectors by exploiting opportunities for using the low-value byproducts (i.e. wastes) of certain processes as raw materials for others." Graedel and Allenby (1995) observe that wastes are merely residues of materials and products that our economy has not yet learned to use efficiently. In a successful industrial ecosystem, industrial processes must generate a minimum of unrecyclable waste while also minimizing permanent consumption of scarce material and energy resources. Linkages between processes are critical: "A process that produces relatively large quantities of waste that can be used in another process may be preferable to one that produces smaller amounts of waste for which there is no use" (Frosch and Gallopoulos 1989, 149).

Industrial ecology is a holistic, systems approach that, like eco-efficiency, will ultimately integrate a number of tools aimed at resource conservation and pollution prevention, including Design for Environment (DFE) and the related Life Cycle Analysis (LCA). Many products cannot be economically recycled, for example, if they cannot be easily disassembled or contain components made of composite materials. Among the roles of DFE is the design of products whose content is easily. Life Cycle Analysis is complimentary to DFE, is product-based and concerned with the environmental impact of the product throughout its life span. LCA provides the information necessary for DFE, sharing the goal of increasing material return flows from both producers and consumers to recyclers.

In the optimal industrial ecosystem, production, consumption, and recycling activities would be locally integrated with the shortest possible distances between each. In modern societal systems, however, production and end-consumption are often geographically separated (Korhonen 2002), thus increasing the difficulty and costs of material recovery. The necessary components for establishment of an economically functional industrial ecosystem are described by Ayres and Ayres (1996). A multi-firm industrial ecosystem will usually require a large operational scale and both vertical and horizontal integration.

> An industrial ecosystem must look like a single economic entity (firm) from the outside. It will have consolidated inputs and outputs (products). It will compete with other such entities (firms) in both raw material and product markets. It will also compete with other firms for capital. From the inside, however, central ownership with hierarchical management is almost certainly not the optimum solution. Too much depends upon very sensitive and continuous adjustments between the different components of the system (p. 290).

The authors note that a modern conglomerate, where autonomous units are linked to a corporate parent by a purely financial set of controls, each competing for funds on the basis of profits, does not provide a satisfactory solution either. Industrial ecosystems will require close long-term cooperation and planning between waste producers and consumers, since neither can change either processes or production levels without affecting the other. Thus, internal technological choices and financial transactions must be premised upon what is good for the industrial system as a whole, rather than any one firm. An industrial ecosystem is likely to consist of a single major waste exporter with numerous satellite waste converters using the residuals of the primary firm to manufacture other products. The low value of residual materials dictates local use, so that a centralized industrial organization is necessary in which all firms involved are in relatively near proximity to one another.

The Ayres identify three current industrial organizational strategies that might potentially serve as models upon which to build an industrial ecosystem. The first is the "common ownership" model of vertical integration, exemplified by corporations such as IBM and GM who own all or most of their suppliers and manage the entire collection centrally. A second model may be found in the retail marketing organization, such as those created by WalMart or MacDonald's. Both of these potential models have significant flaws. Vertical integration tends to be cumbersome, often losing markets to more agile competitors due to centralized decision-making process that is slow to react to changing circumstances. The marketing organization provides little incentive for cooperation among suppliers.

The third model for inter-firm cooperation might be derived from the Japanese system of keiretsu, a family of firms normally controlled by a large bank, with links to a common trading company, and several major first-tier manufacturers spread over a range of industries. Each of the first-tier companies generally has a substantial number of smaller satellite suppliers in what is termed a vertical keiretsu. As discussed in Chapter 3 and elsewhere in this volume, the firms in these keiretsus are closely linked economically and in terms of knowledge-sharing. As a model for an industrial ecosystem, the *keiretsu* suffers from some of the disadvantages of the other organizational types, but has several advantages, including a primarily horizontal integration and a tendency for close geographical association of unit firms. Furthermore, Erkman (1997) points out that the Japanese Ministry of International Trade and Industry (MITI) began developing practical applications of industrial ecology in the early 1970s, and is the only country where these ideas were taken seriously and put into practice on a large scale. The consequences, according to Erkman, are that:

> It is through technology developed in the context of an economy that has fully integrated ecological constraints that Japan intends to maintain its status as a great power….whereas this thinking has been incorporated in long term and large scale industrial strategies in Japan, it has been traditionally (and still remains) mainly academic in the West (p. 5).

At present, industrial ecology remains more of a concept than a practical reality, but points the direction for future industrial production in a sustainable manner. Primary problems associated with realization of the concept are likely to be development of technologies to recover a greater percentage of waste that now escapes capture, to develop products and markets based upon reclaimed materials, and to break down barriers to inter-firm cooperation. A number of small-scale industrial ecology prototypes, often referred to as “eco-industrial parks (EIP) have been established internationally, and more are planned. One of the earliest and best-known efforts evolved in the town of Kalundborg, Denmark, consisting of about a dozen diverse facilities including an electric power plant, an oil refinery, district heating, a biotechnology production plant, a plasterboard factory, a sulfuric acid producer, cement producers, and local agricultural and horticultural operations (Romm 1994; Lowe *et. al*. 1997). A similar inter-firm cooperative has been established in the Finnish community of Jyväskylä, where a regional power plant, supplied by wood waste from a local plywood mill, diverts waste heat from electricity generation to local households and industry (Korhonen 2002).

In the United States, the President's Council on Sustainable Development under the Clinton administration adopted the eco-park concept as a basis for demonstration projects in four U.S. communities: Chattanooga, Tennessee; Brownsville, Texas; Baltimore, Maryland; and Cape Charles, Virginia (Lowe *et. al*. 1997). Many other communities in this country are planning such projects. Other, less ambitious steps toward building industrial ecologies are also being taken, ranging from agreements between industrial firms to waste exchange services. Examples of waste commodification in the United States are presented below.

For example, the Edward C. Levy Company, located in the Great Lakes area, has made arrangements with regional iron and steel mills to obtain and process waste slag from the furnaces of these companies. Slag consists of impurities that float on top of the molten metal. The Levy company recovers more than 1.5 million tons of metal from slag each year, and pulverizes and size-screens the remaining material, converting it into construction materials which are widely marketed through the northwest.[5] In West Alexandria, Ohio, a Morton International facility formerly incinerated a flammable waste stream from its polyester resin process, but has worked with a supplier to develop a

[5] Edward C. Levy Company webpage: http://www.edwclevy.com

process to convert this waste into a resin that could be used as a plasticizer for black electrical tape.[6] The Toyota Motor Manufacturing automobile plant in Kentucky is currently negotiating arrangements to send its paint waste to a brick manufacturer, where the waste will be turned into construction material.[7]

Waste exchanges and waste matching services have been established in numerous locations across the United States, in the effort to promote the reuse or recycling of industrial wastes. These services, usually free, operate rather like classified advertising in which manufacturers place advertisements describing materials wanted and other ads describing materials available, listed by category. A sampling of many such examples includes RENEW, established by the Texas legislature in 1987, which "has assisted in the successful exchange of 802 million pounds of material, saving participating firms more than $10 million in avoided disposal costs, while helping them earn almost $7 million from the sale of materials."[8]

RCBC Mex, a materials exchange in British Columbia, describes itself as "a dating service for your wastes" and has kept nearly 5.6 million pounds of waste out of regional landfills.[9] CalMAX, the California Materials Exchange, helps "businesses and organizations find alternatives to the disposal of valuable materials or wastes," and has diverted more than 1,300 million pounds from landfills since 1992.[10] Chase Instruments used the Tennessee Materials Exchange to locate a Georgia asphalt company that would take as much as 150,000 pounds of mixed waste glass each month to use in producing road materials. From the examples above, it is apparent that many manufacturers are

[6] USEPA Envirosense webpage: http://es.epa.gov/techinfo/facts/cma/cma-fs3.html
[7] See Chapter 10.
[8] RENEW website: http://www.tnrcc.state.tx.us/exec/oppr/renew/renew.html.
[9] Recycling Council of British Columbia website: http://www.rcbc.bc.ca/index.htm.

aware of economic benefits that can be realized through waste commodification, and that the sort of linkages necessary for an industrial ecology are slowly being forged.

A perfect industrial ecosystem can never exist, if for no other reason than that the entropy principle dictates there will always be some loss of matter an energy from any system (Georgescu-Roegen 1971). Environmental economists also note that there is an optimum recycling rate, since marginal costs increase with the recycled fraction, and exergy[11] analysis indicates that recycling may only be desirable when the exergy costs for recycling are lower than the exergy costs of disposal or production from new materials (Hertwich 1997). Neither is the existing geographical pattern of industrial location ideal for developing the necessary connections in an economically viable manner. However, as the costs for both compliance with environmental regulations and landfill disposal continue to increase and firms seek greater efficiency in production operations, there is ever greater incentive to treat waste as a substance of potential value.

2.4. Environmental Management Systems

The adoption of environmental management systems (EMSs) by many corporations since the mid-1990s is distinctly representative of the ecological modernization movement. An EMS can be described as a subset of general management systems consisting of a formal structure of standardized management principles that are intended to improve both business and environmental performance (Boiral and Sala 1998; Nash and Ehrenfeld 2001; Florida and Davison 2001). An EMS is a regulatory structure that is

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[10] CalMAX website: http://www.ciwmb.ca.gov/calmax/.

[11] Exergy is a property inherent in the Second Law of Thermodynamics. It is measured as the total amount of free energies in a system, and refers to the amount of work that can be extracted from a given amount of energy Unlike energy, exergy can be consumed.

developed within the organization, in contrast to regulatory requirements that are externally imposed.

Although there are several types of EMS, the most common model is based upon the Deming plan – do – check – act cycle integral to Total Quality Management (TQM) and seeks continuous incremental improvement. Because TQM and the philosophy of continuous improvement are, as described in Chapter 3, integral to the Japanese lean production system, an EMS tends to mesh smoothly with Japanese methods (Kitazawa and Sarkis 2000). For this and other reasons, Japanese firms have exhibited a higher rate of EMS adoption than any other nationality (Anon. 1999).

The increasing use of EMSs encapsulates the major developmental themes within ecological modernization. The voluntary adoption of an EMS represents an acknowledgement and assumption of a greater social and environmental responsibility by corporations. This movement follows the shift in emphasis from the rigid system of command-and-control regulations that has dominated government environmental policy for the last three decades, to a greater focus on pollution prevention that allows more flexible and innovative solutions (Mazurek *et. al*. 1995). Environmental regulation in the United States and elsewhere is evolving from reactive to proactive approaches, from costly and complex prescriptive protocols to voluntary market-based and incentive driven forms (Taylor 2000). According to Stenzel (2000), however, EMS standards constitute process standards, not performance standards, and cannot be a substitute for government regulation. Similarly, the USEPA, while encouraging implementation, notes that EMSs are a complement to environmental regulation and enforcement and not a replacement.[12]

[12] USEPA *Position statement on Environmental Management Systems*, 15 May 2002, http://www.epa.gove/ems/policy/position.htm.

Comparison of federal toxic waste data to EMS implementation indicates that the presence of an EMS is a highly significant determinant for reduced pollutant emissions (Corbett and Russo 2001). Aside from demonstrated improvements in environmental performance, potential cost reductions, greater innovativeness, and increased competitiveness have all been cited as drivers for adoption of an EMS (Bhat 1998; Erickson and King 1999; Jørgensen 1999; Coglianese and Nash 2001). The so-called Porter Hypothesis, described earlier in this chapter, advances the idea that strict environmental regulations, when properly designed to foster both pollution prevention and resource productivity, can encourage innovation and efficiency in firms and thereby improve competitiveness (Porter 1991; Porter and van der Linde 1995a, 1995b).

From a sample of more than 200 manufacturing firms, Florida and Davison (2001) found that plants adopting an EMS and pollution prevention strategies tended to be more innovative as a general characteristic, “more likely to adopt a wide range of advanced or innovative practices” (p. 88). This finding suggests that it is more likely that innovative firms adopt EMSs, rather than that EMS adoption itself stimulates innovation; an EMS is perceived by such firms as another tool to improve environmental performance or competitiveness. Supporting this conclusion, Andrews *et. al*. (2001), reporting preliminary results of a pilot project to investigate EMS implementation (see also Amaral *et. al*. 2000), found that most firms in the study had previously participated in other voluntary environmental management incentive programs.

Other possible advantages that have been identified in the literature include reduction of potential liability since EMS implementers can likely prove due diligence; reduction of the intensity of regulatory scrutiny; increased access to foreign markets requiring such standards; and enhancement of public image and trust (Bhat 1998; Erikson and King 1999; Taylor 2000). EMS adopters, according to Florida and Davison, were more likely to "be better corporate citizens….more likely to share information with the community and to obtain input from stakeholders in making environmental decisions and setting environmental priorities" (p. 99). Similarly, according to Andrews et. al., (2001, 45)

> [F]acilities that had such plans were far more likely to involve suppliers and customers in pollution prevention initiatives, consider pollution prevention in product design and business planning, use materials accounting, have pollution prevention teams and training, and reward their employees for pollution prevention initiatives.

The environmental management system is, in the last analysis, no more than a tool; performance outcomes depend upon the dedication and skill with which the tool is used. EMSs are implemented by facilities of all sizes in many industrial sectors (Andrews et. al. 2001). However, "Many firms may use EMSs to simply document current practices, not transform them," write Coglianese and Nash (2001, 14). "Indeed, in certain instances, the formalization achieved through EMS implementation may tend to lock in existing practices. Managers may be reluctant to introduce change in facilities where formal EMS procedures have been carefully documented, every worker has been trained, and third-party registrars have certified the system." Performance improvements will largely depend upon the effectiveness of implementation and commitment of management to environmental goals. Some firms may adopt an EMS as a form of imitative behavior, seeking legitimization in regard to their customers or in the view of public opinion. In this regard, Coglianese and Nash observed that EMS adopters that lack commitment to making environmental improvements are likely to implement these systems "only in token or ritualistic ways." Corbett and Russo (2001) note that it is the dirtiest firms that are most likely to benefit from EMS adoption but, "Like smoking cessation and weight loss, those most likely to gain from new behavioral patterns might be the least likely to join the program!"

According to Monaghan (1997), a successful environmental management system requires commitment from the top, through which environmental performance improvement is perceived as part of the mainstream management of the company and is addressed to all activities. The EMS must be formalized through structures and programs, be capable of being externally verifiable, and be publicized. A multi-firm study of EMS development and implementation conducted jointly by the University of North Carolina at Chapel Hill and the Environmental Law Institute (Amaral *et. al*. 2000) noted that, ideally, EMS design should include a high level of input from facility employees, achieved through establishment of cross-functional teams. The researchers found that most facilities used the team approach to build their EMS, led by the facility environmental manager.

Monaghan identifies five stages of EMS implementation, similar in kind to the processes necessary for any effective management discipline:

> 1. Carrying out a review of the environmental impacts/effects of the activity and the relevant legislation.
>
> 2. Preparing an environmental policy geared to the business of the company and its environmental impacts.
>
> 3. Establishing a management structure to implement the policy, including training of those responsible.
>
> 4. Setting environmental objectives and improvement targets.
>
> 5. Introducing an auditing and review process (p. 241).

The Amaral *et. al*. study (2000) found that facilities' objectives and targets centered equally upon pollution prevention and regulatory compliance, but also addressed a number of other areas, including product stewardship and employee environmental education. More detailed examination of the EMS implementation process can be found associated with the case studies in Chapters 10-12.

Nash and Ehrenfeld (2001) identify three primary classes of environmental management systems, based upon the source of their development. The firm-structured EMS is developed by an individual company to meet its own goals and reflects its own authority structure. An EMS of this sort is not subjected to third-party verification and is usually the least transparent to external stakeholders. The second major category is the trade association EMS. These have a common set of environmental objectives developed by the association for member firms, which include management practices associated with pollution prevention and improved environmental performance. Trade association EMSs include those developed by the American Forest and Paper Association and the American Chemistry Council's[13] "Responsible Care" program.

The last major category includes the international standards, such as ISO-14001, developed by the International Standards Organization, or the European Union's Eco-Management and Audit Scheme (EMAS). ISO-14001 is the most widely adopted standard and has been the focus of most recent research. The development of international standards, according to Stenzel (2000) can serve as a bridge between domestic regulation and a global framework for environmental management, thus serving the goals of sustainable development. For the purpose of discussion, to Nash and

[13] The ACC was formerly known as the Chemical Manufacturers Association (CMA) but adopted a new name in 2000.

Ehrenfeld's classification may be added voluntary industry guidelines, which are not environmental management systems but represent general environmental principles or codes of conduct. Like the trade association standards, these guidelines rely upon peer pressure and public opinion to encourage compliance.

The discussion that follows will focus upon two examples from these categories most relevant to an investigation of Japanese industrial transplants; beginning with an account of the Japanese Keidanren Voluntary Action Plan guidelines and concluding with a more extended consideration of ISO-14001.

2.4.1. Japan's Keidanren Voluntary Action Plan on the Environment

Because this research project concerns Japanese corporations operating abroad, it is appropriate to take a closer look at the national environmental context from which these corporations derive. In essence, Japan is a small island nation, almost totally lacking in natural resources, with half the population of the United States packed into a land area slightly smaller than California. Under such circumstances, resource productivity and pollution prevention very early became significant concerns of the Japanese people and government. Park (1988; see also Miller and Moore 1990) identifies three phases of response by the Japanese business community to environmental problems: (1) a national awakening during the late 1960s to the mid-1970s to an industrial pollution crisis resulting in adoption of some of the most stringent environmental standards in the world;[14] (2) beginning during the same period, a focus upon energy efficiency and resource productivity as an answer to Japan's dependency upon imported oil and raw

[14] For accounts of Minimata and Itai-Itai diseases, the infamous environmental disasters associated with bioaccumulative toxic chemicals in Japan, see Rothman (1972) and Francis (1994).

materials; and (3) a growing awareness by industry in the late 1980s of global environmental problems such as climate change and depletion of the ozone layer.

Japanese environmental policy closely followed the U.S. model, with the enactment of environmental laws and a regulatory “command and control” system established to reduce air and water pollution from factories. When the traditional approach based on standards and regulation proved ineffective in dealing with global environmental problems that emerged during the 1980s, policy reform embodied in the 1993 Basic Environmental Law shifted to reliance upon voluntary actions “based on the spirit of participation and partnership,” again paralleling the movement in the West toward ecological modernization. Japanese corporations favored this approach, based on unilateral commitments, to avoid more stringent government regulation (Imura 1999).

Since 1946, major Japanese corporations have been represented in an association known as Keidanren, or the Japan Federation of Economic Organizations, and it was this organization that took the lead in developing voluntary environmental guidelines for member industries.[15] In 2002 Keidanren merged with the Japan Federation of Employer’s Associations (Nikkeiren) to form Nippon Keidanren, the largest business lobby in Japan. Hiroshi Okuda, current chair of Toyota Motor Corporation, was named to head the organization.[16]

The Keidanren’s first environmental initiative was the formulation and adoption of the

[15] The Keidanren has received very little attention from academic circles in the West, and, other than information contained within the organization’s website, little has been published in English concerning the activities of this group. Unless otherwise credited, information in this discussion concerning the activities of Keidanren was obtained from the organization’s website, http://www.keidanren.or.jp.

[16] “Nippon Keidanren inaugurated,” *Journal of Japanese Trade and Industry*, September/October 2002. Japan Economic Foundation, electronic journal.

Ten-Points-Environmental Guidelines for the Japanese Enterprises Operating Abroad

1. Establish a constructive attitude toward environmental protection and try to raise complete awareness of the issues among those concerned.

2. Make environmental protection a priority at overseas sites and, as a minimum requirement, abide by the environmental standards of the host country. Apply Japanese standards concerning the management of harmful substances.

3. Conduct a full environmental assessment before starting overseas business operations. After the start of activities, try to collect data, and if necessary, conduct an assessment.

4. Confer fully with the parties concerned at the operational site and cooperate with them in the transfer and local application of environment-related Japanese technologies and know-how.

5. Establish an environmental management system, including the appointment of staff responsible for environmental control. Also, try to improve qualifications for the necessary personnel.

6. Provide the local community with information on environmental measures on a regular basis.

7. Be sure that when environment-related issues arise, efforts are made to prevent them from developing into social and cultural frictions. Deal with them through scientific and rational discussions.

8. Cooperate in the promotion of the host country's scientific and rational environmental measures.

9. Actively publicize, both at home and abroad, the activities of overseas businesses that reflect our activities on the environmental consideration.

10. Ensure that the home offices of the corporations operating overseas understand the importance of the measures for dealing with environmental issues, as they affect their overseas affiliates. The head office must try to establish a support system that can, for instance, send specialists abroad whenever the need arises.

Figure 2.1. Keidanren Ten-Points Environmental Guidelines for Overseas Operations

Source: http://www.keidanren.or.jp.

Global Environmental Charter in 1991, which stated that "Each company must aim at being a good global corporate citizen, recognizing that grappling with environmental problems is essential to its own existence and its activities." Associated with the Charter was a set of guidelines to be observed by companies operating overseas (Figure 2.1). Specific recommendations for overseas affiliates include conduct of environmental audits, establishment of an environmental management system, and promoting transparency of environmental issues with the local community.

In 1996, following the passage of the Basic Environmental Law with its associated policy shift, the Keidanren announced the Appeal to the Environment, declaring its intention to develop and adopt voluntary action plans aimed primarily to combat global warming. Subsequently, in 1997, the Keidenran Voluntary Action Plan on the Environment was released, broadened in scope to address four objectives: measures to combat global warming, waste disposal measures, environmental management systems based on ISO-14001, and environmental conservation in overseas business activities (Imura 1999). Each member industry separately crafted and contributed a voluntary action plan that addressed issues specific to that industry, so that currently 43 industrial sector plans comprise the entirety of the Keidanren plan.

For example, the action plan developed by the Japan Automobile Manufacturers Association addressed the four objectives with specific targets and measures. In regard to waste disposal, targets were set to achieve a greater than 90 percent recycling of new car models after the year 2002, and a reduction in final disposal of manufacturing waste to less than 40 percent of the 1990 level by 2000. Measures to be addressed in order to achieve these targets include determining an effective use of shredder dust generated from used cars, development of technology for dismantling used cars, and reduction of environmental burden substances (toxics) to half by the end of 2000 and to a third by the end of 2005. The plan also called for complete elimination of two toxic chemicals by the end of 1999, trichloroethylene and tetrachloroethylene.[17] In the area of environmental management, the automobile manufacturers' action plan promotes achievement of facility certification in the ISO-14001 EMS standard.

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[17] These two substances are also targeted for eventual elimination in U.S. industry; use was greatly curtailed through the EPA's 33/50 priority chemical program. See Chapter 5 for details on the program.

The Basic Environmental Law passed in Japan encouraged voluntary actions for environmental protection without specifying exactly what actions should be taken. Japanese industry adopted the voluntary approach "to take actions in conformity with the spirit of these new laws while demonstrating their environmental efforts and making their good image" (Imura 1999, 16). There are no sanctions designed into the action plans against non-attainment of objectives, but these plans are considered to be social contracts and Japanese corporations are particularly conscious about social sanctions.

The issue of social responsibility in this particular context was addressed in a 2001 conference presentation by Valerie Ploumpis, associate director of the Keizai Koho Center of the Japan Institute for Social and Economic Affairs, an organization that works closely with the Keidanren. According to Ploumpis, the Keidanren codes are "not intended to establish legal liability, but, rather, to set forth moral and behavioral guidelines so that individual and corporate behavior will be contained within acceptable ranges." Japanese codes of conduct are enforced through a fear of disgrace that is alien to Western culture: "For the Japanese, the 3-6 month corporate ostracism and 'naming and shaming' rituals of corporate leaders who have broken company codes of conduct constitute extremely painful punishment."[18]

The Keidanren conducts surveys each year to check progress on the goals embodied within the respective voluntary action plans, and releases survey results to the public through the Internet and other media. Progress on these plans is also reviewed annually by government councils. Although plan status reports do not concern individual firms,

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[18] Ploumpis, Valerie, speaker in session titled, "Does business need government to behave well? No!" at conference: The role of governments in promoting corporate citizenship, Washington, D.C., June 11-12, 2001. National Policy Association.

many firms publish corporate environmental reports. Objectives contained within action plans appear to have been transferred nearly intact to overseas operations in North America. For example, compare the targets and measures contained within the Japanese automobile manufacturers action plan, described above, to those established for Toyota Motor Manufacturing Kentucky, a case study profiled in Chapter 10.

2.4.2. ISO-14001

The desire to facilitate trade through internationally recognized standards, rather than a proliferation of national standards, led to the development of the ISO 14000 series by the International Organization for Standardization,[19] comparable to the ISO 9000 series of standards in the area of quality (USEPA 1998a). Since the ISO 14000 series was launched in 1996, the standards have been embraced by corporations in many nations. American firms, however, have been notably laggard in seeking certification under these standards (Corbett and Kirsch 2000; Boiral and Sala 1998).

The International Organization for Standardization is based in Geneva, Switzerland, and was founded in 1947 to promote "the international harmonization and development of manufacturing, product and communications standards" (EPA 1998a). The organization is comprised of national standards bodies, primarily government agencies or organizations, which represent the interests of producers, consumers, governments and the scientific community (Hunter 1993). The most widely known of the ISO standards is

[19] ISO, despite appearances, is not an acronym for the International Organization for Standardization. Instead, "ISO" is a word derived from the Greek "isos", meaning "equal." The desire of the organization was to create an easily recognizable term that would remain the same in any language around the world and avoid the numerous differing acronyms that would result from the translation of "International Organization for Standardization" into the national languages of members. "ISO" refers both to the organization and to the various standards promulgated.

ISO-9000, which addresses quality assurance and quality management, and like all such standards, is based upon documenting work procedures to track performance consistency. This concept emerged from the American military's quality efforts during World War Two that were widely adapted postwar for commercial use. The ISO began developing an international quality assurance standard in 1980, and released the ISO 9000 series in 1987. In the United States, the so-called Big Three auto manufacturers (Ford, GM, Chrysler) developed QS-9000 for release in 1994, coupling the ISO quality assurance base with industry-specific guidelines drawn from the former auto industry quality programs (Zuckerman 1996). This detail concerning ISO-9000 is included due to a demonstrated connection between ISO-9000 and ISO-14001 certifications, discussed below.

Development of environmental standards began in 1991 and resulted in the establishment of the ISO 14000 series of standards in 1996. In the 14000 series, ISO 14001 is the only standard that is written to be auditable; all the other standards are guidance documents (Boiral and Sala 1998). The required systems and mechanisms in the 14001 standard are designed for continuous improvement in pollution prevention (Abarca 1998). Despite a number of conceptual and implementation problems, a growing number of firms are discovering that 14000 certification is an asset in international trade relations.

ISO 14001 is a voluntary approach derived from principles similar to that of the ISO 9000 quality management series, based on drafting, documenting and applying written procedures. The verifiable core elements of ISO 14001 include an environmental policy signed by senior management, including a commitment to compliance, the prevention of pollution, and continual improvement; objectives and targets developed by the organization for itself based on its assessment of its "significant environmental aspects," its compliance requirements and its consideration of stakeholder interests; implementation and control; and performance monitoring and measurement, and senior management review (EPA 1998a). Under ISO 14001, not only must companies develop an EMS but must ensure that their suppliers do so as well. Once a company has developed and implemented an ISO-14001 EMS, they can become certified by a national accreditation body; the ISO organization does not itself provide certifications or control the activities of accreditation organizations. External verification through regular evaluations by independent auditors is required to maintain certification.

According to a study by Boiral and Sala, the main advantage of 14001 certification perceived by plant managers was the rigorous nature of the standard.

> The firm has to adopt a policy, plans, objectives, and a measurement system, then take corrective action to ensure minimum follow-up of activities that have a potential environmental impact. Regular audits based on checklists do not allow companies to leave anything to chance; they must systematically take into account all elements covered by the standard (p 60).

The documentation required makes it easier for managers to prove "due diligence" when subjected to legal proceedings. Written standards and procedures also allow better control of human behaviors and work methods with potential environmental impacts.

Critics of ISO 14001 have pointed to a number of drawbacks of the model. The standard requires companies to develop and implement an EMS but does not guarantee improvement in environmental protection. The standard focuses on means but does not set limits or regulatory targets. "Environmental performance" in the ISO 14001 system is an ambiguous term, defined relative to the criteria set by the company and its management system.

Stenzel (2000) summarizes the limitations of the development and implementation of a company EMS based on ISO-14001, many of which are similar in nature to criticisms aimed at voluntary standards in general. The company EMS is a product of a non-governmental organization and therefore lacks any democratic input from stakeholders as it is created or implemented. The EMS is based on goals set by the company, which on the one hand allow the company flexibility in terms of costs and needs but provides the potential for a company to set only very lenient goals. ISO-14001 is concerned only with process and not outcomes; the EMS does not establish performance standards, which are instead derived from regulatory requirements, but does provide a means to improve performance. Whether or not improvement is in fact achieved depends upon self-enforcement and commitment to the process. Finally, Stenzel notes, the quality of the third-party audit depends upon the qualifications and integrity of the auditor. In the United States, auditors are accredited through the Registrar Accreditation Board (RAB), but auditor credentials have not yet been internationally standardized.

Although embracing the ISO-9000 standards, firms in the United States have generally been slow to adopt ISO-14001. Some firms are concerned about liability exposure if external auditors are required to share their reports with the EPA. Others believe that the process is time-consuming and costly and provides no real benefits, or that their existing EMS is equal to or superior to ISO-14001. An international study by Corbett and Kirsch (2000) found, however, that “From small, single-site operations to large multinationals, companies on four continents reported no problems with the ISO 14000 certification process" (p. 8), and that none regretted seeking certification.

There is some indication that, especially for companies who conduct international business, failure to seek ISO-14001 certification may can lead to loss of contracts or missed opportunities. Over the next few years, more and more customers are expected to add ISO certification to their contract clauses, particularly in the automotive, electronics and aeronautical sectors. Governments, banks, and insurance companies have developed an interest in ISO 14001 as a means to assess the environmental risks of industrial operations. As the standard becomes more widely adopted, certification may become necessary as a passport to international markets (Boiral and Sala 1998; Zuckerman 1996). In the United States, Ford and GM announced in 1999 that they will require suppliers to become certified in ISO-14001 over the next few years (Anon. 1999), a policy that was soon followed by other automakers including Toyota and Honda.

In a separate paper, Corbett and Kirsch (2001) used their research data on ISO-9000 and ISO-14001 certification to analyze for the underlying factors that may explain the international pattern of ISO-14001 diffusion. In their 2000 article, the authors had noted that many firms had attributed ease of ISO-14001 implementation to having previously gone through the certification process for ISO-9000. In their later analysis, this connection was found to be statistically very significant; ISO-14001 certification was associated with ISO-9000 certification, although the analysis was unable to determine if this was a consequence of similar driving factors or facilitation through prior ISO-9000 certification. The statistical relationship was also supported by research published in King and Lenox (2001).

In the Corbett and Kirsch (2001) analysis, the relationship was tested as ISO-9000 count per unit GDP compared to ISO-14001 count per unit GDP, to correct for country size. Other factors found to be significant were export-propensity and national environmental attitude. Export-propensity was measured as the ration between export value and GDP. National environmental attitude was measured by an internationally comparable historical perspective of government actions toward environmental issues; e.g., that country's record for participation (ratification) in regard to 23 international environmental treaties. Neither GDP nor industrial sector were found to have significance.

As of December 31, 2001, 36,765 companies in 112 nations had achieved ISO 14000 certification, representing a single-year increase of more than 60 percent from the 22,897 certifications existing at the end of 2000 (ISO 2002). Figure 2.2 depicts certifications by global region and for the ten leading nations, by certification number, from 1996 through 2001. ISO registration is pursued with particular zeal by companies in Europe and the developed nations of East Asia. Japan, alone holding 22 percent, is the world leader in total certifications, followed by Germany with 9 percent and the United Kingdom with 7.4 percent. The United States ranked in sixth place with 1,645 certifications or about 4.5 percent of the total. Note that the data is not sorted according to the nationality of the firm, but only by the country in which the facility is located. A significant proportion of the firms in the United States having 14000 certification may be foreign-owned rather than based in America. Russo's (2001) study of ISO-14001 and the electronics industry in the U.S. found that Japanese firms were twelve times as likely to adopt this EMS compared to other facilities.

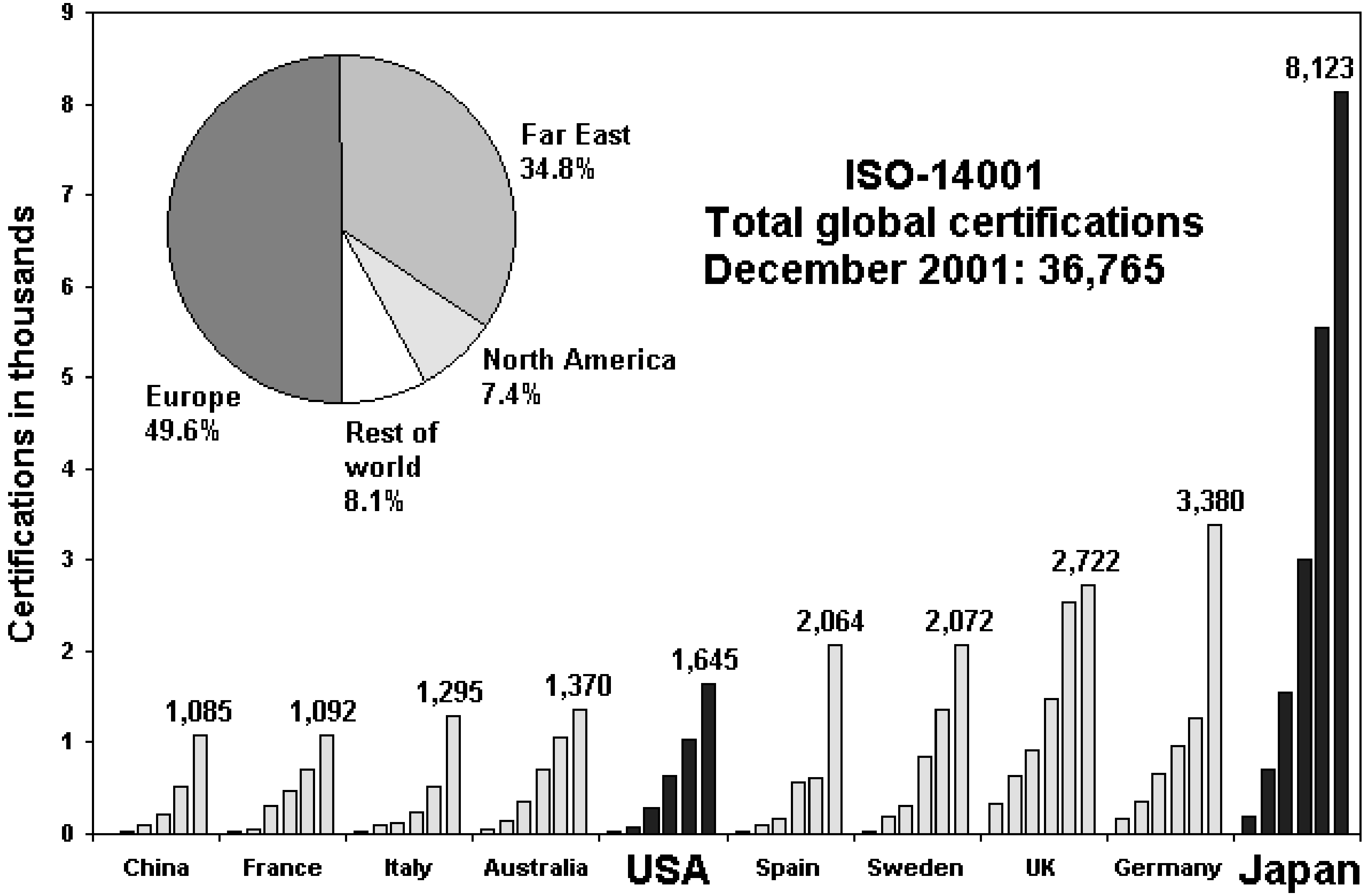

Figure 2.2. Global ISO-14001 certification: Top ten
Source: ISO (2002)

ISO data on registrations within the United States indicates that the concentration of certifications is distributed in a pattern very similar to that of the majority of Japanese transplants - along the west coast and in the eastern U.S. along what is known as “auto alley” – a regional concentration of automobile assembly plants and supplier firms that stretches from Michigan through Georgia. Figure 2.3 shows the national distribution of certifications and closely parallels the distribution of Japanese investment (see Figure 6.2, Chapter 6).

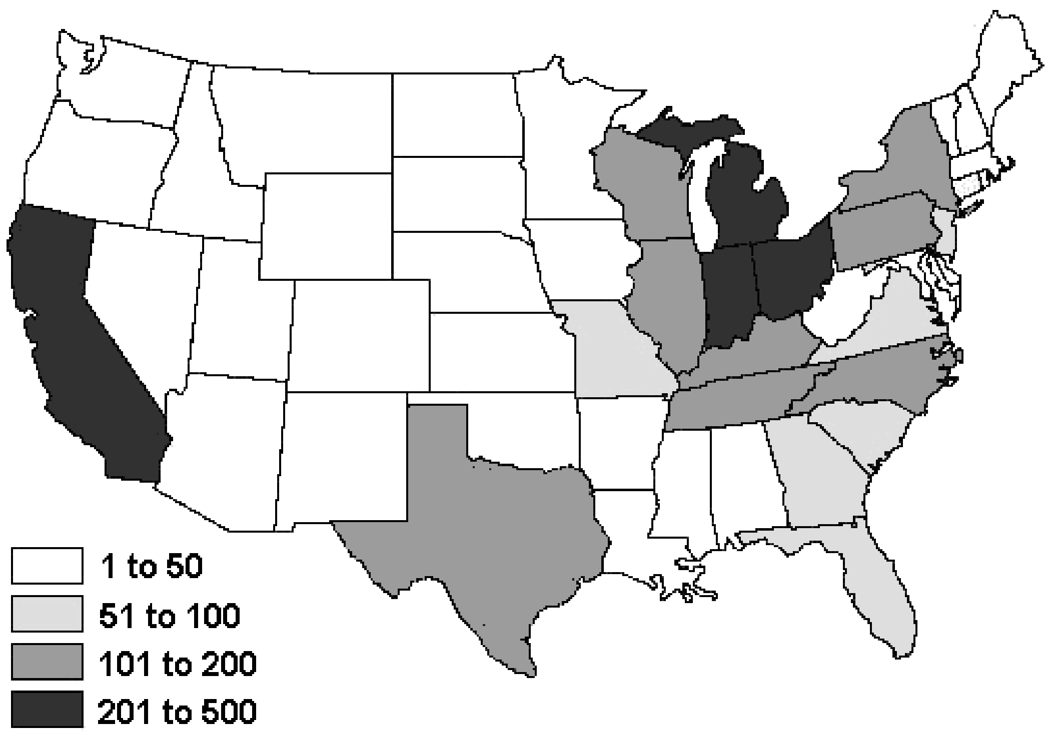

Figure 2.3. Geographical distribution of ISO-14001 certifications in the United States, 2002
Source: World Preferred Registry

The enthusiastic adoption of ISO 14000 by Japanese companies has several apparent roots. Japanese corporations, confident in their own quality-control systems, were slow to adopt ISO 9000 quality standards. Lacking these certifications, they were caught short when clients in Europe and North America began to insist that suppliers be registered. An extensive ISO-9000 registration effort was organized by the Japanese Ministry of International Trade and Industry (MITI) to avoid losing export trade. Not wishing to repeat this experience, Japan was one of the first countries to embrace the 14000 standards, and has maintained the fastest rate of new registrations. Another important factor is likely the strong endorsement of the standards by the national government, which has supported EMSs since 1993. Prefecture and local governments also offer grants and loans to organizations establishing or registering and EMS. Leadership by major corporations in Japan such as Sony, Hitachi, and Toyota, who have set examples by their own registration, provided further incentive; many, such as Toyota, have taken a further step by requiring many suppliers to achieve similar certification (Anon 1999; Corbett and Russo 2001).

Aside from concerns such as implementation costs and increased paperwork, the lack of clear support from the U.S. Environmental Protection Agency appears to be a major factor accounting for the reluctance by American corporations to seek ISO 14000 registration (Boiral and Sala 1998; Hasek 1998). The EPA, which does not foresee using ISO 14001 standards as regulatory requirements, views these standards as simply one of many possible voluntary environmental management systems. The agency provides information about ISO 14001 but does not promote these standards over any other EMS. Lacking any statement from the EPA on the legal benefits of ISO, lacking endorsement from their customers, facing environmental regulations considered to be among the world's strictest and most inclusive, American industry has thus far little incentive to seek ISO certification (Hasek 1998).

Japanese companies operating at home and transplants in North America have sought and acquired ISO 14001 certification in greater numbers than firms of any other nation. Research previously described indicates that firms who adopt EMSs such as ISO-14001 tend to improve their environmental performance in terms of reduced pollutant emissions; some investigators have also suggested that the presence of an EMS can enhance overall competitiveness. Similar claims have been made for the lean production systems used by Japanese firms. Accordingly, an important goal of the study is to investigate, through the case studies, how the ISO system of environmental standards, a European innovation, has been integrated into the "lean" production systems typical of modern Japanese manufacturing.

2.5. Chapter summary

Eco-efficiency, industrial ecology, and environmental management systems are each key features representing the ecological modernization movement. Each reflects a shift from the traditional command-and-control regulatory structure, with its emphasis upon end-of-pipe abatement technology, towards more flexible, innovative, process-oriented solutions that seek to prevent pollution before it is generated. None of the features of ecological modernization can truly be considered in isolation, because these are conjunctive and mutually reinforcing elements on the path toward sustainable societies.

Those who criticize eco-efficiency as well-intended but insufficient are correct; efficiency alone will not solve our environmental problems, nor do its primary promoters, the World Business Council for Sustainable Development, make this claim. Yet efficiency in the use of resources will be a critical element within an ecologically intelligent economy. Environmental management systems of themselves are little more than a set of rules for careful monitoring and documentation of procedures, and so are of little value without meaningful goals and commitment to performance improvement. An industrial ecosystem is a macroeconomic design framework that requires tools, methods and a guiding philosophy. Eco-efficiency can provide the philosophy, an EMS can provide some of the tools; an industrial ecosystem constitutes the systematic structure to enhance their effectiveness.

The Japanese system of manufacturing, often referred to as "lean" production, or some effectual equivalent, may also prove to be one of those tools. Quite often, in both popular and academic literature, we find "lean production" and "green production" used almost synonymously, with the implication that Japanese methods convey environmental benefits in the form of resource conservation and reduced pollution. Yet even lean production, alone, is insufficient, but when combined with the full spectrum of tools and systems being developed or in conceptual stages, may contribute to true sustainability.

The two chapters that follow describe the core elements and concepts of Japanese production systems, and emphasize that these are not static but constantly evolving in response to changing circumstances. As more and more Western businesses adopt and transform these methods, the end result is likely to be an eclectic blend that is Japanese only in part of its heritage, but far more benign in its environmental consequences.

Chapter Three

Japanese Management Systems

3.1. Remade in Japan: The quiet revolution

During the two decades immediately following World War Two, as Japan struggled to rebuild its industrial capacity, the label "Made in Japan" attached to consumer goods imported into the United States came to symbolize poorly made, low quality merchandise. American politicians, businessmen and academics, smug with the superior productivity and performance of American industrial capitalism, were generous with advice and assistance intended to spur development of the island nation. During this period, however, a quiet revolution was occurring. Toyota Motor Corporation was engaged in developing a new form of production that it would freely share with the whole of Japanese industry, borrowing the best concepts and techniques from Western mass production but uniquely adapting them to the social and cultural context of Japan. By the mid-1980s, the Japanese were no longer the humble students of Fordist principles but had become the masters, instead, of a system of industrial production widely acknowledged to be superior to Western mass production in quality and productivity. American industry now sought to learn from the Japanese, rather than to instruct.

This system was based upon the elimination of waste in all its forms[1], rather than tolerance of "acceptable" levels; striving for continuous improvement of processes and methods, rather than to be satisfied with "good enough"; and harnessing the knowledge and creativity of the line worker by involving them in decision-making, rather than treating them as disposable, insensible cogs in the machine of production. These pillars of Japanese production systems are the antithesis of accepted practice in Western manufacturing. Whether the Toyota system, and its evolutionary variants, represent an alternate form of Fordism or constitute a post-Fordist paradigm remains even today subject to considerable debate, but there is little doubt that Japanese manufacturers have achieved a great competitive advantage.

This chapter focuses upon Japanese production systems as they are practiced in Japan, introducing key concepts, characteristics and terminology that play a part in the discussions within ensuing chapters. Since the purpose of this research project is to evaluate the environmental performance of Japanese transplants in the United States, Chapter 4, which follows, examines how Japanese methods have been transferred, transformed and hybridized within the American context.

3.2. General characteristics of Japanese management systems

Japanese management systems have been referred to, mainly in the Western literature, by many terms: Toyota production system (Ohno 1988); Toyotism (Dohse *et. al*, 1985); just-in-time production (Schonberger 1982); innovation-mediated production (Kenney and Florida 1993); continuous-improvement manufacturing (Hall 1987); and lean production (Womack *et. al*. 1990), among others. Noting that there are significant differences among Japanese firms, Liker *et. al*. (1999) prefers the more generic "Japanese management systems." Despite these differences, however, Liker and associates acknowledge that there are "family resemblances" or certain core practices common to the production systems of "world-class" Japanese firms. Many of the descriptions of Japanese management systems have focused primarily on the technology and

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[1] Waste is defined as any activity or object that does not add value to the item produced (Fujimoto 1999).

organization of production, particularly as regards the "just-in-time" system orientation (see, for example, Schonberger 1982; Monden 1981a,b,c). More recently, Western literature has recognized that the success of Japanese management systems is dependent not just on production technology but also upon social factors.

These social factors, which Sugimori (1977) refers to as the "respect for humans system" and Liker *et. al*. (1999) as "factory based knowledge creation," harness worker knowledge at the point of production through participation in the decision-making process. According to Shimada (1993), the success of Japanese management systems can be attributed to neither to technology nor social organization alone, but to their intersection which he designates "humanware technology," interactive and interdependent. It is the social organization of labor, in which status distinctions are blurred, workers are self-regulating and decisions on production and inventory control are made at the level of the shop floor, that most distinguishes Japanese practices from those of traditional western manufacturing. The technology and organization of production is in large part derived from Fordism; labor practices clearly are not. Hence, the debate continues, and is unlikely to be easily resolved, as to whether Japanese management systems are Fordist or post-Fordist.

Japanese production methods constitute an integrated system of spatial, temporal, and social organization intended to enhance material flows. The features which distinguish the production system, as opposed to those concerned primarily with human resources, are centered upon a collection of practices known as the just-in-time (JIT) system. Many American businessmen who are only vaguely familiar with the principles of JIT mistakenly assume that it is merely an efficient system for inventory control, but JIT is far more intrinsic than an inventory system. Just-in-time is instead more of a constitutional philosophy that provides the basis for the organization and operation of all processes and activities not only within the plant but for external supportive transactions as well. The JIT system is intended to reduce costs and assure a continuous flow of production through reduction of inventory "buffers" of materials and components.

Substantial inventories are characteristic of Fordist production systems, which seek to gain economies of scale through large production runs using dedicated machines. Large inventories serve as buffers which protect the system from disruptions caused by defective parts, equipment breakdowns, schedule fluctuations and other vicissitudes (Shimada 1993). The economies of scale gained through large lot production are expected to compensate for the costs of high inventory levels and high defect rates. Systemic problems of this sort, however, are precisely those which JIT is intended to discover and correct. A striking analogy was used by Taiichi Ohno (1988), considered the originator of the Toyota system, to highlight the problems inherent with large inventories. When the ship of production is afloat on a deep lake of inventory, problems lie submerged and invisible; if the level of the water – inventory – is dropped, then the boulders and snags become exposed as inefficiencies in the system. By eliminating inventory buffers, JIT deliberately stresses the production system and renders it vulnerable, so that hidden problems are made visible. Correction of such problems increases the efficiency of the system as a whole.

Traditional Fordist manufacturing operates as a "push" system. Demand for materials or components is forecast for each stage of production which then produce parts according to the schedule; each process thereby pushes parts into the succeeding process.

In contrast, the just-in-time operative process employs the “pull” principle, where each process pulls only that which is immediately needed from the preceding process, replenishing that which has been consumed. In this way production is matched with need, the whole chain of production being driven by the requirements of the final assembly process that are passed sequentially upstream without the need for advance scheduling of inputs. No step of the production process produces more than is needed by the next step, so that there are no inventories built in excess of this need; ideally, each production step produces a single part corresponding to that which is used in the unit at that moment coming off the final assembly line. To avoid great fluctuations in demand which would require excess inventories at various production stages, production leveling or smoothing takes place at final assembly. Leveling aims to impose a relatively constant demand, daily and even hourly, in terms of the total number of units produced and of the mixture of products (Sugimori *et. al*. 1977; see also Kimura and Terada 1981 and Monden 1981a,b,c).

Fujimoto (1999) identified three types of organizational capabilities possessed by successful firms: routinized manufacturing, routinized learning, and evolutionary learning. Fujimoto illustrated these concepts by recalling a observation made to him in 1984 by the manager of a Toyota group automaker:

> What do you think is the essence of just in time? There are three possible answers. The beginner’s answer would be that JIT is good simply because it reduces inventory cost. An intermediate-level answer is that JIT reveals production problems and triggers kaizen [problem solving for process improvement]. But the third answer is that JIT infuses cost consciousness into all employees. When JIT keeps on forcing workers to face production problems one after another, the people finally start to see everything as a potential source of cost or productivity problems, and then seek problems actively. This is the level we have to reach (p. 271).

The just-in-time system therefore represents an overarching philosophy seeking more efficient production processes and superior product quality, rather than representing a few tools intended for narrow aims. In the sections that follow, Fujimoto's three organizational capabilities are shown to be integral to Japanese management systems.

3.3. Core just-in-time practices

A review of the literature suggests that there are certain core practices that must be implemented for the successful operation of JIT, which are supported by a number of infrastructure features and practices (Sakakibara *et. al*. 1997; Nakamura *et. al*. 1999). These essential JIT practices include (1) set-up time reduction; (2) schedule flexibility; (3) preventative maintenance; (4) equipment layout; (5) kanban system; (6) pull system support; and (7) JIT supplier relationships. Infrastructure practices relate to work force organization and management, quality management, product design, and the overall manufacturing strategy. In keeping with the distinction made previously between production practices and those concerned with human resources, work force organization and management as infrastructure characteristics will be addressed as a separate topic in this chapter. In addition to the plant and corporate infrastructure features, many writers have also identified the Japanese cultural milieu as uniquely supportive to this new form of industrial management, thus posing a potential problem to transfer of Japanese management systems abroad.

Production of components in small lots to achieve low stock buffers and leveled production requires greatly increased flexibility in the production equipment. For stamped parts, for example, dies must be frequently changed to reflect a variety of products withdrawn by subsequent processes. Each time that the dies are changed in a press, there is an attendant set-up cost in the time required to make the change and subsequent adjustments. When very large lots are produced that represent several days or even weeks of inventory, as in traditional Fordist systems, there is little incentive to reduce set-up times which typically entailed several hours. For successful operation of a just-in-time system, however, set-up times must be minimized.

Through standardization of preparation, machine modifications and worker training, Toyota was able to reduce set-up time in its pressing department from about three hours in 1954 to only three minutes in 1965 (Monden 1981a; see also Shingo 1984), a feat which literally astonished Western observers. The increased flexibility achieved by such a dramatic reduction of set-up time has permitted mixed-model production, not only in final assembly but also in subassembly and fabrication. Under Fordism, mixed-model production has been undertaken only on a limited basis in final assembly (Schonberger 1982).

Schedule flexibility, while related to human resource practices, is included at this point because it was identified by Sakakibara *et. al*. (1997) and Nakamura *et. al*. (1999),. as a core JIT practice. The pull system decentralizes production and inventory control by delegating these functions to shop supervisors and foremen. This shop-floor focus increases flexibility and responsiveness of the production system in ways that cannot be achieved through rigid and externally-imposed scheduling.

In a traditional Fordist system, with its fragmented and rigid job classifications, workers have little or no involvement with the production equipment beyond their rote tasks. In a JIT system, in contrast, Total Productive Maintenance (TPM) is a company-wide activity that involves not only plant engineers and maintenance specialists but also the line workers, as part of their daily routines. TPM seeks to maximize equipment effectiveness throughout the entire life of the equipment (Imai 1986). Activities in which direct workers are involved include cleaning the machines, periodically checking machine performance, conducting minor repairs and tool changes, and creating and analyzing the statistics of process capabilities (Fujimoto 1999).

Equipment and processes within Japanese plants are configured to enhance the JIT process with an emphasis upon flexibility, in ways that differ substantially from Western factories. In many Western factories, machines are arranged in groupings by type (lathe, milling, boring, grinding, etc), but in the Japanese factory, the layout is product-focused rather than operation-focused, so that machines are arranged according to the sequence of operations for a particular product group (Fujimoto 1999). Where Western production lines tend to be linear or L-shaped, production lines in Japanese plants often make use of manufacturing cells, arranging lines parallel or in a U-shape. Such configurations, which are most prevalent among companies that closely adhere to the Toyota model, allow workers to manage tasks on both sides of the U or on adjacent sides of parallel lines (Schonberger 1982). The number of workers at any given station is also flexible and varies according to the workload. If the production volume diminishes in a particular line, workers begin to handle additional tasks, freeing others to move to stations with a heavier load (Schonberger 1982; Fujimoto 1999). Stations are located close together so that parts can simply be handed from one process to the next, avoiding the use of conveyors which hold excess inventory. The elimination of most in-process inventory through the JIT system also eliminates the need for “white space” or storage areas along the production lines for in-process inventory, so that Japanese plants tend to be smaller, for the same production volume, than Western factories (Schonberger 1982).

Japan's competitive advantage in manufacturing has often been attributed to a more advanced technology, particularly to a far greater dependence upon robotics. According to Bushnell (1994) and Pil and MacDuffie (1999), the levels of automation between the U.S. and Japan are comparable. The difference lies in the type of automation employed, and how a robotic device is defined. Japanese plants tend more to use flexible automation, or robotic devices, than U.S. plants, which rely more upon dedicated machinery. Where robotics are employed, however, Japanese firms use less sophisticated devices in greater numbers. Many of the so-called "robots" are actually simple parts-transfer devices, as compared to programmable, multi-function machines. If relatively simple "pick and place" devices are defined as robots, then Japanese manufacturers do in fact use more robots.

Automation in the Japanese factory tends, however, to be conservative both economically and technologically. Robotics associated with Japanese production systems are generally of low cost, with relatively few functions, and are often custom made in-house for specific purposes (Liker *et. al*. 1999). Honda, in particular, designs and produces its own simple single-function robots and in consequence has a very high robotic density within its assembly plants; Toyota, in contrast, tends to utilize standardized robots in lesser numbers than Honda (Pil and MacDuffie 1999). In general, Japanese plants favor semi-automated rather than fully automated processes and have been moving more and more toward automation assisted production (Fujimoto 1999). For example, a worker may place lug nuts on a wheel which are then tightened by a robotic device. Busnell (1994) noted that robots are most likely to be used by Japanese companies to replace dedicated machines, unlike in the United States, where robots are more often used to replace people. Pil and MacDuffie (1999) observed that Japanese plants have a different philosophy with regard to the division of labor between human and machine. Technology can, on the one hand, be used for controlling and deskilling workers, or can be used to empower and upskill them: at Japanese-owned plants the goal is to strive for the latter. Machines are used to assist human endeavor, not to replace the workers.

The kanban system is one of the most familiar elements – at least by name – of the just-in-time production system; in fact, the JIT system is sometimes incorrectly referred to as the Kanban system. As Monden (1981a, 42) notes, “The Toyota production system is the way to make products, whereas the Kanban system is the way to manage this production method.” Kanban (“signboard”) is a system of communication, usually in the form of a card attached to a parts container, that moves between adjacent production processes and promotes just-in-time replenishment and production of components as they are utilized. Although there are several variations of the kanban system, including electronic forms, the version followed by Toyota and Honda (and many of their suppliers) involves the use of two cards, known respectively as the “withdrawal” kanban and the “production” kanban. When a parts container is emptied during production, the withdrawal kanban card is removed and taken back to the previous process, where it is attached to a full container. At the same time, the production kanban previous affixed to the container is removed and serves as a directive to manufacture more of the component (Monden 1981b). Thus, the kanban system pulls parts through the JIT production system, in contrast to the MRP (materials requirement planning) schedule commonly used in Western facilities that pushes parts through the system (Schonberger 1982).

JIT production lines include a number of features and practices intended to support the pull system. These include the use of jidoka (automatic detection of defects), assembly line stop cords, poka-yoke (fool-proofing), and visual management, many of which are associated with the concept of worker control of production that is an intrinsic characteristic of Japanese management systems. Jidoka, also sometimes called "autonomation" (reflecting an autonomous process, Ohno 1988; Monden 1981a), refers to a type of machine that is able to detect defective inputs, processes, or outputs and automatically shut down. Such machines are not intended to correct the problem that caused the shutdown, but rather to force human intervention to solve the problem and improve the process. Stop cords placed along assembly lines so that workers can halt the process in case of defects or other production problems are essentially a manual form of jidoka. Poka-yoke, also sometimes called baka-yoke,[2] refers to process or product designs that make defects physically impossible; for example, machine attachments to prevent incorrect loading of materials. Jidoka, stop cords and poka-yoke are all intended to dramatize manufacturing problems and act as pressure for process improvements (Fujimoto 1999).

The JIT system also makes effective use of visual management features, such as the "andon" signboards or "trouble lights" installed above assembly lines, which, when combined with jidoka and stop cords, indicate the location and nature of problems along the line so that supervisors can respond quickly and keep the line moving whenever

[2] Poka-yoke represents a more recent terminology. These terms are also used without the hyphen, as in "pokayoke" or "bakayoke."

possible. Other visual management features include color coding of parts containers and vehicle specification sheets attached to car bodies on the line. Less obvious than such distinctive features is the ability of attention to neatness and cleanliness, typical of Japanese plants, to dramatize disorder and reveal problems. "Good housekeeping" practices are formalized through the "5-S" movement, which takes its name from the initials for five Japanese words related to order and cleanliness.[3]

Application of the principles of just-in-time to external transactions is crucial to the smooth functioning of production operations within the Japanese assembly plant. Because excess purchased inventory is no more desirable than that which is manufactured in-house, the production system pulls materials and components from suppliers on an incremental, just-in-time basis. This may require suppliers to maintain schedules that call for daily delivery of parts, or even several times each day. Establishment of a JIT flow of materials throughout the production system requires continuous interaction, close communications, and joint commitment between assembly plants and their suppliers (Imai 1986; Kenney and Florida 1993). Tight organizational linkages are further enhanced by the tendency for assemblers to delegate some of the responsibilities for process and product development to suppliers, often sharing in the risks and costs (Fujimoto 1999).

MacDuffie and Helper (1999) note that requirements for reliability in product delivery and quality, assumption of shared responsibility in product development, and rapid response to problems are unlikely to be met by supplier firms unless such firms have

[3] *Seiri* - to straighten up, including differentation between what is necessary and unnecessary to have on hand and elimination of the latter; *seiton* – to put things in order so that they will be ready when needed; *seiso* – to keep the workplace clean; *seiketsu* – to maintain personal cleanliness; and *shitsuke* – to maintain discipline, to follow standard procedures (Imai 1986).

themselves adopted, internally, JIT and other Japanese management practices. Similarly, Pil and MacDuffie (1999) suggest that the capabilities of an assembly plant reside in the strengths of its relationships with its suppliers and the abilities of those suppliers. Assembly plants thus have a vested interest in developing the capabilities and efficiency of suppliers in order to assure the continuous flow of materials through the system with gradual reductions in the cost of those materials. Many of the core firms, particularly in the automotive industry, have established supplier development programs which instruct suppliers in the principles of Japanese management systems.

From these characteristics it becomes apparent that a necessary and defining feature of the relationship between assembly plants and their suppliers, just as it is within individual plants, is the free flow of information both upstream and downstream. Two-way information flows allows the close coordination required for the operation of a just-in-time network of suppliers and for incremental improvements in efficiency which upgrade the performance of the entire system and reduce costs for both suppliers and customers. Because the JIT system is premised upon continually stressing the production system and does not provide inventory buffers against problems within the system, it is vulnerable to disruption within and without. Accordingly, the operation of a JIT network requires, above all, stability and encouragement of trust between suppliers and their customer (Kenney and Florida 1993; Imai 1986).

Stability of network relationships and interfirm trust is built through long-term contracts involving considerably fewer supplier firms per core customer than is customary for Fordist systems. This allows interaction of greater depth and the building of confidence based on the history of the relationship. The assembly plant is able to depend upon the competencies of the long-term supplier to provide high-quality parts in exactly the proper quantities precisely when needed. For trusted suppliers, the assembly plant often eliminates the receiving inspection (Schonberger 1982). The supplier receives technological assistance, sharing of the risks involved with product or process development, and benefits from the customer's practice of production leveling that minimizes volume fluctuations.

The supplier system is structured as a pyramid, with the assembly plant at the hub and surrounded by successive outward tiers of suppliers; as many as ten levels may be involved. The hub plant deals primarily with the suppliers of the first tier, who in turn purchase parts and materials from the second tier, and so on through the hierarchy. Typically, an auto assembly plant has less than 200 first-tier suppliers; at each tier outward, the number of firms involved increases. First-tier suppliers generally provide more complex components and subassemblies, rather than individual parts, and are usually located in close geographic proximity to the core firm (Fujimoto 1999). Production of the most critical parts, such as engines, transmissions, and major body panels for automobiles, is commonly undertaken by the assembly plant rather than delegated to suppliers (Womack 1990).

The pyramidal structure is not absolute, however, since many suppliers provide components to more than one major customer. Fujimoto (1999, 314) described the networks of parts transactions in the Japanese supplier system as resembling "not so much isolated mountains of dedicated suppliers as a mountain range of overlapping and open hierarchies." His evaluation of the automotive supplier structure existing in the 1980s noted that there was no one pattern of transactions and identified five types of first-tier suppliers: (1) independent suppliers that deal with any assemblers; (2) Toyota group suppliers that deal with any assemblers but Nissan group assemblers; (3) Nissan group suppliers that deal with any assemblers but Toyota group assemblers; (4) dedicated suppliers to one assembler; and (5) other suppliers. Only Toyota and Nissan had developed full-scale supplier systems, whereas Honda, Mitsubishi and Mazda tended to rely on the independent, Toyota group, or Nissan group suppliers supplemented by a relatively small group of dedicated suppliers. Fujimoto further observed that, in the 1990s, the barriers between the Toyota group and the Nissan group suppliers appeared to be lowering.

In summary, the relationships between assembly plants and their supplier networks is as much a social relationship as one of strictly contractual obligation, and serves as an external corollary of the just-in-time system practiced within the core firm. These relationships, and particularly their role in knowledge creation and transfer, are discussed in greater detail in the introductory sections for the case studies in Chapters 10,11 and 12.

3.4. Workforce organization and management: A system for knowledge capture

Despite some evident differences in systems organization and integration and the coordination of material flows, the processes and technology involved in Japanese industry are clearly derived from , and remain within, the Fordist tradition of assembly-line mass production. The most significant difference between Fordist and Japanese management systems is in the organization and management of the workforce; a difference that, according to some commentators, places the Japanese methods beyond Fordism. Critics of the Japanese methods view this new system of workplace social relations as an exploitative means of employee control in an intensified work environment (Graham 1995; Parker and Slaughter 1995; Unterweger 1993; Katama 1982). Proponents, on the other hand, consider the nature of these relations to be "empowering" and egalitarian (Gavroglou 1998; MacDuffie 1995; Kenney and Florida 1993; Imai 1986; Ouchi 1981). The discussion that follows, in this section, will focus upon the nature of Japanese workplace social relations from the viewpoint of advocates; an evaluation of what has been called "the dark side" of lean production will be briefly postponed, to be examined in Chapter 4 in the context of overseas diffusion and adoption of Japanese methods.

Labor relations within the Japanese system of production are characterized by a far greater degree of cooperation between labor and management than exists in traditional Fordist systems. Just-in-time production, based on elimination of buffer stocks and performance improvement through continuous stress upon the system, is highly vulnerable to disruption by work slowdowns and stoppages, and so harmonious relations are essential to maintain smooth functioning of the system. The structure of social relations in a Japanese factory is intended to foster loyalty to the company and an alignment of the workers' interests with those of the company, bringing about a sense of community.

This cooperative nature of labor and management is not a consequence of the modern Japanese production system but was, instead, a prior development that made the modern system possible. Following the labor struggles of the 1950s in Japan, new institutional arrangements emerged in which the capital-labor relationship was less adversarial (Gavroglou 1998). In the view of Mashiko Aoki (1985), the Japanese company today operates under the joint control and for the joint benefit of labor and capital, rather than being the exclusive property of capital. This alignment of joint interest has been one of the primary sources for the competitive advantage experienced by Japanese firms. Workers perceive their personal welfare as linked to the welfare of the company and so are more inclined to engage in behavior that enhances efficiency and productivity. The resultant strong inclination for collaboration allows the firm to acquire and integrate knowledge gained from all levels, with particular significance attached to the contributions of the workers of the shop floor who are closest to the actual production processes. The role of the production worker thus becomes central to the functioning of the company.

The Japanese production system accordingly places greater emphasis upon human resources than Fordist regimes. The key attributes of social relations within Japanese industrial firms can, therefore, be described as based upon (1) worker empowerment; (2) collaboration across status barriers; and (3) creation and harnessing of knowledge at the point of production. Workplace practices and features associated with these core attributes facilitate the just-in-time production system, and include team-based work organization, multiskilled workers, egalitarian environment, decisions by consensus, and free and multidirectional flow of information through the organization. In addition, certain human resource institutions specific to the Japanese context are likewise derived from the central role of the worker and are also supportive of the production system: enterprise unions, lifetime employment, and seniority-based wages. These institutional HRM traits are, in the literature, thought to be less likely to be successfully transferred to a different national context.

The concept of "team" as applied to the Japanese factory environment is somewhat ambiguous because it refers not only to the formal structural unit of production but also to the idea of "teamwork," cooperative relations "among work teams, among departments, among functional specialties, and among organizational levels" (MacDuffie 1995, 57). This duplexity is refined by Liker *et. al*. (1999), who classifies teams into "on-line" and "off-line" forms.

The emphasis is to develop at all levels the capacity and motivation to make decisions, where those who follow instructions are expected to be capable of improving and elaborating upon them (Bushnell 1994). According to Kenney and Florida (1993), the on-line team is the basic mechanism for achieving systematic integration of production tasks, and serves to move many of the decision-making functions from management to the shop floor. The team is also the basis for solving production problems. Workers actually involved in the production process are more likely to be aware of problems and potential solutions than managers distant from everyday practice. Bushnell states (p. 240): "The effort to synchronize operations and search for causes of problems encourages a collaborative group based organization and makes work more socially rewarding."

Under the Japanese system, work is not assigned to individuals but to the teams, whose members decide the allocation of tasks. Commonly this involves a rotation so that each member of the team becomes skilled in every function, facilitated by task standardization and the absence of a complex and rigid system of job classifications. Workers thus become multiskilled and able to substitute for any absent member. More significantly, workers accumulate an increasing knowledge of the production process; with a broader overview of the system, workers are better able to contribute suggestions for process and product improvement (Kenney and Florida 1993). Typically, an assembly-line team at a Toyota plant consists of five team members and a team leader, a union member who fills in for missing workers, deals with line stops and other problems, coordinates process-improvement (kaizen) activities, and handles some administrative functions (Fujimoto 1999). According to MacDuffie (1995), the team leader serves in a "quasi-coach, quasi-staff support" role very unlike the authoritarian foreman of traditional mass production systems in the West.

The team is a social group, and so serves social functions as well as strictly production functions. The team is a mechanism for the socialization of new workers, in which knowledge is shared through apprenticeship-like practices. According to Kenney and Florida (1993, 39), the team "becomes the source of motivation, discipline, and social control for team members, driving them to work harder and more collectively. In this way, workers are encouraged, stimulated, and provided incentives to offer up their ideas and continuously improve the production process."

Off-line teams are equivalent to the "small-group activities" commonly referred to in management literature and defined by Imai (1986, 96-97) as "informal, voluntary small groups organized within the company to carry out specific tasks in the workshop." Such off-line team efforts may include quality control (QC) circles, zero-defect movements, safety groups, productivity committees and many other ad-hoc groups. Participants in off-line groups typically include representatives from all levels of the firm, and such groups are in fact often used for cross-training.

Teams, whether on- or off-line, function to generate new knowledge that can be applied to process and product improvements and which is diffused across the organization (Liker *et. al*. 1999). The best-known of off-line teams is the QC circle, which occupies a prominent place in the management literature. The quality circle is not limited to quality concerns alone but may often address productivity or other issues; thus the quality circle is in large part synonymous with off-line small-group activities in general. In some organizations, quality circles remain as voluntary gatherings during regular work hours or after work, which in the latter case may or may not be compensated (Imai 1986). In other companies, such as Toyota, the quality circle has been incorporated formally into the Total Quality Control program (Fujimoto 1999). Groups typically meet weekly or biweekly for about an hour and spend from three to six months in consideration of a given issue or theme (Gavroglou 1998).

Quality circles and other activities, group-based or individual, intended to enhance system performance, are part of the "kaizen" process of "continuous improvement." Kaizen, according to Imai (1986) is "the single most important concept in Japanese management – the key to Japanese competitive success" (p. xxix) and "the unifying thread running through the philosophy, the systems, and the problem-solving tools developed in Japan over the last 30 years" (p. xxxii). Kaizen refers to a process of continuous incremental improvement undertaken, on a daily basis, by everyone associated with the process of production, from the shop floor worker to management at the highest level. Kaizen involves the constant evaluation of system performance and the continual upward revision of standards for productivity and quality.

In regard to process improvement, Imai emphasizes the difference in orientation between Japanese and Western attitudes. Where Western manufacturers are primarily concerned with results, Japanese industry is characterized by process-oriented thinking.

Progress in the West is sought through innovation, which entails radical improvements made through large investments in technology and equipment; Japanese kaizen is concerned with improving standards through small, gradual changes. The kaizen process is therefore undramatic and subtle, producing results that are seldom immediately visible but result in cumulative and quantifiable progress over the long term.

Kaizen, according to Fujimoto (1999, 114-116) emphasizes the following: (1) employing practices such as jidoka that reveal production problems to workers on the spot, and most importantly, fostering the "kaizen mind," or "problem consciousness of workers, supervisors, and plant engineers [which] facilitates quick detection of problems on the shop floor"; (2) quick problem-solving, accomplished by "empowering and equipping" the workers who have daily experience on the shop floor "with the tools for identifying root causes, finding alternatives, and solving the problems"; (3) standardization of problem-solving tools, which facilitates "the diffusion and retention of improvement skills and experiences to employees"; (4) quick experimentation and implementation, where experiments with minor system alterations are conducted prior to any formal proposal (factory as laboratory concept), thus both encouraging valid suggestions to be made and resulting in a high level of acceptance for proposals; and (5) routinized retention through knowledge – manual interactions. This latter refers to a "two-way conversation between tacit knowledge and formal written procedures," where written standards are constantly revised and the stability of the workforce fosters retention of tacit knowledge.

Imai (1986) notes that, although group efforts such as quality circles are important, kaizen is a much an individual initiative as a group activity and takes place at several levels within the company: management-oriented kaizen, which concerns systems and procedures; group/team oriented kaizen concerning processes in the same shop; and individual kaizen, which addresses a single work station. One of the more significant kaizen activities is the suggestion system, adopted by Japanese manufacturers during the 1950s following a visit by Toyota executives to Ford plants in the United States. Toyota, notes Fujimoto (1999, 70) "recognized the suggestion system as a competitive weapon" to reduce manufacturing costs, and henceforth the suggestion system became a core element of kaizen.

The suggestion system in Japanese plants, as a primary source for kaizen activity, receives contributions from both individuals and groups. According to Imai (1986), most of the suggestions that have economic impact are derived from small-group activity, whereas individual suggestions tend more to have a morale-boosting or educational value. Managers in Japan tend also to be more receptive to suggestions that improve working conditions than their Western counterparts, where the focus is almost exclusively upon the cost of the change and the economic return. In Japan, suggestions are considered valid and likely to be implemented if they contribute to any of the following: making the work easier; removing drudgery or nuisance; making the work safer; increasing productivity; improving product quality; or savings in time or cost.

Japanese companies greatly desire suggestions for improvement from the shop floor workers, and provide incentives in both positive and negative forms. On the one hand, substantial financial rewards or recognition may be provided for valid suggestions; on the other, many firms keep records tracking suggestions from individuals that are used to establish that person's annual performance rating. Individuals who contribute little in the way of suggestions may receive smaller bonuses or even be subjected to criticism from supervisors or co-workers (Katama 1982). Kenney and Florida (1993) note that, in some cases, numbers may be inflated by trivial suggestions to appease management.

MacDuffie (1995) points out that the ideas of workers are not the dominant influence in the organization of work in the Japanese factory; the initial specifications for the work process are established by engineering staff. Suggestions from floor workers must be approved by engineers and managers before adoption. Even so, he notes, "the fact remains that workers are encouraged, even expected, to contribute their ideas about improving their jobs; their suggestions are seen as valid and significant by managers and engineers, and are often adopted; and work organization and training policies are directed towards improving worker abilities to contribute to this cognitive process, rather than the reverse" (p. 56). According to MacDuffie, the Japanese system legitimizes worker's cognitive inputs to improving the production process.

A commonly-used company-wide kaizen technique, involving both management and floor workers, is the application of the PDCA cycle, a method first devised by Walter Shewhart and popularized by W. Edwards Deming in Japan. PDCA, which stands for Plan – Do – Check – Act,[4] is a series of activities intended to make continuous improvements and thus continually raise the expected performance standards. The Plan segment of the cycle concerns identifying a problem and developing a plan for improvement; the Do segment involves implementation of the plan on a trial basis; the Check (or Study) segment evaluates the results; and the Act segment implements the new method as standard practice. The fifth step, as noted by Deming (1986), is to continue

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[4] Deming later revised the nomenclature to Plan – Do – Study – Act (PDSA) as more reflective of the actual process, but many Japanese companies still refer to the activity as PDCA.

the process, ever raising the standards for productivity or quality (see Figure 3.1). According to Imai (1986, 63), "PDCA is thus understood as a process through which new standards are set only to be challenged, revised, and replaced by newer and better standards. While most Western workers see standards as fixed goals, Japan's PDCA practitioners view standards as the place to start for doing a better job next time."

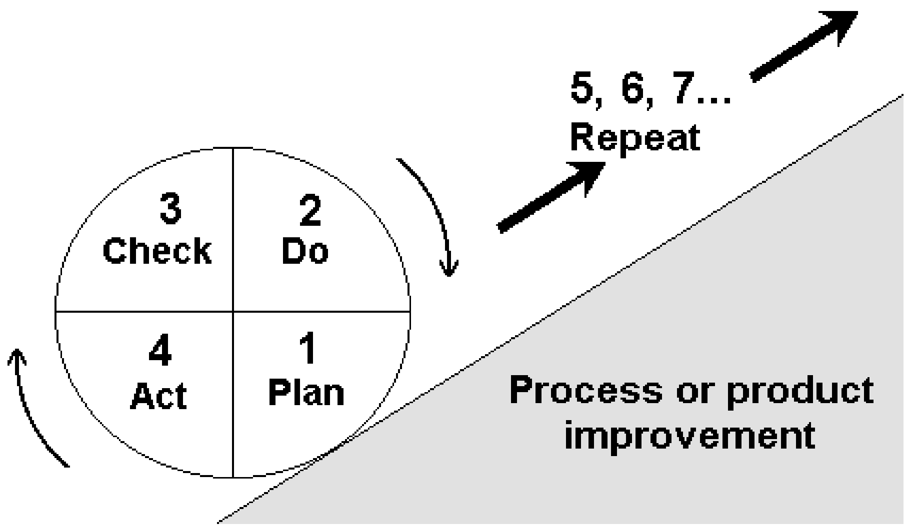

Figure 3.1. The PDCA Cycle or Deming Wheel
Graphic by the author, based on Imai (1986) and Deming (1986).

Although the Japanese factory environment can hardly lay claim to being an egalitarian society, despite some claims to the contrary (e.g., Ouchi 1981), many of the workplace practices serve to reduce status barriers among workers and between workers and management. The promotion of a limited form of egalitarianism facilitates cooperation between management and workers, the free flow of information, and fosters loyalty to the company and its goals. Policies and strategies intended to diminish status distinctions include comprehensive job rotation, equitable shift rotation, consolidated job classifications, reduced management privileges, and reduced income differentials between management and workers.

In addition to the routine job rotations among members of a work team, workers are also periodically rotated into other work groups engaged in different production tasks as part of the effort to build multiskilled employees. Rotation is also practiced at management levels; managers are expected to become generalists with a broad knowledge of factory processes, rather than specialists. Shift rotation is also a common practice, in which all workers spend a few weeks on the day shift and then rotate to the night shift for an equal period. This practice ensures that each shift contains experienced workers, as opposed to the Western practice of filling night shifts with workers having the least seniority. Also in contrast to Fordist practice, Japanese plants have far fewer job classifications at the shop level, and management hierarchies are much flatter. Where a Western factory may have several hundred functional specialties, most Japanese plants have five or fewer classes of production workers (Bushnell 1994; Kenney and Florida 1993).

Absent from most Japanese factories are such executive "perks" as separate washrooms, cafeterias, and parking lots. Managers do not have enclosed offices, but occupy desks in large open areas along with other administrative and clerical staff. Income differentials between management and floor workers are much smaller than in Western companies; missing are the obscenely inflated compensation packages typical of executives in the West, and shop floor workers frequently earn more than supervisors as a result of overtime. Recruiting of new employees focuses upon attitude, valuing a disposition for teamwork rather than acquired skills. Although education is a consideration in initial hiring, this is disregarded in subsequent career development; even college graduates start on the bottom rung. Managers and engineers are expected to spend little of their time sitting in offices but to practice "management by walking around" the shop floor, observing, questioning, getting their hands dirty, usually tieless and wearing the company uniform rather than a suit (Miyai 1995; Jurgens 1993; Kenney and Florida 1993).

Many writers have attributed the success of Japanese management systems to a set of workforce institutions sometimes referred to as the "Three Sacred Treasures"[5]: enterprise unions, lifetime employment, and seniority-based pay and promotion. Although these features, particularly lifetime employment policies, provide support to many aspects of JIT, it appears doubtful that they are, in fact, essential to operation of Japanese-style production. As Miyai (1995) noted, these institutions are unlikely to be effectively transferred to other national contexts, yet there are many Japanese corporations operating successfully in other countries using Japanese management systems and approaches.

The enterprise union, the dominant form of unionization in Japan, differs significantly from the Western form of management-labor relations in that these unions are based upon individual firms rather than industries or trades, and that the membership includes both blue-collar and white-collar workers (Cusumano 1985; Gavroglou 1998). Unions were introduced to postwar Japan by the Americans during the Occupation (1945-1952), and initially included both company unions and industrial unions. According to Clark (1979), the company-based union developed as a consequence of poor communications in the postwar environment that made it difficult to gather workers by industry from different

[5] An analogy to the three symbolic treasures of the Imperial Throne (Miyai 1995).

regions, leading to the organization of workers in individual firms. Miyai (1995) attributes the company union to organization efforts by all employees within a firm, including supervisors and managers at first, to negotiate for higher wages at a time when much of the population was near starvation. Several large industrial unions were also organized in Japan after the war, including the All-Japan Automobile Industry Labor Union (Cusumano 1985).

Following a series of unsuccessful strikes from 1949 to 1953, militant labor organizations were defeated and replaced by more compliant versions of the company-based union (Kenney and Florida 1993). Today, enterprise unions are organized into industrial federations, in turn associated with a centralized national labor organization that deals with broader issues such as political or institutional reforms. Although an enterprise union is associated with nearly every industrial firm in Japan, a number of firms are represented by both company-sponsored and worker-organized unions. The existence of plural unions offers workers an alternative in the event management interests are perceived to dominate the company union (Gavroglou 1998).

According to Gavroglou, organized labor participates in policy making through two mechanisms: collective bargaining and joint consultation meetings. Collective bargaining takes place on an annual basis and addresses working conditions and compensation. Joint consultation undertakes a broad scope of issues, including basic policy and management, but labor's role in decision-making is consultative only and the results of such meetings are less binding than collective bargaining. In addition to joint consultation meetings between members of the enterprise union and management, union interests are also represented in workshop and committee meetings, as well as various other small-group activities. Although the Japanese enterprise unions are perceived as more cooperative with management than Western unions, and strikes are extremely rare, management tends not to act against labor's fundamental interests, "because so much of the firm's performance is predicated on a devoted and cooperative workforce" (p. 241). Under JIT, labor's power is actually enhanced by the relative fragility of the production system.

A primary focus of the enterprise unions from the beginning has been employment security. The policy of lifetime employment guarantees, which applies to a substantial percentage of Japanese industrial employees, is both a source of power for labor and of benefit to the production system. The majority of male workers in large firms – 88 percent – and more than half of male workers in small firms are covered by this policy; female workers, however, are generally excluded as a consequence of entrenched sexism in Japanese society (Gavroglou 1998). Since there is no legal or contractual basis, according to Miyai (1995), lifetime employment "represents the general expectation of employees, and management's commitment" (p. 31). In practice, lifetime employment is institutionalized, and layoffs are not a management option: "Given the preclusion of capital's (and management's) ultimate productivist sanction against labor, layoffs, the privileged position of management in decision making does not result in the marginalization of labor's fundamental interests in the decision-making process" (Gavroglou 1998, 241). Companies cannot dismiss employees, but workers are free to change jobs. The net result is "near-perfect job security" for workers, and for management, little risk of losing trained and experienced employees (Miyai 1995).

In consequence, the practice of lifetime employment has been identified as supportive of a wide range of practices in the JIT environment. Gavroglou (1998) notes that lifetime employment virtually forces investment in extensive training since the company is essentially “stuck” with its workforce; the company receives returns from such investment since workers are not likely to take acquired skills elsewhere (Nakamura 1999; Pil and MacDuffie 1999; Kenney and Florida 1993; Ouchi 1981). Lifetime employment reduces employee turnover; fosters successful teamwork; and induces a commitment to kaizen (Pil and MacDuffie 1999; Gavroglou 1998; Kenney and Florida 1993). Despite the severe recession of the 1990s in Japan, lifetime employment remains entrenched (Gavroglou 1998).

Pay and promotion in Japanese firms tend more to be based upon seniority than merit, although merit and ability are included in calculating compensation. According to Miyai (1995), the seniority system is in part derived from a social tradition of respect for elders, and in part from a recognition that the value of an employee to an organization increases over time with the accumulation of skills and experience. All Japanese firms use a formula in which seniority is the base and adjustments are made according to performance and ability; the weighting of each factor varies according to company and extensive use is made of bonuses (Kenney and Florida 1993).

Of the “Three Golden Treasures,” lifetime employment, or, more accurately, “long-term job security” (Miyai 1995), appears to have the greatest significance both in the development and operation of the modern Japanese production system. Because labor’s fundamental interests are thus protected, Japanese firms are, according to Gavroglou (1998), forced to discover efficiency improvements to compensate for the added costs of over-employment. Furthermore, Japanese firms are more efficient because the integration of labor and management functions in the labor process facilitates flexibility; and because Japanese firms are less likely to be wasteful of human capital in which long-term investments have been made.

Although much has been made in the business and academic literature concerning these “Golden” institutional features, Miyai (1995), however, asserts that there are other workforce characteristics of the Japanese system that are far more significant. Primary among these are (1) the lack of status distinction among employees; (2) the production-floor orientation that values workers’ ideas and suggestions; and (3) decision-making based on consensus and teamwork spirit, reflecting the group consciousness characteristic of Japanese organizations. In these features resides much of labor’s particular contribution to the competitive advantages of the Japanese production system.

3.5. Supportive infrastructure practices

Nakamura et. al. (1999) identified certain infrastructure practices as supportive of the just-in-time system, including product design for manufacturability, quality management, and the overall corporate strategy. Of these, quality management, known variously as Total Quality Control (TQC) or Total Quality Management (TQM), has received the greatest attention in the literature. A discussion of infrastructure must also include an assessment of the significance of the cultural and institutional context for industry in Japan, where tighter linkages exist between government and business than in the United States.

TQC/TQM refers to a company-wide, completely integrated effort to improve product and process quality. While it entails both specific practices and measures of performance, in Japan TQC/TQM represents more of an embedded philosophy than simply a set of tools. TQC/TQM is considered so significant to competitiveness that it is often identified as a separate element of Japanese management systems distinct from JIT practices. Schonberger (1982) refers to "JIT and TQC" as the core elements of Japanese manufacturing, and among the characteristics of "world class manufacturers" (1986); Fujimoto (1999) refers to the TPS [Toyota Production System] and TQC as the primary sources for Toyota's competitive advantage; and Flynn *et. al*. (1995) to JIT and TQM as practices that function effectively in isolation but synergistically improve performance in combination.

Other writers consider TQC/TQM to be but one of many core elements of Japanese production systems (Sakakibara *et. al*. 1997; Nakamura *et. al*. 1999; Hamilton and Smith 1993). Masaaki Imai (1986) takes a different approach, regarding TQC and the various elements of JIT as belonging under the umbrella of kaizen, or continuous improvement. Imai defines TQC as "organized kaizen activities involving everyone in a company – managers and workers – in a totally integrated effort toward improving performance at every level" (p. xxv). According to Cowton (1994), the concepts of statistical quality control inherent to TQC/TQM "are sometimes presented as independent from, bundled with, or incorporating JIT" (p. 431).

The terms "TQC" and "TQM" are often used interchangeably in the literature but, while overlap exists, do not always refer to the same concepts. This is a consequence of the transfer of the principles and techniques of quality control from the United States to Japan, where synthesis and substantial modification occurred, followed by transfer back to the United States where hasty, imitative adoption by many U.S. corporations often led to disappointing performance. The evolutionary path for the concept of total quality began in the United States with the development of statistical methods for quality control prior to World War Two. In 1950, the Union of Japanese Scientists and Engineers (JUSE) invited W. Edwards Deming to Japan to teach courses on statistical process control (SPC). Deming, who had been strongly influenced by Walter Shewhart's views on process, went beyond statistical methods to describe a management philosophy premised on problem solving and continuous improvement in production and service (Dooley 2000).

In 1951, Armand Feigenbaum's *Total Quality Control* was published, emphasizing a systematic view of the product life cycle, and in 1954, Joseph M. Juran visited Japan, where he extended the concepts of quality control from the shop floor to the total organization. The concepts of these three Americans were synthesized into a system that became known as Company-Wide Quality Control (CWQC) and later, simply as TQC or Total Quality Control (Dooley 2000). The TQC model constituted a set of concepts, systems and tools that defined general process management on a basis that was both scientific and self-improving.

In the United States, while many of these concepts of total quality were familiar to members of the engineering profession, they were wholly unknown to corporate management even by the early 1980s. Whereas little attention had been paid to Deming and other quality gurus in the U.S., Schonberger (1982) attributes the more receptive environment of Japan to specific environmental factors: (1) the Japanese tendency to avoid waste, as a consequence of resource scarcity; and (2) a cultural climate which discourages specialization and encourages group participation in activities. During the

1980s, a refined and transformed version of total Quality Control was reimported back to the United States with the establishment of Japanese industrial transplants, particularly in the automotive industry. U.S. firms, who had lost market shares to the Japanese, sought to discover the sources of Japan's competitive advantage and identified superior product and process quality management as one such factor. Many of the principles of Japanese TQC were translated into a Westernized version known as Total Quality Management or TQM (Dooley 2000). To conform with international practice, Japan changed the name of its quality system to TQM, even though Japanese TQC and Western TQM are not in complete accord. Accordingly, quality management at Japanese firms may be seen referred to as either TQC or TQM.

According to Cole (1999), the primary attributes of TQC systems are a focus on the customer (where the "customer" is the next process in line, as well as the ultimate consumer), continuous improvement, and workforce participation. Flynn *et. al*. (1995), using the term TQM, identify core practices such as statistical process control, customer focus, and interfunctional design, distinguishing these from performance measures such as defects in parts per million, percentage of units passing inspection, and perceptions of the customers. The goals of quality management, according to the authors, are continuous improvement of all processes, customer-driven quality, production without defects, and data-based decision-making.

The study by Flynn *et. al*. (1995) found a distinct mutually supportive relationship between TQM and JIT practices and firm performance, where common infrastructure practices formed a strong foundation for both JIT performance and quality performance. The authors concluded that:

> JIT practices interacted with common infrastructure practices and TQM practices by exposing opportunities for process improvement and reducing the potential for spoilage and damage through the reduction of inventories. The best users of unique TQM practices, combined with common infrastructure practices, are capable of solving problems to improve the production process. However, they may have difficulty finding problems whose solution can improve a process if inventory buffers mask their effects. The plants with the best quality performance are given an added boost through JIT's ability to pinpoint problems for subsequent solution using TQM approaches (p. 1354).

Thus we find that many of the practices associated with JIT are also part of Japanese TQC, such as jidoka, poka-yoke, line stops, and visual management features. The shop floor is the focus for both JIT and TQC; both systems rely upon harnessing the knowledge of the people most closely associated with the production processes - the line workers. Kaizen activities such as quality circles and suggestion systems are directed at continuous improvement of both process efficiency and product quality. Japanese production systems seek to attain zero product defects,[6] and this can only be achieved when all workers are actively involved in quality improvement. As a result, Japanese factories typically have minimal quality control departments, because these are redundant when every worker is a quality inspector.

"Design for manufacturability" was found by Nakamura et. al. (1999) to represent another common infrastructure practice supporting the JIT process, described simply by Fujimoto (1999, 184) as "designing components easy to produce." Most of the manufacturing cost for a product is determined in the design phase of product development. To ensure ease of manufacture, product features are evaluated with respect to process capabilities and limitations, in order to facilitate handling and assembly, lower costs, and improve quality. The goal is optimization of both product and process, and

[6] "Zero" defects is recognized as an ideal to strive toward, rather than a real possibility.

commonly results in a simplified, more reliable product with fewer parts requiring individual assembly. Simplification and increased reliability facilitates the reduction of in-process inventory buffers and speeds up process throughput. Design for manufacturability requires close communication and cooperation between the design and manufacturing functions within an organization, and hence is well suited for the Japanese factory environment where teamwork and free flow of information are characteristic (Nakamura *et. al*. 1999; Sakakibara *et. al*. 1997; Venkatachalam 1992; Dean and Susman 1989).

Sakakibara et. al. (1997) notes that the connection between manufacturing strategy and JIT is rarely discussed in the literature. According to the author's analysis, firms whose business strategies are built upon the capabilities of JIT practices are more likely to correspond to the more progressive firms described within Wheelwright and Haye's (1985) framework for manufacturing effectiveness and enhanced competitive advantage. Such firms move from "safe" traditional approaches to adoption of innovative and integrated practices, incorporating the capabilities of manufacturing into their overall corporate strategy. The most advanced companies, according to Wheelwright and Hayes, are characterized by three management principles: (1) Emphasis of activities that facilitate, encourage and reward effective interaction between manufacturing and both marketing and engineering, requiring people to regard each other as equals and contribute to areas other than their own, and providing for multidirectional flow of information, support and influence; (2) Recognition that product and process technologies must interact; and (3) Focusing of attention and resources on only those factors (e.g., manufacturing, quality and overhead reduction) that are essential to the long-term success of the business (pp. 108-109). Although Wheelwright and Hayes made no specific mention of Japanese management systems, it is perhaps no coincidence that these three principles rather effectively summarize the philosophy underlying Japanese manufacturing practices.

Before turning to a consideration of the diffusion of Japanese management systems to North America, an evaluation of the cultural and institutional context of manufacturing in Japan is in order. In addition to certain organizational practices such as lifetime employment, enterprise unions, and seniority-based compensation, these are the features least likely to be successfully or completely transferred to a new environment. Cultural factors include a relatively homogenous, rather than culturally diverse, society; a group orientation with a habit of obedience to authority; centering of daily life around work; and a highly educated population. Institutional factors include the keiretsu organizational structure, supplier associations, and the close relationship between government and business in Japan.

Although any sweeping generalization must be regarded as suspect, there is considerable evidence that the cultural attributes of Japan and the United States are distinctly different, and that these national characteristics have played a significant role in the development of Japanese management systems. In 1985, Ronen and Shenkar performed a review of empirical studies that compared general attitudes about work, in terms of values and goals, and used this data to assign countries into groups or clusters of similar characteristics. The result of this synthesis was to distinguish Japan, along with a very few other countries, as “independent”; that is, a nation whose attributes of culture and development do not resemble those of any other country but are apparently unique.

Japanese society is one of the most homogenous of any advanced nation in the world today, resulting in large part from centuries of deliberate conservative isolationist policy. The effect of this homogeneity, combined with the high population density of Japan, has resulted in a society that is oriented toward a group consciousness, valuing cooperative relationships rather than individualism (Benedict 1946; Nakane 1972; Ouchi 1981; Sugimori *et. al*. 1986). This homogeneity, according to Kawamura (1994), likely fosters integration and a sense of unity among employees, and may facilitate implementation of aspects of the Japanese production systems such as flexible job assignments and work organization, and the development of multi-skilled workers. Itagaki (1994) suggests that Japanese organizations promote homogeneity and a sense of belonging to the group through various egalitarian measures and shared social activities.

This "group consciousness," as it has been termed by many writers, permeates Japanese society from household to corporation. Nakane (1972) described the significance of the group as "family-like," in that

> …a group where membership is based on the situational position of individuals within a common frame tends to become a closed world. Inside it, a sense of unity is promoted by means of the member's total emotional participation, which further strengthens group solidarity. In general, groups share a common structure, an internal organization by which the members are tied vertically into a delicately graded order (p. 23).

According to Jurgens et. al. (1993), the group principle occupies a central role in the production and social organization of the Japanese factory, with a wide range of functions that include serving as a substitute family and social network; a place for learning; an organizer of leisure time; and a unit for performance and quality regulation (group-focused rather than individual-focused). Nakane goes one step farther, stating that the company provides the whole social existence of a person, pervading even the private lives of workers. According to Sullivan (1992), private loyalty to the group or firm takes precedence over loyalty to abstractions such as the "public good" or "society." Along with Jurgens, many other writers have attributed the use of work teams in Japanese production systems as a natural development from the group principle; Sullivan, however, argues that the use of teams is not driven by Japanese culture, but is simply clever exploitation of Japanese self-perceptions: "A theory of work as meaningful living primes employees for socialization in groups, as does the belief that the company has a legitimate social mission" (p. 105).[7]

Sullivan's "work as meaningful living" was identified by Sugimori *et. al*. (1977) as one of the important traits that distinguished the Japanese concept of labor from that of European and American workers. Sullivan's analysis of the Japanese work ethic notes

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[7] Sullivan's (1992)) analysis of Japanese organizations contradicts much of what has been written about the egalitarian nature of these environments. He suggests (pp. 88-107) that many of the worker related traits of the production system represent a Japanese national ideology, the *nihonjinron*, that is more myth than reality The *nihonjinron* ideology, which "purports to create a legitimizing basis for the economic and business life of the nation," presents a greatly simplified version of the actual social behavior of Japanese managers and workers. Sullivan criticizes Ouchi's (1981) Theory Z as presenting an idealized picture of conditions within Japanese companies. In the Theory Z firm, "the workplace is egalitarian, behavior is open, everyone is treated equitably and employees develop mutual understanding and a willingness to be obligated to each other without contracts or negotiations. They are motivated to want as individuals what the organization wants as an enterprise, because their values become strongly linked to corporate values." The reality, according to Sullivan, is that "the Japanese workplace is characterized by order, stability, predictability, and cohesion emerging from the subtle and not so subtle controls devised by powerful managers. In well-run companies all of this methodical regimentation can be quite effective. Managers provide employees with the training and resources to do what is expected of them and are eager to hear any employee ideas about how to do the job better…Employees in Japanese organizations are not autonomous free spirits eagerly taking part in creative rap sessions with managers and then rushing back to their work stations to implement some new idea." Japanese organizations are not the democratic and communal environments of Theory Z, although aspects of Theory Z are present. "The Japanese were not lying about promising these things," notes Sullivan. "They were simply picking up a management theory congenial to Americans and using it as a basis for their negotiations." In summary, whereas on the one hand, Japanese management philosophies are "riddled with fashionable *nihonjinron* writings about how unique Japanese culture is and how this uniqueness carries over into managing," American academics have, on the other, put forth pet theories as though they represented actual conditions in Japan. Further discussion of this perspective is presented in the following chapter.

that citizens tend to perceive work as carrying out obligations to society and self: "Work is a human activity expected by Japanese society. It is what one does if one is a respected member of the community, regardless of whether or not anything productive comes of it….toil is simply the act of being human. It is one of the things one does to affirm existence as meaningful" (p. 93). Along with group consciousness and a high educational attainment, "centering their daily living around work" was among the attributes of Japanese workers that Sugimori and associates considered to be human resource advantages contributing to Toyota's development of a successful production system.

The group principle also extends to interfirm relationships. Clark's (1979, 49-97) examination of Japanese industrial organization identifies several tendencies in which companies in Japan differ from the forms and practices of the West. These tendencies include: (1) Japanese companies tend to be narrowly specialized in one or a few closely related businesses, rather than engaging in diverse enterprises;[8] (2) companies tend to be arranged in a hierarchy, in which the largest companies have the most status; and (3) companies are generally associated with other companies in some group arrangement.

Nearly every firm in Japan is associated with an industrial group known as "keiretsu." The keiretsu are derived from the family-owned holding companies called zaibatsu that controlled huge industrial empires before World War Two and were reassembled, in slightly different forms, after the end of the American Occupation (Miyashita and Russell 1996). There are two main types of keiretsu today, the horizontal or "capital" keiretsu

[8] Mitsubishi Electric Company is one of several exceptions to this tendency. See the case study for Mitsubishi Electric Automotive, Chapter 9.

and the vertical or "production" keiretsu. The horizontal keiretsu[9] consists of a group of companies in different industries centered around a main bank and several other associated financial institutions, typically also including a trust bank, a general trading company, and one or more insurance companies, so that all financial needs of the group can be met internally (Nakamura 2000). The firms involved are linked by cross-shareholding, trading relations, and close personal relationships among executives. The main bank provides low-cost financing to the industrial concerns in the group, holds equity, coordinates activities, monitors performance and provides management assistance if necessary. The trading company coordinates trade within the group, among different keiretsu, and with foreign customers (Miyashita and Russell 1996).

There are at present six major horizontal keiretsu that collectively control about 17 percent of all Japanese corporate assets (Kreft 2001). The "Big Six" keiretsu are Mitsubishi, Mitsui, Sumitomo, Fuji, Daiichi-Kangyo and Sanwa, and associated with these main groups are less than 200 large industrial corporations who directly participate in directing the affairs of the keiretsu. Most Japanese corporations belong to a single keiretsu; a few, such as Hitachi, belong to more than one; some are only loosely associated, such as Toyota; and some are independent, such as Honda or Sony. Even the independents, however, are not entirely free from ties to a keiretsu central bank, and should the company run into financial difficulties, may ultimately be incorporated into a keiretsu structure (Miyashita and Russell 1996).

The vertical keiretsu is essentially the model described earlier in this chapter, consisting of a single major manufacturer and its hierarchy of smaller supplier firms. The dominant company typically owns a percentage of its subsidiary or supplier firms, some

[9] These are also referred to, by various writers, as either bank keiretsu or financial keiretsu.

of which may have been spun-off from the primary firm, but the supplier firms are independent entities (Nakamura 2000). These keiretsu are commonly referred to as "vertical" because of a generally pyramidal structure with the main firm as central in transactional and technical relations; the industrial structure is actually horizontal rather than vertically integrated. Most of the vertical keiretsu consist of two separate hierarchies, one for production and one for distribution and sales (Miyashita and Russell 1996).

Most of the prominent industrial firms in the capital keiretsu are also at the head of their own production keiretsu. The different types of keiretsu relationships can be illustrated using two of the companies featured in the case studies in Chapters 10 and 11: Toyota Motor Manufacturing and Honda of America. The Toyota Group is a member of the Mitsui horizontal keiretsu, but is very independent in consequence of its economic power. Excluding the Big Six and the Industrial Bank of Japan, Toyota is by far the largest keiretsu in Japan. Furthermore, Toyota is in the process of evolving into something between a horizontal and vertical keiretsu, by virtue of investment diversification into other businesses including real estate and insurance (Miyashita and Russell 1996).

The Honda Group, on the other hand, is not officially associated with any financial keiretsu but has close ties to the Mitsubishi Bank. Honda's economic power is far less than Toyota, in Japan ranking in third place behind Nissan and just barely ahead of Mazda and Mitsubishi. Although Honda's financial relationship with the Mitsubishi bank predates the existence of Mitsubishi Motor Corporation, increasingly the bank has felt obligated to support its own keiretsu group member, requiring Honda to increase borrowings from other banks. Honda Group has a finance company, a trading company and a transportation company but, as noted previously, does not have an extensive supplier network of its own and depends primarily upon purchases from companies that supply multiple automakers (Miyashita and Russell 1996).

Associated with the production keiretsu, but differing in some significant aspects, are the suppliers' associations, known as kyoryokukai. Organized by and, to a large degree, controlled by the core firm, most of what is known about the supplier's associations is derived from research concerning the automotive industry in Japan. Every Japanese automaker, with the sole exception of Honda, has established an association for its major parts suppliers; in addition, more than 300 primary parts suppliers, many of which belong to an assembler's association, have their own associations comprised of companies from still lower tiers. The suppliers' associations are not precisely congruent with production keiretsus, since many suppliers hold multiple memberships in other assembler's associations (Sako 1995).

Hines and Rich (1998) define a suppliers' association in terms of "mutual benefit," being a group of the most important suppliers for a given assembler who hold regular meetings to share knowledge about best practices and to improve their joint competitive advantage through cooperation. As a consequence, "any innovation in process, technology or management area can rapidly be shared and emulated by large sections of the complete supplier community." This works to mutual benefit, because "each element of competitive advantage can be leveraged many times over leading to a considerable competitive advantage [for the auto assembly firm]" (p. 530). Hines and Rich refer to this process as "outsourcing competitive advantage." Research by Sako (1995) indicates that the prime mover for diffusion of information within a suppliers' association is not the assembly plant but tends instead to be a first tier supplier firm, independent from the keiretsu, that takes a leadership role in the association. Independent firms are more likely to have membership in multiple suppliers' associations; some, in fact hold memberships in as many as eight different associations, covering nearly the entire spectrum of Japanese automakers. Such firms are the means by which much information is transmitted from one association to another, rather than top down from the assembler. As Sako notes, the Japanese automobile industry is not so much a group of overlapping keiretsus but a network in which information moves both vertically and horizontally.

The Japanese management systems which, in the early 1980s[10], began the process of overseas transfer through direct foreign investment, did not arise fully conceived nor, as often claimed, were they the consequence of careful planning and development. Neither was the management system originally developed by Toyota adopted intact by other manufacturers even within Japan.[11] The Toyota Production System, from which Japanese management variants were derived, developed through an evolutionary, trial-and-error process which is described by Fujimoto (1999) as "multi-path system emergence." This is not intended to reduce the historical process to randomness, but reflects the concept that social systems often evolve because of unanticipated events and

[10] A number of Japanese transplants were established prior to the 1980s but failed to capture the attention of Western industrialists as did the great wave of later investment during the Japanese economic bubble, which occurred at a time when the Japanese were increasing their share of several important markets formerly dominated by the West.

[11] For example, Toyota emphasizes the use of quality circles, whereas Honda tends more to encourage individual initiative and innovation (Gavroglou 1998); Honda also does not practice leveled schedules nor pure JIT to the same extent as Toyota (Liker *et. al.* 1999). Nissan made a deliberate decision in the 1950s not to copy Toyota's manufacturing system and more nearly resembles a Fordist system; while Nissan requires just-in-time deliveries from suppliers, it does not employ the "pull principle" in production and produces in large volumes (Cusumano 1985).

unplanned behavior: “Decision makers often don’t know beforehand which path will lead to a successful outcome – deliberate planning, environmental imperatives, intuition, imitation, or luck” (p. 8). Although pure chance and historical imperatives are significant to the emergence of a system, the enhanced capabilities and competitive advantage of the Toyota system were a result of that company’s evolutionary learning ability. Fujimoto’s thesis is that system evolution does not necessarily constitute progress, but brings about adaptation to environmental requirements, in which system changes may be both evolutionary (incremental) and revolutionary (innovative).

Japanese industrial management systems continue to evolve, in response to changes both domestic and abroad. The following chapter examines the environmental adaptations that resulted from transplantation of the Japanese system to North America, creating a hybrid form.

Chapter Four

Lean Production in North America: Potential Environmental Benefits from a Hybrid System

4.1. Contextual Issues

The review in the previous chapter suggests that Japanese management systems, as employed in Japan, are characterized by a number of core features and practices. Although the implementation of these systems may vary in detail from company to company, in the most successful firms there exists a common focus upon waste elimination, continuous improvement, and accessing and integrating the knowledge of all employees. These three traits appear to be the driving factors responsible for the competitive advantage experienced by Japanese firms compared to Western firms during the latter part of the twentieth century. The increasing share of international markets captured by Japanese corporations fostered an interest in Japanese production and management methods in the West, an interest greatly enhanced by the great wave of Japanese overseas investment that commenced in the early 1980s.[1] In consequence, a significant number of firms in the United States today employ some form of Japanese management systems, including not only Japanese transplants but also many domestic companies.

The same characteristics of waste reduction, continuous improvement, and integration of knowledge that are representative of the Japanese system appear also to be exactly those attributes capable of improving the environmental performance of corporations, in terms of the eco-efficiency paradigm. If Japanese methods are being successfully

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[1] The factors contributing to increased Japanese direct investment overseas are examined in Chapter 6.

transferred to North America, and if these systems have the potential to generate environmental benefits, then certain issues must be addressed in order to comprehend the interaction between these circumstances. These issues include the means by which Japanese management systems have and are being transferred; the extent of alteration, if any, of these systems in the North American context; the nature of Japanese systems' potential for environmental performance improvement; and the existing empirical evidence for or against such environmental benefits. These are the issues that are the focus of this chapter.

4.2. Diffusion and hybridization of lean production in North America

The 1990 U.S. national best-selling book, *The machine that changed the world* (Womack et. al.), extolled the virtues of Japanese management systems and introduced the term "lean production" to the lexicon.[2] Since that time, "lean production" or "lean management" has been used generically in Western business and academic literature to refer to the application of the principles and philosophy of Japanese management systems in companies both in Japan and abroad. Inasmuch as Womack and his associates in the International Motor Vehicle Program (IMVP) at MIT were referring primarily to the shop-floor features of JIT production rather than cultural or institutional attributes, a distinction is here made between "Japanese management systems" and "lean production." The term lean production, in this work, is used to refer to production systems based on Japanese methods that have been transferred to a new environment overseas. Use of the term "lean production" uncouples the concept from its Japanese cultural context and

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[2] The book was a popularized summary of numerous papers by researchers associated with the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology (MIT).

lends emphasis to the idea that this is a production system that may be adapted to many environments.

Just as Gramsci (1971) argued that the Fordist model of production was not tied to the American cultural context, many researchers today contend that the principles of lean production are not bound to Japanese culture. At the same time, however, there is widespread recognition that the transfer of a complex management system from one nation to another, particularly when the nations involved differ so greatly in culture and social organization as Japan and the United States, often results in selective adoption of characteristics. The result may be a hybrid form which combines some attributes of Japanese production systems with those in the Western, Fordist tradition.

4.2.1. Diffusion pathways

The diffusion of lean production methods into North America is the result of the confluence of numerous information pathways. Two types of firms have been involved in the transfer as recipients: Japanese-owned transplants, and Western firms seeking to adopt Japanese methods either to improve their competitive position or to facilitate doing business with Japanese transplants. In the former case, Japanese firms are not simply picked up in one country and set down as transplants in another with all production systems intact, nor possessing a workforce grounded in Japanese methods and habituated to cooperative management-labor relations. Japanese transplants must accommodate and acclimatize a non-Japanese workforce, in large part directed by non-Japanese management except in the higher echelons. In the latter case, Western companies accustomed to Fordist production systems and labor relations are faced with even greater obstacles to system transfer. In either case, transfer of Japanese production methods requires considerable and continuing input from primary and/or secondary sources for successful implementation.

Primary sources may be considered as those through which philosophy and practice flows directly from senders (Japanese firms) to receivers (transplants or Western firms). In essence, primary sources are people who are thoroughly knowledgable and experienced in the production system as practiced in Japan, and who carry this specialized knowledge with them to a new environment. Such sources allow the transfer of tacit knowledge about processes that is less likely to be conveyed through secondary sources. Secondary sources are indirect information transfer, through which companies pattern operations based upon descriptions and analysis of Japanese systems or through training received from Western institutions such as universities or consultant firms. These are information sources at least one remove from the original system practice. Japanese transplant firms are more dependent upon primary sources, and Western firms upon secondary sources, for implementation of Japanese production systems.

Primary sources include:

1. Japanese expatriates. Japanese corporations commonly assign executives, managers and engineers from Japan to extended overseas duty in transplant manufacturing operations, both to facilitate transfer of the production system and to promote better communications between the parent company and the foreign subsidiary. The presence of expatriate Japanese has been identified as one of the most important criteria allowing Japanese technical, organizational, and cultural attributes to be replicated in transplants (Pil and MacDuffie 1999; Peterson et. al. 1999; Kumon et. al. 1994a; Abo 1994). Expatriates may be relatively long-term residents as employees of the

transplant firm. Alternatively, expatriates may be transients on loan from Japan to assist during the start-up period; or after firm establishment to assist with installation and/or implementation of new processes and procedures; or on periodic, routine visits on a consultative basis.

A 1989 collaborative study of 34 Japanese transplant firms located in the U.S. and Canada, reported in Kamiyama (1994),[3] determined that the ratio of Japanese expatriates ranged from less than 1 percent to more than 14 percent, averaging a little more than 3 percent of total employee numbers. Automobile parts manufacturers tended to have the highest percentage, and consumer electronics firms the least; automobile assembly plants and semiconductor producers fell in between. Pil and MacDuffie (1999) likewise reported that, for auto assembly plants, expatriates constituted about 2 percent of employees: the typical assembler averaged 60 expatriates, of which about half were engineers and most of the remainder were top and middle managers. Both Kamiyama and Pil and MacDuffie noted that there was considerable variance among transplants, even within the same industry, and attributed this to diverse corporate strategies.

Kawamura (1994) noted that the general practice in transplants was to assign Japanese expatriates to key posts in various departments, usually as head of a section. Senior positions in manufacturing, production engineering and finance were usually filled by Japanese nationals, whereas American senior managers tended to be assigned to positions concerned with personnel. According to the survey results reported by Kamiyama (1994), the post of (local) company president and more than half of the senior positions

[3] Citations for Kamiyama (1994); Abo (1994); Kawamura (1994); Kumon et. al. (1994a,b) and others not referred to in the present work all represent collaborative research on the same project by members of the Japanese Multinational Enterprise Study Group, published collectively as *Hybrid factory: The Japanese production system in the United States*, edited by Tetsuo Abo.

tended to be occupied by expatriates. The domination of senior posts by expatriates was most pronounced for manufacturers of automobile parts and semiconductors; distribution of senior positions most nearly reached parity between Japanese and local managers within automobile assembly plants and producers of consumer electronics, though still favoring expatriates.

According to Kawamura (1994), the export of Japanese nationals highly familiar with the Japanese system is one component, along with “ready-made” production technology, of the effort to reproduce plant operations overseas that are similar to those in Japanese plants. Assumptions implicit in the use of expatriates are that transfer can be better accomplished through direct supervision than by formal procedures and training; that expatriates embody the norms and culture of the home country in ways that cannot be emulated by American managers; and that Japanese expatriates are thus better suited to implement Japanese cultural and management approaches (Peterson et. al. 1999). In fact, according to Abo (1994), the real role of the expatriate may be to shape organizational behavior more than technical or process characteristics. In contrast to this viewpoint, the study of bearing manufacturer NSK by Brannen et. al. (1999) illustrates a quite different corporate strategy, where the decision was made to focus on transfer of the technical production system while leaving human resource management policies to local management.

Sullivan (1992) provides some additional insight on the strategies involved in the use of expatriates, noting that expatriates often serve to tighten corporate control over transplants. The extent to which control becomes an issue is dependent upon corporate strategy: some Japanese transplants regard themselves essentially as a Japanese company in a foreign land; others transplants view themselves as American companies. In the latter case, corporate strategy is for increasing localization or "Americanization" of the subsidiary through gradual replacement of expatriates in management positions by locals, a tendency which is also noted by Kumon (1994b). For companies such as Honda, which has declared a commitment to Americanization, expatriates have fostered a system of apprenticeships, both within the company's own production facilities and outward through the supplier chain, through which local managers gain experience in Japanese methods and build autonomous local capabilities. Furthermore, "Localization programs, in which Americans begin to move into top spots and have a shot at company-wide posts, attract high-quality managers with valuable skills" (Sullivan 1992, 84).

2. "Japanization" of key employees. Key local employees – managers, supervisors, team leaders – are often sent by transplants to Japan to work in the factories of the parent company for periods ranging from a few weeks to several months and thereby directly assimilate production methods and organizational culture. Kumon et. al. (1994a) identify this practice, along with a high ratio of expatriates, as critical factors in facilitating the transfer process. Transplant managers interviewed by Pil and MacDuffie (1999) indicated their belief that sending local workers to Japan for education and training was even more significant than the presence of Japanese expatriates. Transplant employees may be assigned to Japan prior to start-up of a new facility, as part of routine training for key employees for an established operation, or to receive training on new equipment or procedures prior to overseas implementation (Liker *et. al.*, 1999). Employees sent to Japan are assigned to a trainer and given both formal instruction and experience on production lines, becoming socialized in practices such as kaizen and work teams. This

process, according to Kenney and Florida (1993) “facilitates the transfer of tacit knowledge of the production process and behavioral aspects” as well as the acquisition of skills. Anecdotal evidence from the case studies (see Chapters 10-12) suggests that this practice is widespread in study area transplants.

Sullivan (1992) notes that, in recent years, Japanese transplants have taken to hiring young university graduates with little work experience and sending them to Japan for periods of up to several years. Assigned to the headquarters company for training, socialization and language development, these recruits are also assigned to work in various divisions of the company including assembly lines and sales outlets. This process fosters a global perspective of the company and is intended to develop American managers whose loyalty is to the company (compare to item 6 below, “Mobility of Western management personnel”). Upon their return to the transplant facility, Japanized personnel are ideally suited to function as intermediaries between local employees and Japanese managers.

Secondary sources include:

3. Business and academic literature concerning Japanese production systems. A group of Toyota employees first introduced the basic principles of the Toyota Production System to the English-speaking world in a 1977 article in the *International Journal of Production Research* (Sugimori, Kusunoki, Cho and Uchikawa). The system was further described in English in 1981 by Kimura and Tereda, published in the same journal, and through a series of articles in *Industrial Engineering* by Yasuhiro Monden (1981a,b,c). In that same year, Schonberger’s *Japanese manufacturing techniques* and Ouchi’s *Theory Z* suggested the application of Japanese manufacturing methods to firms in the United

States. Previously, Japanese methods were believed to be culturally embedded and non-transferable (Fujimoto 1999). Business and academic literature promoting the use of JIT and other Japanese techniques has greatly proliferated since the early 1980s, but a landmark work during this time was *The machine that changed the world*. This 1990 book by Womack, Roos and Jones has probably done more than any other to popularize lean production (and generate controversy). Currently, Internet websites concerned with describing, promoting, or critiquing lean production methods are legion.

In addition to published information, we may also include in this category various training manuals and procedural documents, produced by the company and utilized within the transplant. Such sources must be considered secondary because they cannot effectively convey tacit knowledge.

4. Training conducted by core transplant firms to promote Japanese methods in their supplier hierarchy. The largest transplants, particularly in the automotive industry, have established formal and informal training services available at no cost to supplier firms, intended to foster productivity and cost-efficiency using the Japanese model. Training programs include workshops and seminars and exchange of employees, and core firms also maintain a frequent consultative and advisory presence within their most significant supplier companies. Training activities sponsored by core transplants are considered secondary sources because evidence indicates that such firms are themselves hybrid versions of Japanese production systems. Chapters 10, 11, and 12, which concern case studies of Japanese transplants in the United States, examine the information flow relationships between core firms and suppliers in greater depth.

5. Training conducted by Western universities or consulting firms. Many universities and business colleges in the United States have added "lean management" courses to their curriculum, and offer workshops and seminars as a service to the business community. Training of this sort is frequently offered with titles that refer to "world class manufacturing" or "manufacturing excellence," and incorporate many principles of lean production along with more recent and complementary developments such as Six Sigma.[4] Although no specific studies were discovered during investigation of the literature that addressed this issue, university involvement in promotion of lean techniques would appear widespread.

Formal programs or centers for research and education would appear most likely to be established in regions with a significant Japanese manufacturing presence. Examples from the study area include the Lean Manufacturing Program sponsored by the University of Kentucky's Center for Robotics and Manufacturing Systems, which also provides technical assistance to regional manufacturers; the Tennessee Manufacturing Extension Program associated with the University of Tennessee's Center for Industrial Services, which provides Tennessee manufacturers with training in lean production, ISO-14001, plant safety and other areas designed to improve productivity, competitiveness and profitability; and the Lean Certification Program offered by Bowling Green State University's (Ohio) Center for Applied Technology. BGSU's Center notes, "Most programs focus only on the technical. This program will teach social systems as well as

[4] "Six Sigma" is essentially a "next-generation" development of TQM that originated in the West, devised and promoted by Motorola Corporation. Six Sigma uses statistical tools for continuous improvement in overall business performance, including both processes and product quality. For more information see http://mu.motorola.com/sixsigma.shtml.

technical systems. Sociology drives technology. If management understands social systems and culture, the organization will operate more successfully."[5]

Many business management consulting firms have also established lean production programs in recent years to take advantage of the great interest in Japanese methods. There is a great number of such firms; among those operating out of the eastern United States are Florida-based HPK Group LLC,[6] which serves all 50 states; Lean Manufacturing Solutions,[7] with offices in Kentucky and North Carolina, teaching the Toyota Production System; and Rhode Island's Duggan and Associates, Inc,[8] who assist companies to create "factories of the future." Worthy of special mention is Connecticut-based Productivity, Inc.,[9] ("Our mission is methodology transfer"), which is affiliated with Productivity Press, publishers of numerous books on Japanese methods, including reprints of such "classics" as Ohno (1988) and Shingo (1984). Productivity Inc. has recently partnered with the Center for Excellence in Manufacturing Management at Ohio State University's Fisher Business College to offer internships and certificates in lean production management.

University and consultant lean production programs apparently serve as educational resources for Japanese transplants as well as Western corporations. The case of Link-Belt Construction Equipment, a subsidiary of Sumitomo, is profiled in Chapter 12.

6. Mobility of Western management personnel. According to Kenney and Florida (1993), one of the most serious problems facing implementation of the Japanese system

[5] BGSU Program website, http://www.bgsu.edu/colleges/technology/special_pro/LeanManufact.pdf
[6] http://hpkgroupllc.com
[7] http://www.leansolutions.net
[8] http://dugganinc.com
[9] http://productivityinc.com

in the United States is the development and retention of American managers. Western managers tend to be career oriented and frequently change jobs and companies, in contrast to Japanese managers who are more company-oriented and relatively immobile. Abo (1994) notes that the turnover rate of supervisors and white-collar managers in the transplants is often higher than that of the blue-collar workers. Shimada (1993) observes that many local middle-managers join Japanese transplants to learn new skills and system knowledge; once knowledge is acquired, the foreign managers leave the Japanese company and take their new skills to domestic companies whose organization is more "comfortable." The free flow of information within a Japanese plant, according to Kenney and Florida (1993), means that a defecting manager can take valuable information to competitors.

In summary, just as the Toyota Production System, parent of today's variety of Japanese management methods, can be described as a product of a multi-path emergent process within Japan (Fujimoto 1999), so will the multi-path transfer of these methods overseas lead to further recontextualization and adaptation. Liker et. al. (1999) notes that "transplant" is hardly an appropriate term to refer to cross-border, cross-cultural transfer; "transformation" is more descriptive of the process. Japanese management systems at core firms "may serve as a reference point, but, in the international transfer process, each facility will experience its own developmental sequence, and numerous unplanned adaptations or mutations will occur" (p. 23).

4.2.2. The hybridization process: Adaptive innovation

Two opposing perspectives about the nature of Japanese production systems dominate the literature concerning transferability: (1) adoption of core JIT production practices alone, separate from sociocultural practices, will lead to improvement in manufacturing performance; and (2) Japanese production systems represent a new form of work organization and cannot be reduced to a set of simple tools; management-labor relations and other infrastructure practices are integral to performance enhancement. Within the latter perspective, viewpoints range from a perception that Japanese systems are so contextually embedded as to preclude successful transfer to foreign environments (Williams et. al. 1992), to a more widespread recognition that successful transfer has occurred, albeit characterized by partial implementation and hybridization.

Of the reductionists, Womack *et. al*. (1990) are perhaps the most optimistic in their perceptions of the widespread applicability of lean production, viewing the system as essentially independent from Japanese society and culture: “We believe that the fundamental ideas of lean production are universal – applicable anywhere by anyone…” (p. 9). The authors, who are convinced that lean production methods are far superior to traditional Fordist mass production, urge adoption as an imperative for American automakers who wish to remain globally competitive: “[T]he whole world should adopt lean production, and as quickly as possible” (p. 225). Similarly, a study by Nakamura *et. al*. (1999) comparing management practices of manufacturers in Japan, Japanese transplants, and American-owned facilities, concluded that: “The core JIT practices are generic in that the successful implementation of these practices *alone* is likely to lead to a successful JIT system” (p. 371, original emphasis).

The assessment of lean production by Womack and his colleagues in the IMVP has been criticized as overly simplistic. Kenney and Florida (1993) observe that the view popularized by Womack “provides an accurate surface-level description of the operation of Japanese automobile factories, but it neglects the crucial role of intellectual labor at the point of production" (p. 25). The IMPV characterization of the Japanese system as a set of simple forms, "capable of simply being picked up and adopted by Western producers in piecemeal fashion" (*Ibid*.), fails to account for the structural, organizational, and institutional context of Japanese production. Shigeo Shingo (1981), one of the shapers and promoters of the Toyota Production System, stated "We should make a decision to adapt the systems only after understanding not only each method itself but also the relationship between them" (p. 332). Lean production is not just shop-floor practices, according to Kenney and Florida (1993), but a new form of work organization that employs not only worker skills but worker intelligence. Given this recognition, however, Kenney and Florida are equally optimistic regarding the adoption of Japanese methods and the benefits to be derived: "The Japanese system…consists of organizational practices whose fundamental 'genetic code' can be successfully inserted into another society and can then begin to successfully reproduce in the new environment" (p. 8).

Fujimoto (1999, 274) notes that an emergent manufacturing system, such as the Toyota-style system in Japan, "is likely to be a mixture of articulated and functional procedures, tacit but functional knowledge, and non-functional or dysfunctional routines." Transfer of such a complex system to a different context virtually ensures transformation, because many of the key elements of this system are embedded in firm-specific and tacit knowledge. It is the tacit knowledge that is most likely to be lost during the transfer process, because receiving firms will tend to implement those aspects that are capable of being described and functionally explained. If essentially tacit knowledge is missing, according to Fujimoto, then the outcome may not be as effective as the original model. If, however, the dysfunctional parts of the original system are eliminated during the transfer and adoption process, the outcome may be an improved model.

Research concerning the adoption of management innovations indicates that the speed and extent of diffusion depends upon the characteristics of the sender and receiver, the communication process between them, and the nature of what is being transferred (Liker *et. al*. 1999). Important characteristics of the sender are the resources available to facilitate transfer, in terms of a company's size and business situation, and the extent of the firm's commitment of resources (financial, technical, time) to support the transfer. Receiver characteristics influencing transfer are firm size, resources available for implementation, and relative dependency upon successful implementation. Through the interaction of senders and receivers, complex and imperfect sender models are filtered and reshaped by the beliefs and values of receiving firms, "resulting in new interpretations of what is being transferred" (p. 24).

Describing this phenomenon, Westney (1999,385-386) notes, "When complex organizational systems developed in one social context (in this case Japan) are transferred to a different setting (the United States), they change, the resulting system is neither a copy of the original model nor a replica of existing local patterns, but something different." The new model is a hybrid, which can be defined as a management system in which some features are derived from the sender (home country practices) and some are derived from the receiver (host country practices). Individual components of the system may also be hybridized, resulting in forms that are typical neither of sender nor receiver (Adler 1999). Thus, in the case of Japanese transplants, we may well expect to find certain practices transferred intact from Japan, some practices adopted from U.S. firms without substantial modification, and some practices that are neither precisely Japanese nor Western but represent a new and different way. According to Westney (1999, 385-386), “hybridization becomes adaptive innovation, producing new organizational patterns that become part of the organizational landscape in the new setting.”

The consensus of most researchers is that the Japanese have been successful in transferring their production system to North America, but only in part, thereby creating a form hybridized from Japanese and Fordist elements. Furthermore, just as in Japan, there is considerable variation within industries and among Japanese transplants, even those operating in the same industry.[10] Research findings by Kenney and Florida (1993), Shimada (1993), Abo (1994), Adler (1999), and Jenkins and Florida (1999), among others indicate that most of the core JIT production practices have been successfully transferred to U.S. transplants in forms similar to the original model, but that human resource practices have generally been adapted to suit local conditions.

Research conducted by the Japanese Multinational Enterprise Study Group (JMNESG) over a ten-year period and reported by Kamiyama and others in *Hybrid factory* (1994) may represent one of the most thorough and detailed analyses of the transfer of Japanese practices to North America. This research was intended to compare direct application versus adaptation of Japanese methods within transplant firms. The investigators divided organizational practices into six relational groups, each containing elements representative of Japanese management systems. On the basis of observations made at 34 Japanese transplants in Canada and the United States, each element was assigned a value from 1 to 5, where 1 represents practices typical of traditional U.S. companies and 5 represents practices most like those of companies in Japan (see Table 4.1). The mean for

Table 4.1. Application - adaptation evaluation criteria used by the Japanese Multinational Enterprise Study Group
Source: Kawamura (1994). Bottom row represents overall rating for category.

Work organization & admin.	Production control	Procurement	Group consciousness	Labor relations	Parent-Subsidiary Relations
Job classes Job rotation Training Promotion Team leaders	Equipment Quality control Maintenance Operations management	Local content Suppliers Procurement method	Small group activities Information sharing Sense of unity	Hiring policy Job security Labor unions Grievance procedures	Ratio of expatriates Delegation of authority Position of Amer. mgrs.
2.9	**3.3**	**3.0**	**3.2**	**3.6**	**3.6**

all categories was 3.3, which the author interpreted as a relatively high application of Japanese methods, considering the difficulties inherent in transferring complex systems from one national context to another. Even so, Kamiyama notes, if the factory in Japan is used as the standard of comparison, this translates to a degree of direct application not much greater than 50 percent. Thus, U.S. and Japanese practices coexist in approximately equal proportions in the transplant firms.

Findings from the JMNSEG study indicated that the elements of production control, labor relations, and parent-subsidiary relations tended to be most like those of factories in Japan, whereas work organization and administration more resembled U.S. practice. The means for work organization and administration were, however, of sufficient magnitude to suggest that transplants were attempting to systematically introduce Japanese practice in these areas. The relatively high values for production control methods may, according to Kamiyama, represent importation of production equipment rather than a high application of the "Japanese method." Support for this contention is provided by

[10] This is also supported by the results from the mail survey, discussed in Chapter 8.

Shimada (1993), who notes that the equipment and layout of the production floor in transplants is virtually identical to factories in Japan.

A survey of automotive supplier firms conducted in 1988 by Kenney and Florida (1993) found that 68 percent of suppliers employed a JIT system internally. Comparing transplant automobile assembly factories in the United States to those in Japan, Pil and MacDuffie (1999) found little difference in terms of buffers, whether in terms of incoming inventory, in-process, or end-of-line repair. Comparing automation and technology, the authors also found little difference between home-country and transplant firms, both in total automation and by deployment within different plant areas. Furthermore, Pil and MacDuffie found no statistical difference in product quality between those manufactured in Japan and in the U.S., although transplant firms did not match the product mix complexity of firms located in Japan. In each of these cases, the authors note, both Japanese firms and transplants differed significantly from U.S. based plants, the former having far less inventory, more automation, higher quality, and higher levels of product mix complexity.

In terms of industry differences, Abo (1994) commenting in the same volume, noted that transplants in the automotive industry tended more to resemble plants in Japan, whereas those in consumer electronics were more adaptive and Fordist in practice. This observation is also confirmed by Jenkins and Florida (1999). Similarly, Sumi (1998) noted that transplants in the U.S. Midwest, where automotive firms are concentrated, tended to more closely resemble Japanese facilities in their social relations than those on the West Coast, where consumer electronics transplants are more dominant. Even in the Midwestern plants, however, social relations exhibited great variability and the evolution of a stable corporate culture was still unrealized. Adler (1999) notes that, for multinational corporations, human resource management practices are more likely to be hybridized in transfer than are production, marketing, or financial practices. Shimada (1993) noted that human resource practices in Japanese transplants were being adapted to U.S. conditions, and Abo (1994), commenting on the JMNESG findings, also observed that there was a "weak intake" of Japanese HR policies and practices.

Specific differences and similarities between human resource practice in Japan and the North American transplants have been noted by many writers. Adler (1999) found that teamwork and broad, flexible work roles were characteristic of auto assembly plants in the United States as well as Japan. Similarly, Kenney and Florida (1993) and Pil and MacDuffie (1999) both found that teams and job rotation were both common practices in transplants. Kenney and Florida's study concerned automotive parts suppliers, of which more than three-quarters used work teams. The authors survey found that, although rotation within teams was characteristic of these firms, rotation between different teams was less frequent than in Japan. Pil and MacDuffie's study focused on automobile assembly plants in Japan and the United States, including both transplant and U.S.-based firms. At the assembly transplants, workers were found to rotate tasks almost as frequently as in Japan, both within teams and across teams in a given department. U.S. firms did not practice job rotation.

Both Kenney and Florida and Pil and MacDuffie found that Japanese transplants employed far fewer job classifications than traditional American plants. The Japanese assembly transplants in Pil and MacDuffie's study averaged one production worker classification and one or two maintenance worker classifications, compared to five classifications for production workers and maintenance workers in Japan and nearly fifty in U.S.-owned auto plants. Kenney and Florida's survey of transplant parts suppliers found 65 percent of such firms had three or fewer classifications for production workers, and 86 percent had five or fewer. Similar results, for a broader range of transplant industries, were obtained in the JMNESG study reported by Kamiyama (1994), where firms averaged no more than seven to eight job classifications.

Suggestion systems and quality circles are both employed by transplants in the U.S., according to Pil and MacDuffie, but to a lesser degree than in plants in Japan. Whereas an average of 80 percent of production workers in automobile assembly plants in Japan are involved in quality circles, only about a quarter of the workers in transplants are so involved. Approximately four suggestions per worker were received annually in transplant firms, of which 70 percent were implemented, compared to 23 suggestions per worker and an 84 percent implementation rate in Japan plants. U.S.-based auto assembly plants, notes Pil and MacDuffie, receive on average only one suggestion for every four workers, and implement only 41 percent of suggestions received.

Japanese transplant firms, faced with distinct cultural and attitudinal differences, have sought to promote lean production practices such as kaizen activities, teamwork, and identification with the company and its goals through locational strategies, selective hiring, and socialization. Locational strategies involve plant siting in rural areas where the workforce is less unionized and thus less likely to resist alteration of traditional roles; this practice is discussed below and in some detail in Chapter 6. Selective hiring involves careful screening and extensive testing of applicants to ascertain if they possess the right "attitude" for teamwork and active participation in process improvement, a process that has been facilitated by the large numbers of candidates that have typically applied for positions in Japanese factories upon start-up. According to Kenney and Florida (1993) the screening process attempts to duplicate the "group consciousness" and company loyalty exhibited by Japanese workers, evaluating candidates on the basis of group skills, problem-solving (kaizen) ability, and individual initiative. Once hired, workers undergo training and socialization intended to foster teamwork and kaizen activity.

The implementation of successful kaizen activities and other organizational practices has been somewhat difficult in the transplants, which Kenney and Florida attribute in large part to American middle managers conditioned to traditional Fordist labor relations. Japanese firms have, according to the authors, begun promoting shop-floor workers to supervisory positions in an effort to overcome the divide between white-collar and blue-collar employees. Kamiyama (1994) among others, notes that peaceful labor relations are one of the most important considerations for success of the Japanese production system. Toward this end, in the United States, many transplants have undertaken measures to reduce status barriers and promote a sense of unity between labor and management, becoming, in many cases, even more symbolically egalitarian than factories in Japan (Pil and MacDuffie 1999; Adler 1999).

Japanese transplants in the United States have exhibited mixed results in transferring institutional practices. There appears to be a general consensus that the Japanese have been successful in recreating the just-in-time supplier network in the United States in nearly the same form as found in Japan (Florida and Kenney 1991; Abo (1994); MacDuffie and Helper 1999).[11] Japanese automakers have also, to a relatively large

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[11] Further discussion of supplier relations among transplants may be found in Chapters 6, 10, 11, and 12.

extent, succeeding in establishing supplier associations in the United States which include both Japanese transplants and U.S.-owned supplier firms in four states: Kentucky, Tennessee, Mississippi and Alabama. The Kentucky association, the Bluegrass Automotive Manufacturers Association (BAMA), most closely resembles the original Japanese model. Established in 1989 with only 13 members, BAMA has since grown to include nearly 100 members, associated on a voluntary basis (Dyer and Nobeoka 2000). According to Kenney and Florida, BAMA is, for Toyota, "a vehicle for instilling cooperation and interaction among its suppliers to improve its domestic supply base and diffusing JIT practices to U.S.-based suppliers" (p. 151). Members share knowledge through meetings at various levels, participate in tours of "best practice" plants, and engage in group social activities (Dyer and Nobeoka 2000).

The three other manufacturers associations, TAMA in Tennessee, AAMA in Alabama, and MAMA in Mississippi, deviate from the Japan model in that the associations are not sponsored by a single assembly plant but instead involve relationships with several automakers, including non-Japanese assemblers. TAMA was the first of the supplier associations in the United States, initiated by Nissan in 1986, and soon recruited the new (1990) Saturn plant into participation (Jeter 2001). AAMA follows the TAMA model of relations with multiple automakers rather than the sole-sponsorship pattern typical of Japanese supplier associations and BAMA. The 78 members of the Alabama association include automakers Mercedes-Benz, Honda, and Toyota, all of whom have assembly plants in the state, as well as supplier firms and representatives from state economic development agencies and the University of Alabama.

MAMA is the newest and, with about 25 members, the smallest of the supplier associations. The primary customer for Mississippi automotive manufacturers is the Nissan plant in Tennessee, and, beginning in 2003, a new Nissan assembly plant established in Canton, Mississippi. According to a representative from TAMA, the four supplier associations often cross-communicate with one another on issues that affect the global automobile industry. Although Ohio has a much larger and denser concentration of supplier firms than the southern states, and in Honda the first Japanese transplant automaker, the state has no supplier association. This is consistent with the situation in Japan, where Honda lacks a well-developed supplier network, and, alone among Japanese automakers, has sponsored no supplier association at home.

Other support institutions have been transferred less successfully; or, at least, have been more hybridized. This is particularly true for the three so-called pillars of the Japanese system: enterprise unions, lifetime employment, and seniority-based wages and promotion. In each case, efforts have been made to transfer aspects of these institutions insofar as the foreign environment would allow.

Company-based unions have been illegal in the United States since the passage of the National Labor Relations Act (Wagner Act) in 1935, and so transplants were unable to establish enterprise unions based on the Japanese model of labor relations. A cooperative and harmonious labor environment is considered essential to Japanese methods of just-in-time production where buffers are minimized and the system thereby rendered more vulnerable to disruption. Although all manufacturing firms in Japan are unionized, U.S. management-labor relations are perceived as adversarial by the Japanese and an obstacle to the successful transfer of the Japanese production system. Japanese transplants have therefore adopted strategies of avoiding unions whenever possible and, when it is not, to use their economic leverage to force acceptance by unions of nontraditional labor practices (Pil and MacDuffie 1999; Adler 1999; Kamiyama 1994; Kenney and Florida 1993).

A variety of strategies are used by transplant firms to avoid unions: plant site selection; vigorous anti-union campaigns when necessary; and promotion of working conditions and benefits at parity or superior to unionized plants. Japanese transplants in the eastern United States exhibit a locational preference for small-town or rural locations, which many researchers have interpreted as avoidance of regions with a union tradition in the workforce (Shaver 1998; Ó Uallacháin and Reid 1997; Reid 1997,1990; Rubenstein 1996; Woodward 1992).[12] When attempts have been made to unionize, Japanese plants have resisted strongly and in most cases have been able to defeat such efforts. More positively, the transplant firms have endeavored to preclude union sentiment by fostering a harmonious environment, where working conditions and worker empowerment are equivalent in merit if not in form to that found in union shops. This strategy is referred to as "union substitution" by Adler (1999). This is accomplished primarily through wage parity, egalitarian measures, and committees of worker representatives to provide labor representation.

A study by Kenney and Florida (1993) found that automobile assembly transplants in the United States paid high wages equivalent to those in UAW plants of the Big Three automakers (Ford, GM, Chrysler), although compensation in transplant suppliers was below union rates. Fostering a sense of community through symbolic egalitarianism, the

[12] See Chapter 6 for a detailed discussion of Japanese site selection strategies.

reduction or elimination of status barriers such as managerial “perks,” is also reflected in the internal wage structure. Pil and MacDuffie’s (1999) study of automobile assembly plants in Japan and U.S. transplants found that, in both situations, the pay differentials between production workers and supervisors are very low. Transplants also make extensive use of bonuses, both at the company and plant level, whereas U.S.-owned firms tend to limit bonuses to a company-performance basis. This may aid in boosting total compensation at supplier firms when business is good. Unlike firms in Japan, however, transplants do not offer bonuses for seniority, nor for individual or work group performance, thus conforming to U.S. practice in this regard.

The establishment of worker committees and other union-like functions in a number of non-union U.S. transplants to represent worker interests in management decisions is an attempt to recreate some of the capabilities of the enterprise union, providing “a similar venue for employee-management consultation and cooperation” (Pil and MacDuffie 1999, 44). Large assembly plants such as Honda, Toyota and Nissan have established employee associations and institutional channels for grievances (Kenney and Florida 1993). The tendency of lean production regimes to push labor organization towards the enterprise unionism model was identified by MacDuffie (1995), because lean production tends to blur the boundaries between traditional job distinctions by developing multi-skilled workers oriented toward group problem-solving. This weakens ties to inter-firm occupational groups and renders both craft and industrial union structures problematic. According to MacDuffie, “[T]he logic of lean production may, in part, push toward an enterprise model of worker representation because firm-specific knowledge about the production system is the clearest boundary to organize around” (p. 64).

The JMNESG study, addressing a broad range of industry types, found that 70 percent of transplant firms in the U.S. and Canada were non-union (Kamiyama 1994). A survey of automotive suppliers by Kenney and Florida (1993) determined that 95 percent of such firms were non-union, and that few workers in these companies had ever belonged to any union. Pil and MacDuffie (1999) noted that, of eleven Japanese assembly transplants in North America, only one-third have been unionized. The actual percentage is lower, since the only three unionized transplant automakers are NUMMI in California, Diamond-Star in Illinois, and Mazda in Michigan.[13] Each of these represents a Japanese joint venture with an American firm, so that Japanese corporations were required to deal with work forces accustomed to traditional union shop organization.

In those cases where acceptance of an American-style union appeared inevitable, Japanese automakers used their economic leverage, in terms of the decision to locate or not, to demand union cooperation in reorganizing according to the requirements of lean production systems. The UAW agreed to assist in implementation of such non-traditional practices as fewer job classifications, work teams, and job rotation, "thus implicating the union in management" (Kenney and Florida 1993). In the auto assembly transplants, therefore, two union models are apparent: the "union substitution" form characteristic of Toyota, Nissan and other non-union plants, and the "union hybrid" created in joint-ventures such as NUMMI (Adler 1999).

So-called "lifetime employment," or, in Miyai's (1995) assessment, "near-perfect job security," has been partly transferred to the U.S. context, though it is unevenly applied

[13] NUMMI (New United Motor Manufacturing Inc) is a joint venture between GM and Toyota; Diamond-Star began as a Mitsubishi-Chrysler joint venture but is now wholly owned by Mitsubishi; and Mazda is a joint venture with Ford.

among different industries. The development of multiskilled employees who are knowledgeable about plant processes is a significant factor for successful operation of lean production systems; layoffs tend to undermine the sense of unity that Japanese plants endeavor to foster. The JMNESG study reported by Kamiyama (1994) found that job security was highest in auto assembly transplants, in which core employees were assured of long-term employment. Automotive supplier transplants received the next highest ranking, though considerably lower than the assemblers. Firms producing consumer electronics and semiconductors ranked lowest; although such firms had a general policy of avoiding layoffs, nevertheless layoffs had taken place on several occasions. Although a desire to avoid layoffs appears to be characteristic of all transplant firms, most have avoided making written commitments to this effect in order to preserve options during economic downturns. Pil and MacDuffie (1999) noted that, to date, there had been no layoffs in any of the assembly transplants; downturns had, instead, been used for additional training of surplus employees. In Japan, the "no-layoff" policy is facilitated by the use of part-time, seasonal, or contract workers to manage demand fluctuations; according to Pil and MacDuffie, such workers constitute nearly 10 percent of the workforce in Japan assembly plants but less than 1 percent in transplant automakers. The much lower percentage of temporary workers in transplant firms reduces their ability to make adjustments during downturns without impacting core employees.

Given the above conditions of application and hybridization of supportive institutions, Pil and MacDuffie (1999) note that two of the "three pillars" of the Japanese employment systems have been partly transferred to the United States context. Although the enterprise union could not be transferred, as such, similar mechanisms have been employed within non-unionized plants to provide for employee representation. Similarly, many of the transplants promote long-term job security for core employees. The third "pillar," seniority-based wages and promotion, has not been transferred very well; findings reported by Kamiyama (1994) and Pil and MacDuffie (1999) indicate that compensation is primarily based upon job classification in transplants. The transfer, in part and modified, of Japanese employment institutions has been most successful in the automotive industry, and particularly among the automobile assembly plants.

This same pattern has been observed for other features of the lean production system, for both shop floor and human resource practices. As a consequence, a generalization can be made that aspects of the Japanese system of production have been most successfully transferred to the eastern United States, where the automotive industry is dominant among transplants, and least successfully along the West Coast, which is characterized more by firms in consumer electronics and semiconductors. Nearly all firms appear to have successfully transferred the core elements of the just-in-time system, along with certain supportive practices as the development of multiskilled workers and encouragement of worker input into the production process.

Transfer of lean production methods is also underway to U.S. domestic manufacturing firms, through a variety of pathways. Terms such as "lean management," "TQM," "continuous improvement" and other concepts derived from Japanese production systems now appear routinely in the literature of business and management, uncoupled from their overseas origin. This would seem to indicate that traditional Fordist systems are themselves becoming hybridized; methods that once appeared new and innovative, have in many cases, become routine business practice in the West. Later in this chapter, lean production, which is premised upon efficient use of resources, is examined for its potential to improve the environmental performance of manufacturing firms. There is, however, a substantial body of literature that criticizes lean production systems as oppressive and controlling rather than empowering, and this, too, must be examined before judgement can be rendered on the benefits of lean production.

4.2.3. Lean and mean? Management by stress

According to proponents, lean production is a system which becomes increasingly more efficient because of its ability to effectively harness worker knowledge at the point of production through aligning the interests of management and labor, in the process reducing the costs of production and creating an environment which is both enriching and empowering for workers. Critics of lean production, in contrast, argue that this picture represents an ideal which has little resemblance to the reality of organizational practice in Japanese factories. These criticisms may be summarized as follows: (1) The lean production system is "fundamentally oppressive," forcing workers to participate in the constant intensification of their own work pace (Parker and Slaughter 1995); (2) Practices which encourage cooperative management-labor relations have not been successfully transferred to the United States, with the result that core strengths of the Japanese system such as teamwork and kaizen activities are often ineffective (Graham 1995). Parker and Slaughter (1995) provide one of the harshest assessments of lean production, designating it "management by stress." This phrase has been used in a entirely different context by proponents, referring to the practice of stressing the JIT production system to discover flaws that may be subsequently corrected to improve overall efficiency. In the conventional view, it is this very practice of operating with minimal buffers that empowers workers by creating a “fragile” system vulnerable to disruption by discontented labor. According to Parker and Slaughter, however, it is not just equipment and processes that are subjected to stress to facilitate continuous improvement, but the human components as well: “Stress becomes a vital management tool both for monitoring and for forcing all personnel to keep up. It is management by continuing stress throughout the system” (p. 44).

The basic premise behind the lean production system is the reduction of waste in all forms in order to achieve cost efficiency; since labor is one of the inputs to the production process, the lean philosophy calls for the elimination of waste in this area as well. This is accomplished by placing increasing stress on the worker to constantly accomplish more with less; fewer resources, fewer workers per task, and less surplus (idle, or recovery) time. Thus, Parker and Slaughter assert, “The real buffer in ‘bufferless’ production is the workers, who are expected to put out extra effort over and above their normal job to maintain production,” despite the inevitable problems that may occur in any system.

In this view, the real purpose of kaizen is to deliberately place stress on the human components, by failing to provide relief or replace those absent, and by pulling workers away from one task area to another and thereby imposing upon those remaining to maintain the pace. Idle time of any sort is waste, and intensification extends to the goal of occupying all of a given worker’s time in continuous labor without the ability to pace himself. Adler (1995) notes that, at the Toyota-GM joint venture in California, NUMMI, standard task times were set with the goal to occupy the experienced worker for 60 seconds out of a hypothetical 60-second cycle time and, in practice averaged 57 seconds out of 60. In contrast, standard task times at the traditional GM-Fremont plant, NUMMI's predecessor,[14] averaged 45 seconds out of a 60-second cycle, allowing the worker rest time between tasks.

The irony, according to Parker and Slaughter, is that under the lean production system workers are induced to participate in the intensification of their own work pace through various strategies. These strategies include cultivation of loyalty to the company and the sense of alignment with the company's goals and fate, appeals to pride, and fear of job loss, but the primary mechanism driving intensification is the team. The team is the unit which has responsibility for meeting production goals, and consequently is the source of tremendous peer pressure upon individual members. If a team member is laggard, absent or away due to sickness or injury, the remaining team members are forced by the system to make up the slack.

Social scientists have conducted a number of studies of labor practices within Japanese automobile assembly plants, with mixed results. While all agree that the work pace is intense, there is divergence of opinion as to whether the lean production system can truly be described as oppressive. Among those whose experiences and/or research suggest an exploitative system are Graham (1995), who obtained employment at the Subaru-Isuzu (SIA) joint venture transplant in Indiana in order to conduct covert participant observation; and Rinehart *et. al*. (1995) and Babson (1995), who used survey methodology with workers at, respectively, the Suzuki-GM (CAMI) plant in Ontario and Mazda in Michigan. Contrasted against these must be the research conducted by Adler (1995; 1999) at the Toyota-GM (NUMMI) plant and that of Besser (1996) concerning the Toyota (TMMK) plant in Kentucky. Of the U.S. assembly transplants studied, SIA and

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[14] The former GM-Fremont plant closed in 1982 and reopened in 1984 as the NUMMI joint venture. See below for more information.

TMMK were the only non-union facilities; NUMMI and Mazda were organized by the United Auto Workers (UAW) and CAMI by the Canadian Auto Workers (CAW) union.

The automobile assembly transplants studied by Graham (1995), Rinehart et. al. (1995) and Babson (1995) all utilized a lean production system similar in most respects to practices in Japanese factories, including the use of work teams and kaizen activities. On the surface, the philosophy of worker empowerment was promoted through new employee orientation, formal lectures, training sessions, official company policies, slogans and exhortations. These researchers found, however, that in practice the reality was quite different. In each case, little value was attached to worker input and direction was essentially from the top down, rather than a process of two-way communication and cooperation. Graham (1995, 137) noted that "At SIA the Japanese model does not enhance worker's autonomy as regards policies and practices. It neither engages workers in managerial aspects of their jobs nor provides an avenue for real involvement in decision making." According to Babson (1995), at Mazda the actual operating concept had little to do with teams; teamwork was, instead, "a rhetorical device." Similarly, Rinehart (1995) concluded that, at CAMI, team spirit was "an empty slogan," observing that in practice, the team represented neither equality of all employees nor partnership with management. The constant intensification of work combined with disillusionment in the Japanese system led to increasing resistance by workers, from refusal to participate in company rituals to outright sabotage, discovering ways to provoke line stoppage in a manner that could not be traced to the perpetrators.

These studies suggest that, in each case, there was a distinct lack of commitment by management to worker participation in decision-making; that, instead, social practices such as work teams were used primarily as means to control workers and facilitate the intensification of work. At Mazda, Babson found that decisions were made by unit leaders, and the team leaders under them were perceived by workers as serving the supervisors rather than the team members. Similarly, at SIA and CAMI, Graham and Rinehart respectively noted that team leaders acted primarily to represent management's interests, implementing decisions made at the level of group leader or above. The 1992 strike at CAMI, the first at a transplant assembler in North America, was focused upon the issues of team organization and the selection of team leaders. At SIA, many workers felt that American managers in the company, who had worked for traditional plants such as GM or Volkswagen, were a large part of the problem, bringing with them Fordist attitudes about labor relations. Graham noted that corporate culture from such plants was likely to be affecting the cooperative atmosphere at SIA.

Kenney and Florida (1993, 287) note that "American managers who have been trained to protect their own power and authority have trouble understanding the Japanese system, which operates on the basis of securing worker's participation – not the unilateral exercise of managerial power." Based on interviews of management at numerous transplants, Kenney and Florida reported that Japanese managers view "unreconstructed" American managers as a significant obstacle to transfer of the Japanese system. The authors note that at the Nissan plant in Tennessee, large numbers of American managers were recruited from the Big Three plants, who attempted to force a fast Japanese work pace by using some traditional Fordist techniques such as elimination of job rotation.[15]

[15] A 1989 UAW effort to unionize the Nissan facility in Tennessee was defeated by a two-to-one margin.

Both Nissan and Mazda faced considerable pressure to accelerate production quickly, which resulted in only partial implementation of the work practices associated with Japanese management. Kenney and Florida refer to this as “pollution of the transfer process by injection of fordist practices by American managers” (p. 269). Blame cannot be entirely assigned to American managers, however, since overall control and responsibility for system transfer resides in the Japanese expatriates who occupy positions of ultimate authority. Since SIA represents a joint venture between two of the smaller Japanese automakers, and CAMI a joint venture between an American firm and a small Japanese automaker, these plants may also have been tempted to take shortcut strategies in facilitating high-volume production. The Japanese perspective on the labor problems experienced at Mazda, where labor relations have long been adversarial, suggests that pressure to accelerate production is a significant contributing factor to unsuccessful transfer.

According to Mazda executive Chiaki Hiroaka, who was involved in training American workers at the Michigan plant, “The effort to establish Mazda-style manufacturing at MMUC was defeated halfway through, in the face of the American labor practice which prevented workers from doing jobs that belong to job categories other than their own.” When the line stopped due to malfunction, production workers did nothing to correct the trouble. Hiroaka’s assertion fails to acknowledge the conditions that led to a non-cooperative attitude, the disillusionment of workers who had anticipated Japanese-style participative relations. In retrospect, Hiroaka observed, they may have been too pushy in introducing the Japanese style. Their over-eagerness resulted from the fact that it was their very first manufacturing venture abroad.[16] Kenney and Florida note that, in Japan, "acceleration of production proceeds much more slowly and allows workers to be cross-trained and rotated" (p. 269). Workers interviewed attributed a high rate of injury in the Mazda plant to American management's failure to fully implement the Japanese system of rotating workers, and thus contributing to repetitive-motion injuries.

Adler (1995) and Besser (1996) found conditions at the NUMMI plant in California and the TMMK plant in Kentucky to be entirely different. While acknowledging that both had a rapid work pace and increasing intensification of work exists in both facilities, the investigators concluded that worker participation in the decision process was concrete and valued, and that workers were in general highly motivated and satisfied with the working conditions. The NUMMI plant had originally been a GM facility characterized by low productivity and poor labor relations, which closed in 1982. The plant reopened in 1984 as New United Motor Manufacturing Inc, a joint venture between GM and Toyota. The new operation, in an agreement with the UAW, rehired a majority of the workers laid off by the 1982 closure.

Adler found that most workers preferred the conditions in the NUMMI organization to those that had prevailed in the GM plant. Here, the organization of labor under the Japanese system was implemented nearly in complete form, so that workers were active

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[16] "Winds of change at Mazda," Hiroshima *Chugoku Shimbun*, 13 May 1998. Electronic version in English language available at: http://www.chugoku-np.co.jp/MAZDA/eindex.html. As a result of declining U.S. and global sales for Mazda, combined with the collapse of the Japanese bubble economy in 1990, the Flat Rock plant became a 50-50 joint venture with Ford Motor Company in 1992, and in 1996, a controlling interest in Mazda corporation was acquired by Ford. Ironically, Mazda workers in factories in the Japanese homeland now feel threatened and insecure as Ford seeks to impose Western-style management there, sentiments reported in various issues of the "Winds of change" series.

participants in defining the conditions of their work environment. Both management and labor viewed their roles as mutual obligation to one another. Management provided job security through a no-layoff policy and relinquished some of its power and prerogatives; in return, an empowered workforce was committed to improving the work process despite an intense pace. To Adler, the NUMMI example suggests that "if management begins with the assumption that workers want to contribute to the goals of the organization, they can design organizational technologies that invite, capture and diffuse suggested improvements to standard practices." In order to produce a NUMMI environment of worker cooperation in the United States, rather than a Mazda or SIA environment of indifference or resistance, Adler suggests that there must be fundamental shift in the attitudes and behavior of both management and labor, and that management must be willing to give up some of its traditional power to labor. In Adler's assessment of NUMMI, "the loss of management's *power over* workers seems to be more than compensated by the competitive benefits of the associated increase in the organization's *power* to accomplish joint goals" (pp. 217-218, original emphasis).

The research conclusions of Besser (1996) are similar to those of Adler. Using qualitative methods including interviews of employees conducted outside the factory environment, Besser found that employees of Toyota Motor Manufacturing Kentucky generally believed that they had significant input into the decision-making process and that the company genuinely cared about its workers. As in the NUMMI case, the perception of job security prompted worker commitment to the goals of the company. According to Besser, most of the elements of the Japanese production system have been successfully transferred to Toyota's Kentucky enterprise, including not only work structure and plant layout but also "work teams and cross-hierarchical teams, job rotation, and the creation of organizational ideology and feelings of community, that is, the company team" (p. 181). Besser's conclusions are supported by Bosman's (1999) later research, which also employed qualitative methods.

It is perhaps no coincidence that the two facilities where investigators found a fully implemented system, including functional mechanisms for worker empowerment, were both Toyota plants. Kenney and Florida (1993) noted that transplant firms such as Toyota, Honda, and Nippondenso[17] have generally avoided problems in labor relations by implementing, from the start of operations, nearly intact versions of Japanese production systems. This lends support to the position that lean production is more than a set of simple tools that can be implemented without changing the organizational culture in any fundamental ways. Successful lean production requires not only adoption of production practices but of social practices that are directed, not as a means of worker control, but to elicit worker participation in knowledge generation and decision-making. As Besser (1996, 183) observes, "The system collapses (or reverts to a Fordist mode of operation) with low-skilled, unmotivated, or angry workers." On a similar note, Kenney and Florida (1993, 275) conclude, "Transplants that have the most confrontational relations appear to be experiencing the least success transferring aspects of the Japanese system, which requires worker initiatives such as kaizen and quality control activities."

In summary, then, the consensus of research indicates that the Japanese system has not been transferred intact to North America, but instead has been modified to suit local circumstances. Practices associated with the organization and management of production

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[17] Nippondenso is a manufacturer of automotive electrical parts and a supplier to Toyota.

most resemble the original model; practices associated with human resources are more likely to consist of a mixture of Japanese and Western elements, or to include elements that are themselves hybridized. Case studies suggest that where the social organization of work recognizes the central role of the worker, where management is willing to share authority and provide job security, lean production systems can function to promote both worker satisfaction and competitive advantage for the company. Lean production appears to be neither a system predicated upon worker oppression nor a workers paradise – although individual plants may be more representative of one or the other.

4.3. Environmental implications of lean production

The literature concerning lean production is substantial, and the consensus of research suggests that, when the core elements of both the production system and human resource organization are implemented, companies are able to improve their overall economic efficiency. A lesser body of literature has more recently focused upon the potential of lean production systems to improve the environmental performance of the firm (Romm 1994; Florida 1996). These and other investigators have identified specific attributes of lean production that, in addition to enhancing economic efficiency, have a complementary effect upon the firm's eco-efficiency. These attributes are a focus upon waste elimination, continuous improvement, and accessing and integrating the knowledge of all employees.

Japanese management systems are so compatible with the concepts of ecological efficiency that many large Japanese corporations, including Toyota, have adopted this as a central policy. Likewise, environmental management systems such as ISO-14001 phase so smoothly with the philosophy of continuous improvement that, as we have seen, Japanese firms have the highest environmental management system adoption rate of any nation. Input from all levels of the organization, but especially from those workers daily engaged with production processes, is essential to continuous improvement and the lean production system appears particularly adept at capturing and harnessing this knowledge. Furthermore, as described in Chapter 2, the horizontal integration characteristic of Japanese keiretsu and supplier networks appears to be the best organizational structure, presently existing, for the development of industrial ecologies. Lean production, by its inherent nature, appears to have the potential to improve the environmental performance of industrial facilities through better conservation of resources, reduced generation of physical waste including pollutants, and better management of unavoidable process waste.

Reduction or elimination of waste is the central premise upon which the entire just-in-time system is based (Ohno 1988). The principle of waste elimination as the economic justification for lean production was described by Shingo (1984), a noted industrial engineer who spent a lifetime refining the Toyota system and training Japanese manufacturers in its principles. For most business enterprises, an appropriate profit is added to the production cost to determine sales price. In contrast to this conventional approach, sales price for Japanese manufacturers is determined by the markets. Thus, profit equals the sales price minus the production cost. Given a fixed sales price, the only way to obtain profit is by the reduction of costs, attained through the dedicated elimination of waste. According to Shingo, cost reduction is essential: "There is no other way for an enterprise to survive except for a perfect elimination of wastes" (p. 111). Through the elimination of wastes and corresponding reduction of production costs, a company may be able to subsequently lower the sales price of its products and increase its competitiveness. The basis of the system is, then, to discover and eliminate wastes in the work which, at traditional plants, are considered natural, acceptable, or "no problem."

The seven procedural wastes inherent in manufacturing processes were first elaborated by Ohno, and most subsequent accounts of lean production similarly highlight waste reduction in terms of procedural wastage; that is, to increase efficiency through better management of time, space and motions involved in industrial processes. Although minimization of physical wastes is implicit within a lean production philosophy (Romm 1994), less overt attention has been given to the potential of these systems for reducing both resource consumption and generation of waste residuals (pollution). A simplified version of Ohno's waste categories has been presented by Cowton (1994) who describes these as wastes involving materials, machines, and people.

Material waste is seldom mentioned in the literature and then usually only in reference to resources (raw materials) or scrap. Shingo's classic *Study of Toyota Production System from Industrial Engineering Viewpoint* (1981) featured a discussion of Ohno's seven wastes but did not specifically address physical waste. Throughout the text, however, Shingo provides numerous examples of the reduction of materials or energy waste in actual practice. An examination of six texts promoting implementation of lean production systems within Western factories all reiterated Ohno's seven wastes but did not discuss physical waste at all except as scrap or rework (Cheng and Podolsky 1993; Ranky 1990; Hernandez 1989; Duncan 1988; Hay 1988; Voss 1987). The focus in the management literature was wholly on organization and process.

Generally speaking, it was not until after the 1992 Rio Earth Summit and the resulting widespread attention given to the concept of sustainable development that a recognition of the potential environmental significance of lean production began to filter into the management and academic literature. An early mass market management book with this focus was Romm‘s (1994) *Lean and Clean: How to Boost Profits and Productivity by Reducing Pollution*. Romm acknowledges that lean production practices are inherently sound environmental strategies inasmuch as they address conservation of resources, raw materials and energy, but considers pollution to be a special case. The potential for reduction or elimination of pollution exists within lean production, but requires the *will* to take an environmental approach, or “lean and clean production.” According to Romm, lean production and clean production are compatible because the systematic reduction of waste is the common goal of each approach.

The environmental potential of lean production was explicitly recognized in the more specialized literature of hazardous waste management. Freeman’s (1990) *Hazardous Waste Minimization* is one of the earliest in this regard, but limits the discussion to a few pages on the potential benefits of the inventory reduction aspect of Just-in-Time. According to Freeman, “Any effective inventory management program must include process waste. Handling waste as if it were a product will help reduce waste and increase the potential for recovery” (p.27). JIT is referred to as the “ultimate” in inventory control procedures.

A more ambitious work by Freeman, *Industrial Pollution Prevention Handbook*, appeared in 1995, reflecting recent developments in pollution control technologies and doctrines. In this industry-oriented text, Freeman virtually attributes the entire concept of pollution prevention to the American debut of lean production principles. One of the management tools integral to lean production systems is known as TQM, a form of organized kaizen or continuous improvement activity. In 1993, the President's Comission for Environmental Quality released a report called *Total Quality Management: A Framework for Pollution Prevention* that described the knowledge and experience in pollution reduction and prevention gained by 12 facilities using TQM principles and tools. Freeman (1995) states: "Although it arrives nearly a decade later to American industry than TQM, pollution prevention is clearly based on the principles of TQM. Like TQM, pollution prevention means total process consciousness and the flexibility to pursue and make radical change" (p. 129). Freeman further asserts,

> The future factory will fully integrate the concept of pollution prevention into its TQM program...The future factory will consider the environmental implications of a new product, service, or workload. It will design pollution prevention into its research experiments. It will insist on pollution prevention in the acquisition of new components or systems from others so that waste generation in the life cycle of its products will be minimized. The future factory will constantly use TQM tools to find problems and seek solutions. It will inculcate the TQM culture into every person in the company (p. 133).

During the 1990s, lean production's environmental potential also entered the academic literature, on a limited basis, as a subject for discussion and investigation. King and Lenox (2001) identified three areas of potential environmental benefits that have been advanced by proponents of the "lean is green" relationship: (1) adoption of lean practices may inadvertently lead to pollution reduction; (2) the process improvement capabilities of lean production may reduce the marginal cost of pollution reduction activities and thereby encourage such activities; and (3) the routine performance monitoring and assessment characteristic of lean production provides realistic information about the costs and benefits of pollution prevention and thereby encourages such activities. Consequently, in King and Lenox's opinion, "we expect establishments that engage in lean manufacturing to adopt proactive environmental management practices." According to the authors, because lean production and environmental management systems such as ISO-14001 share many characteristics, lean firms are more likely to adopt an EMS.

In a discussion of environmental policy and industrial innovation, Wallace (1995, 110) noted that, for Japanese firms, "a widespread culture of continuous improvement, or kaizen, leads directly to reduced pollution." Similarly, Helper, Clifford and Rozwadowski (1997) observe that lean production's focus upon waste reduction has the dual effect of reducing pollution and increasing business efficiency.

According to Wallace, lean production systems convey the ability more easily to cope with design and process change required by environmental regulations. Features of the lean system such as multi-skilled workers and two-way communication facilitate Japanese firms "to understand and respond to environmental problems, which are by their nature long-term and cross-functional and require innovative solutions" (p. 108). Florida (1996) argues that adoption of advanced manufacturing practices – lean production systems – creates incentives for improved environmental performance. Both lean production strategies and "environmentally conscious manufacturing" are characterized by similar principles: "a dedication to productivity improvement, quality, cost reduction, continuous improvement, and technological innovation" (p. 80).

More recently, Rothenberg, Pil and Maxwell (2001) suggest that, while lean production systems may lead to improved resource efficiency, reliance upon these systems may actually contribute to higher emissions because plants utilizing lean production may be more likely to depend upon process change to improve environmental performance rather than investing in costly, yet effective, abatement technology. End-of-pipe abatement technology in effect serves as a protective buffer and thus conflicts with the "bufferless" principles of lean production. Lean manufacturing plants tend to "place greater faith in process improvement as a way to reach future environmental goals" (p. 236).

Florida, Atlas and Cline (2001), in contrast to Florida (1996), suggest that the adoption of advanced business practices such as the just-in-time system is of less significance to adoption of environmentally conscious manufacturing than organizational resources and performance monitoring. In this context, organizational resources include both environmental staff and the active involvement of shop-floor workers in environmental innovation; performance monitoring refers to the ability of an organization to measure, assess and track its performance in key areas.

This contention is of particular interest, for although it diminishes the apparent potential of the JIT system to provide environmental benefits, it does not invalidate the potential for the lean production system as a whole to provide environmental performance enhancement. The emphasis upon the significance of organizational resources complements the focus of a successful lean production system upon human resources, specifically the ability of the system to motivate worker participation and harness worker knowledge. Secondly, performance monitoring involving goal-setting, measuring, and evaluation exactly describes an environmental management system such ISO-14001. Japanese manufacturers have adopted ISO-14001 in greater proportion than the firms of any other nation, in part because the principles and practice of the EMS are so compatible with the continuous improvement philosophy inherent to lean production.

In summary, a relatively sparse body of literature indicates that the adoption of lean production practices have the potential to improve the environmental performance of manufacturing firms, although improvements may be more in the form of resource conservation than pollution prevention. Lean production is implicitly conservative of resources, but also provides a framework for pollution prevention when the *will* to do so is present. That the will to take this extra step exists was evident in the case studies by O'Dell (2001), and in the case studies profiled in the current research. In every case, pollution control technology was used in combination with environmentally proactive process improvement in order to reduce pollutant emissions. Process improvements that seek eco-efficient results may sometimes be less capable in the short-term than control technology, but have the potential to be more eco-effective over the long term.

4.3.1. Is lean really green? Evidence from empirical studies

Popular literature, in both print and electronic media, is replete with examples of firms which have generated environmental benefits through adoption of lean production methods. As Florida (1996) observes, these success stories are no more than "existence proofs" and do not conclusively link lean production to improved environmental performance. Most studies of the environmental implications of lean production rely upon such case studies, combined with survey methodology; research based upon empirical evidence are relatively few. Among studies that do evaluate empirical evidence are Klassen (2000); O'Dell (2001); Rothenberg, Pil and Maxwell (2001); and King and Lenox (2001). In each case, federal waste data from the Toxic Release

Inventory (TRI) or Resource Conservation and Recovery Act (RCRA) programs were utilized to make comparisons among individual firms, both lean and traditional Fordist systems.

Using TRI data for release and transfer of hazardous chemicals, Klassen (2000) compared investment in JIT systems to environmental performance for a sample of 55 plants engaged in furniture manufacture. The results of his analysis indicated that increasing investment in JIT systems was weakly correlated to improved environmental performance. Klassen's definition of a just-in-time system was, however, limited to only a few parameters, such as delivery performance and set-up time, that focused more on process considerations than upon the organization of human resources. The analysis may thus have included firms for which the adoption of lean methods was only partial and perhaps ineffective.

Using TRI and RCRA data, several different metrics including total waste generation and releases and a management efficiency index based on releases-per-worker for individual firms were employed by O'Dell (2001) to compare environmental performance for Japanese and non-Japanese firms in Kentucky. This study concluded that Japanese facilities were more successful in waste reduction than non-Japanese, noting that (1) total hazardous waste produced by Japanese firms remained a stable percentage over time of the total hazardous waste production for all RCRA firms in Kentucky despite a considerable increase in the number and capacity of Japanese plants; (2) the number of Japanese plants producing toxic (TRI) waste was proportionately five times greater than for the general industrial population, but generated only twice as much of this waste category; and (3) releases to the environment, when compared on a per-worker basis, were significantly less for Japanese facilities than for those of other ownership.

Rothenberg *et. al*. (2001) evaluated environmental performance of 25 automobile assembly plants in North America and 7 in Japan, using three metrics: emissions of volatile organic compounds (voc); water use; and energy use. Each of these metrics was measured plant wide and averaged over a two-year period, while controlling for plant age, production volume, and utility costs. In this study, assessment of firm "leanness" included human resource management practices in addition to the structure and processes of production operations. The authors concluded that lean production systems contributed to improved resource efficiency as measured by water and energy consumed per vehicle manufactured. Voc emissions were reduced through improved process efficiency, but remained at higher levels in plants using lean systems for the reasons described in the previous section.

TRI data was used in a 2001 study of 17,499 U.S. manufacturers to test the ability of lean production systems to reduce facilty waste generation and waste emissions (King and Lenox).[18] The "leanness" of a facility was measured of the basis of the use of inventory buffers and work system management that emphasizes a proactive and well-trained work force, process measurement, and continuous improvement. Proxies developed to reflect these characteristics were, respectively, the maximum inventory of chemicals held onsite during a year, obtained from the TRI database; and certification in ISO-9001, a quality management standard. In addition, the investigators also tested as to whether adoption of lean production also promotes adoption of ISO-14001 environmental

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[18] The toxicity-weighted emissions method used by King and Lenox was adapted for use in the current research; see Chapter 5.

management systems. The authors found empirical evidence that "lean production is complementary to environmental performance"; that lean production is associated both with greater source reduction and with lower emissions. In regard to EMS adoption, King and Lenox determined that prior ISO-9000 adoption was associated with ISO-14001 adoption, but cautioned that this may simply indicate that adoption of one standard makes it easier to adopt another, not necessarily that lean production encourages adoption of environmental management standards.

The King and Lenox study used surrogate measures to indicate firms likely to be engaged in lean production but did not control for nationality of firm ownership. Evidence from the literature presented earlier in this chapter suggests that Japanese transplant firms, although subject to hybridization in transfer of their production systems, are likely to establish more complete versions of lean systems than domestic firms because transfer of practices is directly assisted by technology export and the presence of expatriates and "Japanized" key employees. Again using TRI data, King, in collaboration with Shaver (2001), compared the environmental performance of foreign and domestic firms in the chemical and petroleum industries in the United States, and concluded that foreign firms generated more waste, but also processed a greater proportion of this waste. These two tendencies countered one another sufficiently so that "one cannot conclude that [foreign firms] release more pollution" (p. 108). To the authors, these findings suggest that unfamiliarity with local business conditions offsets any inherent technological superiority of foreign firms. The King and Shaver study did not, however, disaggregate foreign firms by nationality so that Japanese firms were grouped with other foreign firms not using lean methods.

In summary, both theory and empirical evidence suggest that lean production methods have the potential to improve firm environmental performance. No empirical studies were located that specifically compared environmental performance of Japanese transplant facilities against those of other ownership, except for the pilot study presented in O'Dell (2001). The following chapter describes the methodology that was used in the current study to investigate environmental performance of Japanese transplants.

Chapter Five

Methodology

5.1. General Methodological Approach

This study employs both quantitative and qualitative methodologies to evaluate environmental performance of industrial firms. Data concerning waste generation and subsequent management strategies by individual facilities is subjected to comparative statistical analysis presented in Chapter 9. These represent public domain data, reported to the US Environmental Protection Agency under the legislative mandate of two separate federal programs, commonly referred to as RCRA and TRI. A second component of the investigation is a mail survey sent to all Japanese transplant facilities in the study area, designed to provide detail concerning environmental management practices and attitudes. Qualitative investigation of actual waste management practices and policies was conducted at five sites, in each case involving visits to the plant floor and interviews with key personnel involved in waste management. Although the case studies do not contribute directly to comparative evaluation of firm performance, these allow investigation of actual waste management practices. The case studies provide depth to the investigation that cannot be obtained solely through quantitative methods.

For the data analysis, there are many possible waste management criteria that might be used to evaluate environmental performance of individual industrial facilities. Such criteria may represent simple accounting of total quantities of waste generated during the production process or the totals or percentages attributed to various post-production methods for recovering or disposing of the wastes. More sophisticated approaches may incorporate multiple variables, such as waste generation per unit of production, per unit of company revenue, or per worker, in an attempt to define an indicator comparable across different facilities.

Any meaningful indicator of industrial environmental performance must take into account three distinct aspects of waste generation and management: magnitude, potential hazard (or toxicity), and management efficiency. Magnitude is concerned with the total quantities of the substances involved; hazard refers to the risk posed by different substances to human and environmental health; and management efficiency concerns the proportion of waste that is not reused or recovered but escapes the production cycle to interact freely with the environment. Waste efficiency also involves the hierarchy of waste management strategies, in that options such as source reduction or recycling are both more efficient and more ecologically desirable than treatment or disposal.

The interplay among these factors is critical to assessing environmental risk. For example, a firm that generates a large amount of waste might seem to be a greater environmental threat than a firm that generates a small amount. Waste does not, however, become an environmental hazard until it begins to interact with the environment. If the large waste producer has implemented strategies that recover nearly all the waste and the smaller producer has not, then the smaller producer may be releasing more waste material to the environment. Further, environmental risk is greatly dependent upon the relative toxicity or other hazardous attributes of any materials that are not recovered. A small amount of a highly toxic substance is likely to pose a greater environmental risk than a larger amount of material of low hazard. Thus any single facet of industrial waste generation is inadequate for assessing either environmental performance of the firm or potential risk to human or environmental health.

Assessing toxicity of chemical substances is a particularly problematic issue. Many individual researchers, as well as government agencies, have attempted to develop classification schemes that rank chemicals according to their potential hazard. Establishment of a uniform system for hazard ranking would allow comparison of the relative toxicity of chemical wastes for individual firms on a common scale, where total quantities of chemical releases have been adjusted according to toxicity weighting factors. No generally accepted ranking system exists at present. Because of the complexities inherent in defining "toxicity," there has been little agreement and there are many competing systems. In the late 1990s the US Environmental Protection Agency attempted to develop a "toxicity weighting factor" to be applied to regulated chemicals as part of its public information database, the Sector Facility Indexing Project (SFIP), but was forced to abandon the effort as a result of widespread criticism of its methodology (Bergeson 1998).

The problems arise because of the widely differing characteristics of various chemicals under different circumstances. Toxicity may vary according to the media, air, land or water, in which the chemical is present; may vary according to the route of exposure, oral, dermal, or through inhalation; may vary according to whether human or ecological health concerns are considered; and may vary in its effects, acute as opposed to chronic, toxic compared to carcinogenic. One classification scheme, the CalTOX model developed by researchers at UC Berkeley, uses no less than four separate toxicity indicators for each of the chemicals in its list, in order to account for differences between carcinogency and toxicity and air and water media.[1]

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[1] http://www.cwo.com/~herd1/caltox.htm

Table 5.1. Environmental statistics for pilot case studies (1996 data)
Source: O'Dell (2001)

Facility # workers	RCRA HazWaste Generation		TRI Toxic Waste Generation		TRI Toxic Waste Releases		
	Total, tons	Per job, lbs	Total, tons	Per job, lbs	Total, tons	Per job, lbs	% total waste
Toyota 6,600	3,648.3	1,105.5	3,440.54	1,042.6	1,141.43	345.9	33.2
Hitachi 650	16.5	50.8	5.05	15.5	0.03	0.09	0.6
KI 350	NA	NA	3.94	22.5	0.04	0.23	1.0
Universal 250	57.4	459.2	410.43	3,673.6	1.52	12.2	0.4
Zeon 165	3.3	40	3,104.36	37,628.6	137.87	1,671.2	4.4

The analyses conducted in the Kentucky pilot study (O'Dell 2001) acknowledged the significance of the toxicity issue but did not address it directly, instead limiting analysis of RCRA/TRI data to two of the three critical factors, magnitude and management efficiency. Data for the five facilities represented by case studies in the pilot investigation are presented in Table 5.1 to make comparisons of environmental performance. The table includes RCRA and TRI data, both evaluated on the basis of total waste generation, and, for TRI only, total releases.[2] Total waste generation alone, as noted, does not address either production efficiency or environmental risk. Efficiency can only be assessed if waste generation is compared to waste management practices. Nor can examination of practices alone convey a sense of environmental risk. For example, the release rate for Toyota is 33.2 percent of production waste and for Zeon, 4.4 percent, but a simple percentage figure tells us nothing about the magnitude of the problem. Conversely, the total quantity of releases reveals little about the relative

[2] Differences between the two federal programs are immediately apparent in terms of total waste generation. The large discrepancies are attributable primarily to the different reporting requirements of the two programs.

efficiency of the production system in terms of waste management. Clearly, neither comprises a meaningful evaluation when used without other contextual information.

To assess environmental performance, measures of magnitude and efficiency need to be combined in terms of some production ratio generalizable across industrial categories. Toyota's in-house use of waste emissions-per-vehicle-built as an indicator of environmental progress[3] might be applied to automobile assembly plants, but cannot be applied to the manufacturers of other products, including automobile parts suppliers, because the units are not comparable. Waste releases per assembled vehicle does not, by any means, correspond to waste releases per auto brake pad, vacuum cleaner, or VCR manufactured. Another method might be to use waste generation per dollar revenue, but accurate information concerning corporate finances at the plant level is often difficult to obtain. This is particularly true for Japanese companies, most of which are privately held. One per-unit measure that may be applied using readily available information is the use of waste releases-per-worker. Whereas releases, when contextualized, are relative to efficiency, the number of workers roughly corresponds to the scale of the operation and is therefore relative to the magnitude of production. The combination of releases-per-worker thus has implications for measuring ecological efficiency, where operational scale comprises the economic indicator and waste releases the environmental indicator.

This is shown in Table 5.1, in the column listing TRI toxic waste releases per job. For example, total TRI waste generation for the Georgetown Toyota plant in 1996 was equivalent to 1,042.6 pounds per worker for each of the factory's 6,600 workers. Since the calculated rate of releases for that year is equivalent to 33.2 percent of total waste

[3] Personal communication 1999, Steve Green, Toyota Motor Manufacturing, Georgetown, Kentucky.

generation, a rate of 345.9 pounds of waste releases per job can be derived. This provides a partial measure of ecological efficiency that takes into account both the magnitude of waste generated and of the proportion released, hence the effectiveness of waste management. Note that, according to this method, Toyota would be credited with a greater efficiency than Zeon even though the automobile maker had nearly eightfold greater releases both in total quantity and as a percentage of total generation. This is a consequence of Toyota's far lower rate of production waste per worker employed, which reflects operational efficiency.

Although the releases-per-worker method provides a measure of waste management efficiency, this should not be confused with ecological risk. The potential impact to the environment from Toyota's airborne emissions is possibly greater than Zeon's simply because Toyota's contribution is much larger. Theoretically, if Zeon operated on the same scale as Toyota, the chemical company's impact upon the environment would be greater than the automobile plant because although Zeon's percentage of releases is less, the releases per worker are five times larger. In reality, however, economies of scale would probably invalidate a direct projection of this sort.

The releases-per-worker method, while providing a means to estimate ecological efficiency for waste management, is subject to several qualifications. A primary weakness in this system is that it only applies to that select group of facilities who are regulated under RCRA and/or TRI. This group is by definition most likely to have significant environmental impacts. The method does not reflect inherent differences in many classes of industry nor the varying hazard depending upon the type of waste produced. Nor does it take account of resource depletion through overconsumption nor of the inefficiency implied by the existence of waste. A low rate, however, is a reflection of the collective effectiveness of the plant's technology, policies and practices.

To assess the overall ecological effectiveness of facility operations, the third factor, toxicity, must be taken into account. Two separate approaches are used in this study to compare facility environmental performance using relative toxicity of releases as a factor in the evaluation. First, while acknowledging that none of the presently existing toxicity scoring systems are able to adequately represent, with a single indicator, both environmental and human health risks inherent in multiple media chemical releases, this investigation employs an adapted version of the toxicity weighting system described in King and Lenox (2000;2001) and King and Shaver (2001). Secondly, an analysis is performed using a limited number of facilities and chemicals; namely, the seventeen chemicals targeted for industry-wide reduction by the EPA in its 33/50 program.

Assessment based on the 33/50 program allows a fourth factor – the temporal dimension – to be brought into the analyses. An environmental snapshot consisting of a single year's waste data says little about trends. A more significant evaluation requires the use of multi-year data. Because the basic set of waste types and chemical substances regulated under RCRA/TRI has been altered several times during the lifetime of these programs, firms cannot be assessed over a period of years simply on the basis of the amount of waste. The temporal element can only be fairly evaluated when only those substances are considered that have been present on the basic list throughout the period. This is the case for the 17 chemicals in the 33/50 TRI program, and so these chemicals will be used to look at trends in environmental performance and impact.

In summary, the analytical methodology employed to compare performance of Japanese transplant facilities to those of other ownership in the study area will be based upon increasingly sophisticated analyses of three factors of waste management: magnitude, efficiency, and toxicity, in order to evaluate overall waste management efficiency and overall potential environmental impact. These factors will be assessed beginning with magnitude alone, in terms of total waste generation and releases; then combine magnitude and efficiency by using releases-per-unit as an analog for overall efficiency; and, finally, combine all three factors to assess total weighted toxicity per unit. "Per-unit" in the analysis refers to investigation of two types of production "units" representing (a) releases-per-worker and (b) releases-per-square-foot of the facility. Depth is added to the analysis by evaluating the data on the basis of similar industrial sectors.

5.2. RCRA and TRI Data

Two public-domain data sources provided the primary information used for statistical performance evaluation in this project: (1) the federal hazardous waste reporting system established under the provisions of RCRA, the Resource Conservation and Recovery Act (1976, amended 1984, 1986, 1992); and (2) the federal Toxic Release Inventory (TRI), a national database established by SARA[4] Title III, Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA, 1986, amended 1997). Each of these programs requires industrial facilities to report on materials that are potentially harmful to human health and the environment, and each of these programs was established prior to a significant presence of Japanese transplants in the United States. Although there is

[4] Superfund Amendments and Reauthorization Act (SARA).

overlap, the programs differ considerably in the classes of materials with which they are concerned.

TRI reporting is more selective than RCRA, in that TRI is concerned with the management of specific chemical substances whereas RCRA regulates a broader range of "hazardous" substances that encompasses classes of materials rather than specific chemicals. Examples of substances reported under TRI include the discrete chemicals CARBON TETRACHLORIDE and METHYL ETHYL KETONE; examples of waste classes reported under RCRA include items such as BROKEN CAR BATTERIES or PAINT CANS/BRUSHES/ROLLERS. Waste from a single facility may be reported under both TRI and RCRA according to the requirements of the program; for example, 2,000 pounds of soil contaminated with 10 pounds of lead would be reported to RCRA as 2,000 pounds of lead-contaminated soil and to TRI as 10 pounds of lead released to the environment. Furthermore, TRI is directed more toward emissions of toxic substances, including airborne emissions, whereas RCRA is concerned with solid waste.

The RCRA program was established in 1976 to address the issue of how to safely manage and dispose of the huge volumes of industrial and municipal solid waste generated nationwide. RCRA Subtitle C (hazardous waste) regulates both newly generated solid waste and the cleanup of a limited number of abandoned hazardous waste sites that meet certain criteria. The legislation regulates and manages hazardous wastes from generation to disposal, taking a "cradle-to-grave" approach (USEPA 2000). Wastes regulated under the RCRA program are divided into two very broad categories: listed hazardous wastes, and characteristic hazardous wastes. Listed hazardous wastes are specific substances that have been listed in the Code of Federal Regulations (CFR). The second category permits regulation of a wide variety of waste substances if they exhibit certain characteristics of toxicity or ignitability, corrosivity, or reactivity (Moya and Fono 2001, 103-108).

The TRI program was implemented in 1987, requiring facilities involved in the handling of listed toxic chemicals to report on the manufacture and use of such chemicals and the amounts of these chemicals released to the environment. The information collected through TRI was greatly expanded by the passage of the 1990 Pollution Prevention Act, which required facilities to report upon waste management activities on- and off-site such as recyling, combustion for energy, and treatment. This expansion greatly enhanced the utility of the TRI database for analysis of trends in waste reduction. Further revisions of the TRI program have doubled the number of regulated chemicals to more than 650 chemicals and toxic chemical categories at present.[5]

Each of the two programs includes a large proportion of facilities that are non-industrial. When initiated in 1987, the TRI program was intended to apply only to industrial facilities. In 1994 Executive Order 12856 directed federal facilities operating in any Standard Industrial Classification (SIC) code to begin reporting to TRI, but these facilities constitute only about one percent of the total regulated population. Beginning in 1998, the TRI scope was expanded to include seven additional non-manufacturing classes of facilities: metal mining, coal mining, electric utilities, commercial hazardous waste treatment, wholesale chemicals and allied products, wholesale petroleum bulk stations, and solvent recovery services. A facility must report to TRI if it falls within SIC manufacturing codes 20 through 39 or is included in the additions noted above, has ten or

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[5] "The Toxics Release Inventory (TRI) and Factors to Consider When Using TRI Data," electronic document, http://www.epa.gov/triinter/tridata/tri00/press/overview.pdf.

more full-time equivalent employees, and manufactures or processes more than 25,000 pounds or otherwise uses more than 10,000 pounds of any listed chemical during the calendar year.[6] Accordingly, a great many small manufacturers are not required to report waste generation and management to TRI.

Facilities regulated under the RCRA program encompass an even broader range than those in the TRI program, as from the beginning no attempt was made to limit applicability solely to manufacturers. RCRA's "cradle-to-grave" waste management system is intended to apply to both generators and transporters of hazardous waste, and to treatment, storage and disposal facilities (TSDFs). According to Moya and Fono (2001, 116), "Generators do not have to be owners or operators of industrial activities that produce hazardous waste. In fact, generators can be anyone who produces hazardous waste intermittently, infrequently, or accidently…." Included among sites regulated by RCRA are a number of inactive industrial facilities where waste generation is solely the result of ongoing cleanup of past contamination. Reporting requirements for regulated facilities differ according to classifications based on waste quantity threshholds. Large quantity generators (LQG) are defined as producing more than 2,200 pounds (1,000 kilos) of hazardous waste per month. Less closely regulated, small quantity generators (SQG, 10-100 kg) and conditionally exempt generators (CEG, 1-10 kg) report on hazardous waste in less detail than SQG facilities.

RCRA and TRI data is available for download from two primary sources: separate databases maintained by the Environmental Protection Agency, separate databases

[6] *Ibid.*

maintained by the Right-to-Know Network (RTK NET).[7] The RTK NET was selected as the data source for the study due to the greater ease involved in making both geographic and facility queries. Queries may be downloaded in delimited text files which are readily convertible into Microsoft Excel™ or other spreadsheet formats. RCRA data is made available to the public, from either source, through the EPA's Biennial Reporting System. RCRA facilities report to the EPA on a biennial basis; TRI data is reported annually.

There are certain inherent difficulties associated with the use of RCRA and TRI data. These difficulties arise from overlapping causes that may be categorized as data inconsistencies and compilation delays. Data inconsistencies arise from changes in program requirements and definitions and from misreporting of information by facilities. In the first case, federal and state programs are subject to constant modifications by both legislatures and regulatory authorities. Both RCRA and the TRI have been substantially revised on several occasions. For example, in 1994, 286 chemicals were added to the list of substances regulated under the TRI program, and in 1998, seven additional industrial sectors were added. This results in data sets that vary over time as to the number of chemical substances included, the reporting requirements for facilities, and the way in which information is organized. Furthermore, the information reported by facilities is not always accurate, sometimes intentionally, sometimes inadvertently, so that figures may be subject to retrospective adjustment. The net effect is to produce substantial delays in report compilation, so that the most accurate data is usually several years old. Despite these problems, federal RCRA and TRI waste data represents the only information available on waste management for large numbers of individual facilities.

[7] http://www.rtk.net. As part of EPCRA's mandate, RTK NET was established in 1989 to facilitate public access to information about toxic waste. The site is operated by two nonprofit organizations, OMB Watch and the Center for Public Data Access, and funded by various government agencies and foundations.

Although 2000 TRI data is now available, 1999 is the most recent year for which RCRA data is available through the EPA's Biennial Reporting System. Consequently, 1999 was chosen as the base year for waste data analyses in order to compile a compatible joint data set.

5.3. Identifying the Sample Populations

Four distinct but overlapping sample populations were selected for the study, based upon the year 1999, each destined for a progressively more detailed analysis: (1) the population of all known manufacturers in the four-state study area; (2) all manufacturers in the study area regulated under the provisions of RCRA; (3) all manufacturers in the study area regulated under the provisions of TRI; and (4) all manufacturers in the study area with a significant (>10%) Japanese ownership. In each of these categories the list of facilities must be considered a "snapshot" for 1999 since the number and characteristics of firms are dynamic, constantly changing even within a single year due to new expansions, openings, closures, mergers and acquisitions.

5.3.1. Total Population of Manufacturers

Very little analysis was planned for the first population, the set of all known manufacturers in the study area. Only limited information was readily available about this population at the firm level without making a substantial financial investment to obtain this in electronic format from commercial directories, or else to conduct an extremely arduous manual data entry of information for nearly 50,000 facilities. Consequently, the industrial population in its entirety serves simply as a baseline against which to compare the magnitude of Japanese investment in these states. In lieu of firm-level data, a discussion of the general nature of the manufacturing industries in the study area may be found in the following chapter, which describes the study area. The number of manufacturers in each state was established using the 2000 editions of the state directories published by Manufacturers' News, Inc, the leading compiler and publisher of information profiling U.S. manufacturers (Table 5.2).

Table 5.2. Total manufacturing facilities by state
Source: Manufacturers' News, Inc.

State	Facilities
Indiana	12,311
Kentucky	5,850
Ohio	22,697
Tennessee	7,079
Total for study area	47,937

5.3.2. Facilities Regulated Under RCRA and TRI

The sample populations used for detailed analysis of hazardous waste management, firms regulated, respectively, under RCRA and TRI, were separately downloaded from the website database of the Right-to-Know Network. The information downloaded included data fields identifying the facility and parameters related to waste generation and management. The RCRA and TRI data files downloaded from RTK were imported into separate Microsoft Excel™ spreadsheets. At this point, several steps were necessary to reduce the massive quantity of information obtained to the essential data fields required for analysis and to populations that consisted solely of manufacturers and did not include other types of regulated but nonindustrial facilities. Once the necessary manipulations had been accomplished, the RCRA and TRI files would be combined into a single database. In the first step, non-essential data fields were deleted from the file. The data fields shown in Table 5.3 were retained for analysis, renamed for simplicity and clarity.

Table 5.3. Data fields used in the combined RCRA/TRI facilities database

Common Fields	RCRA Fields	TRI Fields	Added Fields
EPA_ID FACILITY_NAME ADDRESS CITY COUNTY STATE PRIMARY_SIC LATITUDE (decimal) LONGITUDE (decimal)	RCRA_GEN (generated) RCRA_MNG (managed) RCRA_SHIP (shipped)	TRI_ID NONPRODUCTION_WASTE PRODUCTION_WASTE ALLWASTE RECYCLED_ONSITE RECYCLED_OFFSITE ENERGY_ONSITE ENERGY_OFFSITE TREAT_ONSITE TREAT_OFFSITE RELEASE_FUGITIVE_AIR RELEASE_STACK_AIR RELEASE_WATER RELEASE_UNDERGROUND RELEASE_LAND RELEASES_TOTAL TRANSFER_POTW TRANSFER_NON_POTW REL&TRAN_TOTAL RELEASE/DISPOSE_OFFSITE	RCRA TRI OWNED AUTO #EMPLOYED PLANT_SIZE

Certain fields such as facility name and address, EPA identification number, and Standard Industrial Classification (SIC) code were common to both data sets, while other fields were program-specific to either RCRA or TRI. Several fields were added to the spreadsheet and left blank initially, data to be obtained from other sources. These added fields were: (1) "RCRA" and "TRI" indicators, so that facilities in the combined file could be identified according to whether they were regulated under a single program or both; (2) an "OWNED" indicator for nationality of ownership; (3) a field designated "AUTO" to indicate whether production at this facility was related to the automotive industry; (4) the field "#EMPLOYED" representing the number of workers at the facility;

and (5) “PLANT_SIZE” indicating the size of the facility reported in square feet. A detailed explanation of the program-specific waste-related fields will be found in the chapter concerning data analysis and results.

Once the essential fields were established and standardized in each data set, the next task was to eliminate facilities that would not be included in the analysis. The data files were sorted according to the quantity of waste generated, and those that reported no regulated waste generation for the year 1999 were deleted entirely. For the RCRA population, a relatively small number of sites were eliminated that qualified as SQG or CEG facilities, leaving only the Large Quantity Generators. Both the RCRA and TRI programs include waste-producing sites not engaged in manufacturing, such as electrical power generating stations or military facilities. Elimination of such sites was readily accomplished for the TRI data. The technique was fairly straightforward, based on sorting the data by SIC code and deleting any facilities whose classification was not in manufacturing. Table 5.4 lists the SIC codes representing those facilities that were deleted from the TRI spreadsheet.

Table 5.4. SIC codes associated with deleted facilities

Facility SIC Code	Description of Classification
1031, 1221, 1222	Mining
4212	Trucking
4911, 4931	Electrical generation
4953	Refuse collection & disposal
5013, 5051, 5169, 5171, 5192	Wholesale trade
7389	Business services, includes recyclers and solvent recovery
8731, 9661, 9711	Government & military facilities

For the RCRA data set, however, this winnowing step was more complicated. Like the TRI regulatory program, RCRA includes many non-manufacturing sites. Unlike TRI data, however, where an SIC code is associated with each facility in the database, SIC codes are provided for only a small percentage of RCRA sites. Furthermore, even when RCRA sites may be identified as industrial, a significant number of these sites represent facilities that have been long shut down, in some cases for a decade or more, and reported waste generation is part of a continuing cleanup of a contamination site rather than a consequence of current industrial production. The Union Carbide site in Marietta, Ohio is an example of a long-defunct facility listed in the RCRA database that generates waste on an annual basis solely as a result of remediation efforts under the CERCLA (Superfund) program.

For the majority of RCRA sites, these issues could be resolved by cross-matching against the TRI facilities, which were in active operation for the reporting year and for which SIC classifications were provided by RTK. Cross-matching against the 3,076 validated TRI facilities accounted for about 1,250 RCRA facilities, an overlap of 41 percent, leaving approximately 1,500 RCRA sites of unknown status. Half of this remainder could be readily eliminated, indentifiable by name alone as hospitals, government facilities, universities, power plants, etc. Of the remaining 750 sites, most could then be identified as active facilities by consulting the state manufacturer's directories for 2000 (Manufacturers' News 2000a, 2000b, 2000c, 2000d). The remainder, approximately 200 facilities, required research via the Internet in an effort to locate websites or other documents of a varied nature that could resolve whether or not the facility was active in 1999. Identification of SIC codes and activity status resulted in the elimination of about 150 RCRA facilities which did not qualify as current manufacturers. The final tally for the sample populations after all deletions were made was 3,083 TRI facilities and 1,907 RCRA facilities.

Up to this point the TRI and RCRA facilities were maintained in separate spreadsheets. The RCRA data consisted of a single line for each facility, showing total waste generated, managed on-site, and shipped off-site for management. The TRI data, however, consisted of multiple lines for nearly every facility, since separate totals were provided for each discrete chemical substance representing toxic waste at the site. In order to compatibly merge data from the two regulatory programs, the TRI spreadsheet was imported into Microsoft Access™ in database format, waste data totaled for each facility, and the result then regenerated as a spreadsheet again in Excel™. This accomplished, the two separate spreadsheets were combined into one master file containing waste generation and management data for 3,726 facilities regulated under two overlapping programs. This combined spreadsheet would allow facility waste analyses to be made specific to each program, or for those facilities regulated under both programs.

The most arduous and time-consuming step was obtaining the data for four of the fields added to the spreadsheet: OWNED, AUTO, #EMPLOYED, and PLANT_SIZE. The added fields "TRI" and "RCRA" were easily and swiftly filled prior to merger of the separate sheets, but determining the other facility characteristics was a task that required nearly a year of steady effort to complete. A wide variety of published and Internet resources was employed in this task, including (1) hard-copy published industrial directories from both Manufacturers' News, Inc. and Harris Infosource; (2) subscriber

Internet directories including Hoover's Online[8] and Thomas Register;[9] specific corporate and company websites; state and community economic development websites; Securities and Exchange Commission (SEC) filings; EPA documents; and other web-published documents of diverse origins. Authoritative weight was assigned to sources in the order listed. Internet resources were consulted for all companies in the RCRA/TRI sample population as a supplement to published data, as a cross-check and verification. According to the directory of temporary Internet files stored in the author's personal computer, more than 40,000 individual web pages were investigated for company information between November 2001 and September 2002.

Information concerning nationality of ownership for facilities in the sample populations ("OWNED" field) was obtained primarily from the individual state departments for economic development through their Internet websites.[10] The most detailed firm-level information was available from the state of Kentucky. The Ohio Department of Development website provided an extensive analysis of foreign investment in the state and offered for sale a hard-copy version with additional firm-level detail (Ohio Department of Development 2000). Internet research disclosed, however,

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[8] http://www.hoovers.com/

[9] http://www.thomasregister.com/

[10] (a) http://www.venture-web.or.jp/indiana/menu.html. State of Indiana East Asian Office website. Maintains information concerning foreign investment in Indiana and investment abroad by Indiana corporations. Link to webpage providing list of of facilities of foreign ownership and the communities in which they are located.

(b) http://www.thinkkentucky.com/kyedc/busdirectories.asp. Kentucky Cabinet for Economic Development website, with link to list of facilities of foreign ownership and the communities in which they are located available for download in pdf format.

(c) http://www.odod.state.oh.us/research.htm. State of Ohio Department of Development, Office of Strategic Research website. Link to list of facilities of foreign ownership and the communities in which they are located available for download in pdf format.

(d) http://www.state.tn.us/ecd/idg.htm. Tennessee Department of Economic and Community Development website, Office of International Affairs. Link to list of facilities of foreign ownership and the communities in which they are located available for download in pdf format.

that official state government listings of foreign-based corporations sometimes failed to identify foreign acquisitions of American companies. Examples of foreign-owned facilities not shown in official listings include the Nippert Company in Delaware, Ohio, a subsidiary of the Finnish multinational Outokumpu Oyj acquired in 1983; Nova Chemicals in Painesville, Ohio, whose parent firm Nova is headquartered in Calgary, Canada; and Invensys Precision Die Casting of Russellville, Kentucky, a subsidiary of the United Kingdom's Invensys PLC. Such corrections were made to the spreadsheet when encountered.

The transportation industry is one of the most economically significant sectors for the study area; accordingly the field "AUTO" was added to the spreadsheet in order to assess the impact of waste associated with this sector compared to non-transportation industries. For the purposes of this study, transportation industry is defined as land vehicular transport, including automobiles, trucks, buses and recreational vehicles but excluding aircraft, boat, construction or railroad equipment. Additionally, manufacturers of aftermarket accessories are included in this category, although their products are targeted to consumers rather than original equipment manufacturers (OEMs).

Determining facility involvement in the automotive transportation industry is, however, somewhat problematic. Most assessments of transportation industry are based upon classification by a limited number of SIC codes that are exclusive to vehicular transportation (see Table 5.5). For most investigators, limiting analysis of the automotive industry to only those firms classified within these codes is understandable, because SIC codes provide the only means to rapidly sort manufacturers by type. Reliance on SIC codes, however, excludes a large number of manufacturers whose operations may be

Table 5.5. Standard Industrial Classification (SIC) codes exclusive to motor vehicle transportation.
Source: Occupational Safety and Health Administration (OSHA)

SIC Code	Description
3465	automotive stampings
3592	carburators, pistons, piston rings and valves
3647	vehicular lighting equipment
3694	electrical equipment for internal combustion engines
3711	motor vehicles and passenger car bodies
3713	truck and bus bodies
3714	motor vehicle parts and accessories
3715	truck trailers
3716	motor homes
3751	motorcycles, bicycles and parts

wholly or partly dedicated to production of components for the transportation industry, as in the case of manufacturers of sheet steel, metal castings, aluminum extrusions, or injection-molded plastics.

For example, SIC code 3089 includes plastics molding. Many firms with this classification have nothing at all to do with the transportation industry, but for many others, their entire production consists of automotive parts. Similarly, SIC code 3471 is assigned to firms engaged in metal fabricating, specifically "Electroplating, Plating, Polishing, Anodizing and Coloring." Many of the 3471 firms are small job shops who manufacture a diversity of parts, some or all of which are made for the automotive market. The only practical method to determine whether or not a facility's production is associated with motor vehicles, when the SIC classification is ambiguous, is to laboriously research each individual firm. Neither the SIC codes nor the necessarily brief descriptions included in directories of manufacturers provides sufficient information, in most cases, to make this determination. Other sources, such as examination of the firm's website, were necessary to ascertain involvement in the transportation industry. For example, I/N Kote (New Carlisle, Indiana, SIC code 3471) is reported in directories as a maker of sheet steel, but the company's website[11] indicates that their production is almost exclusively for the automotive industry. In another example, the website[12] for Imagineering Enterprises, Inc. (South Bend, Indiana, SIC code 2899), a maker of anti-wear and anti-corrosion coatings, reports that "Forty percent of our business activity comes from the automotive industry and approximately 30% of our business relates to applications for the aerospace industry. About 15% of our processing adds value to manufacturers in the heavy construction equipment industry and another 10% is in the computer market."

Through assessment of individual company websites and other sources, firms were considered to be involved in manufacturing for the motor vehicle transportion industry if the website referred to this as one of their markets. Although some websites, such as the Imagineering Enterprises, Inc. site, provided specific percentages, the majority simply noted the target markets. Accordingly, this determination was not made on a quantitative basis but simply on the grounds of involvement *per se*. Despite this limitation, this endeavor is believed to be more representative of the motor vehicle segment's contribution to waste generation than studies based only upon the vehicle-exclusive SIC codes.

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[11] I/N Kote website:

[12] Imagineering Enterprises, Inc. website: http://www.imagineering-inc.com/about/history.htm.

The components “#EMPLOYED” and “PLANT_SIZE” are important to establishing a meaningful metric by which waste management can be evaluated for individual facilities. Considerable effort was therefore expended to obtain this information and verify its accuracy. The 2000 industrial directories published by Manufacturers’ News, Inc., supplemented by those from Thomas Infosource, were used as the primary authorities for this information. These references together supplied employment information for about two-thirds of the facilities and facility size information for slightly less than half. Resort was again made to a firm-by-firm investigation using Internet resources, primarily company websites but including also community and county websites listing major employers as well as a variety of other sources when these did not provide needed information. Because 1999 was the base year selected for analysis, an effort was made to obtain information pertinent to that year, by examining reports of firm downsizing and plant capacity expansions.

In most cases, where firms operated facilities at multiple locations in a single community, site-specific information could be obtained for employment and size of the individual plants. For a handful of cases, however, only combined information was available for all company facilities in the community. In such cases, the individual facilities and their waste management information were combined into a single entity in the spreadsheet for data analysis. This accomplished, the final waste management sample population consisted of 3,712 facilities, of which 3,074 were regulated under the provisions of TRI, 1,894 regulated under RCRA, and 1,256 under both programs. For the total facilities in the combined TRI/RCRA spreadsheet, employment information (field

“#EMPLOYED”) was obtained for 3,445 firms (92.8 percent) and plant size information (field “SQUARE_FEET”) for 2,597 firms (69.9 percent).

All necessary data obtained, insofar as possible, the Excel™ spreadsheet was imported into Microsoft Access™ and converted into database format to facilitate analysis of the data. Similarly, a copy of the spreadsheet was imported into PC-based SPSS. A copy of the spreadsheet was also retained in its original form.

5.3.3 Firms of Japanese Ownership

Because the investigation is focused upon Japanese transplant firms, every effort was made to obtain the highest level of detail concerning these firms in the study area. The individual state departments for economic development were contacted, and spreadsheet files were provided gratis by Indiana, Kentucky, and Tennessee. The state of Ohio offered this information in a published report for a reasonable fee (Ohio Department of Development 2000). The information provided generally included facility name, parent company, nationality of ownership, number of employees, SIC code, and function or product. Information from Kentucky also included date of establishment, although in cases where existing US firms had been acquired, the establishment date was for the original company and not of the acquisition.

The lists supplied by the state agencies were comprised of all known Japanese transplant companies in the study area, and so it was necessary to eliminate from the sample population those not engaged in manufacturing. This was accomplished by referring to accompanying SIC codes and to the verbal descriptions of the products, functions or services provided by the company. During the process of researching information about RCRA/TRI companies, a handful of firms of Japanese ownership were discovered that had not appeared on the official state lists, and these were incorporated in the sample population for the study. Using all sources, 533 manufacturing facilities in the four-state study area were identified as having significant (>10%) Japanese ownership.

5.4 Data Analysis

5.4.1 Toxicity Weighting

Manufacturing processes generate many different kinds of wastes that differ significantly in their characteristics. Some wastes are relatively benign, and others deadly in their potential risk to human and ecological health. Accordingly, evaluation of a firm's ecological efficiency in terms of waste volumes alone is misleading unless there is some indication of the hazard posed by the types of wastes involved. A more rigorous comparison of waste management among facilities should therefore include an evaluation of the relative toxicity of the wastes involved. This is a complicated and often controversial task because of the diverse natures of the substances involved. Because toxicity varies according to the environmental media, mode of exposure, mode of action, and whether human or ecological impacts are of primary concern, ranking of chemical substances by relative toxicity has proved problematic and many methods have been devised.

Among the toxicity ranking systems evaluated for this study were Threshold Limit Values (TLVs), workplace exposure levels devised by the American Conference of Governmental Industrial Hygienists (ACGIH)[13]; Toxic Equivalency Potentials (TEPs),

[13] See the ACGIH website, http://www.acgih.org/home.htm, for information regarding the derivation and proper application of TLVs in risk assessment.

calculated by Environmental Defense (Fund) using the Caltox environmental fate and exposure model[14]; the Minnesota Toxicity Index based on work by Pratt, *et. al*. (1993); the Indiana Relative Chemical Hazard Score (IRCHS)[15]; the EPA's Hazard Ranking System (USEPA 1992); and the EPA's multi-pathway Risk-Screening Environmental Indicators (RSEI).[16] None of the existing methods developed for toxicity risk assessment are entirely satisfactory for comparative analyses of all the chemical substances generated by large numbers of industrial facilities, since these methods have ranked only a limited number of the TRI chemicals or employ multiple ranking methods for each substance of concern.

Thus given that no broadly accepted system currently exists for evaluating facility ecological performance in terms of weighted toxicity, an alternative system was chosen adapting the methodology devised by King and Lenox (2000) and subsequently employed by King and Lenox (2001) and King and Shaver (2001). The weighting scheme used in these investigations was based on a system developed by the EPA to serve as a threshold for reporting accidental spills and releases; these threshold values for chemical substances are defined in the CERCLA statute, section 302.4 (USEPA 1998b). "Reportable Quantities" or RQs are based on the intrinsic characteristics of each hazardous substance, such as aquatic toxicity, acute or chronic toxicity, ignitability, raeactivity, and potential carcinogenicity. For each of these characteristics, an RQ value was established by the EPA at one of five levels: 1, 10, 100, 1,000 or 5,000 pounds, and

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[14] See the Environmental Defense "Scorecard" website for information on the derivation and application of TEPs: http://www.scorecard.org/.

[15] See the Indiana Clean Manufacturing Technology Institute (Purdue University) for information on the derivation and application of IRCHS.

[16] The RSEI is currently under development by the EPA's Office of Polluton Prevention and Toxics; of four planned indicators – chronic and acute human health impacts and chronic and acute ecological impacts – at present only the Chronic Human Health Indicator has been completed.

the most stringent RQ (lowest value) became the reporting trigger for that chemical substance. Using the King and Lenox methodology, the toxicity weight for an individual chemical is calculated as the inverse of its reportable quantity.

King and Lenox (2000; 2001) and King and Shaver (2001) applied this methodology to assess aggregate multi-substance toxicity-weighted releases for individual facilities over a multi-year span. The RQ methodology, however, suffers from the same deficit as most of the other toxicity-weighting techniques: RQ values have not been devised for the entire list of TRI chemicals. King and his colleagues sought to overcome this difficulty by limiting their analyses to those 246 hazardous substances that have consistently appeared on the TRI list since its implementation through the present day. Despite this proviso, there were still a significant number of chemicals included in the subset that lacked defined RQ values. With the assistance of a panel of MIT chemical engineering professors, proxy threshold scores were devised for targeted chemical substances where such values were not specified in the CERCLA statute, based on their expert opinion using a comparable assessment methodology.[17] Using proxy RQs combined with statutory RQs in their investigation, King and Lenox (2000) reported that they had compared this measure of toxicity with several other methods, including Purdue's IRCHS, and "found them to be fairly well correlated when looking at aggregate releases."

Although the primary goal of the analyses by King and associates – comparative assessment of environmental performance among industrial firms – is very similar to that of the present investigation, methodological differences required adaptation of their technique. King and Lenox (2000; 2001) and King and Shaver (2001) conducted their

[17] Michael J. Lenox, personal communication, 29 August 2002.

analyses across time, applied only to those core chemicals that have been consistently represented on the TRI list across the period of investigation. This method, while sufficient for their purposes, has the drawback that it does not include the full range of chemical wastes that may have been generated or released by facilities in the study. For example, reported wastes for Facility A may consist entirely of those substances in the core list, whereas reported wastes for Facility B may consist primarily of substances that were added to the TRI list subsequent to the original implementation. If only the core chemical list is used for comparative purposes, as in the King and Lenox and King and Shaver investigations, the significance of waste generation and management for Facility B may be greatly underrepresented. For this reason, toxicity-weighted analysis based on single-year data was chosen as the basis for the present investigation. The temporal element was investigated using a specifically limited set of facilities and chemical substances, the EPA's target list of "Priority Chemicals" described later in this section.

Consistent with the other forms of analysis in this investigation, the year 1999 was chosen as the basis for toxicity-weighted waste comparisons. The defined set of 3,075 TRI facilities for that year were involved in the management of 287 listed TRI chemical waste substances. For these wastes, RQ values established by CERCLA 302.4 comprise 169 or nearly 60 percent of the total number, leaving 118 substances for which no regulatory threshold had been determined. When contacted, Michael Lenox courteously provided the proxy values derived by the MIT panel for King and Lenox (2000), which accounted for 55 additional chemicals. This left a balance of 63 chemical substances lacking either a statutory or derived RQ value. Additional proxy RQ values were assigned by referring to the Environmental Defence organization's Scorecard system,

Table 5.6. RQ value determination method

RQ Value	Statutory	MIT	Scorecard
1	12	1	0
0.1	27	10	3
0.01	66	10	11
0.001	33	7	24
0.0002	31	27	19
Totals	169	55	57

which assigns hazard rankings in percentiles based upon multiple scoring systems.[18] No hazard ranking was available for six of the 63 remaining chemicals, although each was a suspected carcinogen, and these were deleted from the list of wastes. For the 57 chemicals left, an equivalency scale was devised to equate RQ values to Scorecard percentiles; only those Scorecard rankings related to acute toxicity and human health were utilized to assign proxy RQs. Table 5.6 shows the number of chemicals for which each of the three RQ determination methods were used. A detailed breakdown by individual chemicals may be found in Appendix 1.

Adapting the methodology of King and Lenox (2000), where the toxicity weight for an individual chemical is calculated as the inverse of its RQ value, aggregate releases for a given facility are derived by summing the weighted releases reported in the TRI database, and taking its natural log to improve the distribution of the measure.

$$E_i = \ln \sum_{\forall c} w_c e_{ci}$$

[18] http://www.scorecard.org

where E_i is aggregate waste releases for facility i, w_c is the toxicity weight for chemical c, and e_{ci} is the pounds of releases of chemical c. The toxicity-weighted total releases for a facility can then be used in comparative assessments.

5.4.2 Comparative Waste Management Analyses

The objective of the investigation is to evaluate the relative environmental performance in terms of waste management of Japanese industrial transplant facilities compared to non-Japanese facilities in the study area. Since environmental performance can be measured in several different ways, the investigative methodology involves evaluation through a process of steps of increasing sophistication where each level of analysis provides information relevant to the research goal.

Three quantitative waste management metrics were derived from available data: magnitude, management efficiency, and weighted toxicity. Magnitude represents the total RCRA and TRI waste generation and total TRI environmental releases (all media) for each individual facility. Management efficiency is based on TRI releases data only, since RCRA and TRI total waste generation quantities represent waste prior to post-production management strategies such as recycling, treatment or energy recovery, whereas releases to environmental media represent waste that has escaped management. Management efficiency is assessed as per-unit waste generation and releases. Because units such as per-dollar sales revenue or per-item of production are, in the first case difficult to obtain and in the second, not comparable across facilities, parameters related to the scale of operations such as worker numbers or plant areal footage provide units that are both readily obtainable and relevant to management efficiency. Thus waste-per-worker and waste-per-square-foot are used as analogues for management efficiency. The third metric, weighted toxicity, was derived in the manner described in the preceeding section.

Once derived, these metrics were then used to compare firm environmental performance according to ownership nationality (limited to categories of Japanese and non-Japanese) and, to control for differences in production across industries, according to industrial sector using two-digit SIC codes. In addition, reflecting the overall importance of the automobile industry in the study area, specific multi-sector analyses were also made using the standard set of automotive-only codes (see Table 5.5) and also a larger set involving multiple sectors where, on a facility-by-facility basis, automotive components have been identified as a significant market for individual facilities.

Table 5.7 shows the two-digit codes and the multi-code groupings. By analyzing the three metrics of magnitude, management efficiency, and toxicity in their various permutations, different aspects of waste management can be emphasized, as shown in Table 5.8. Magnitude alone, in terms of total waste generation, is indicative of resource utilization effectiveness in the production process inasmuch as waste outputs from manufacturing, regardless of further management strategies, represent underutilized resource inputs and therefore inherent process inefficiencies. Effectiveness is here intentionally distinguished from efficiency, in that the latter can be evaluated aside from all considerations of magnitude. Similarly, magnitude of total waste releases is significant on the basis of effective waste management. Magnitude (of releases), when combined with toxicity weighting, is an indicator of the potential risk to human and ecological health posed by a facility's waste emissions. Efficiency, using scale-dependent parameters such as waste-releases-per-worker or per-facility-square-foot, is

Table 5.7. Standard Industrial Classification codes for sector analysis

Source: Occupational Safety and Health Administration (OSHA)

* Multiple codes across industrial sectors; see Table 9.5 for relevant codes.

** Multiple codes across industrial sectors. Production of vehicles or vehicle components is a significant part of total facility production, determined on a case-by-case basis as described in Section 9.2.2.

SIC Code	Industrial Sector
20	Food and kindred products
21	Tobacco products
22	Textile mill products
23	Apparel and other finished products made from fabrics and similar materials
24	Lumber and wood products except furniture
25	Furniture and fixtures
26	Paper and allied products
27	Printing, publishing and allied industries
28	Chemicals and allied products
29	Petroleum refining and related industries
30	Rubber and misc. plastics products
31	Leather and leather products
32	Stone, clay, glass and concrete products
33	Primary metal industries
34	Fabricated metal products except machinery and transportation equipment
35	Industrial and commercial machinery and computer equipment
36	Electronic and other electrical equipment and components, except computer equipment
37	Transportation equipment
38	Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
39	Miscellaneous manufacturing industries
*	Standard vehicular transportation industries
**	All or significant part is related to vehicular transportation

reflective of the overall performance of the facility in regard to both production processes and post-production waste management strategies, and thus comprises one form of eco-efficiency indicator. When combined with weighted toxicity, this becomes a still more significant indicator of performance effectiveness, where low per-unit waste releases and low toxicity represent a relatively modest environmental “footprint. The ratio derived as toxicity per worker or areal size may serve as an indicator for eco-effectiveness comparisons.

Table 5.8. Waste assessment metrics

Metric	Waste Gen.	Waste Rel.	Nation ality	Sector	Assesses
Magnitude	X	X	X	X	Resource utilization effectiveness
Magnitude Toxicity		X	X	X	Ecological risk or hazard
Efficiency		X	X	X	Management efficiency Ecological efficiency
Efficiency Toxicity		X	X	X	Management efficiency Weighted ecological efficiency (effectiveness)

Analysis of waste management trends across time is problematic because of data inconsistencies previously noted; consequently 1999 was chosen as the base year for facility comparisons. The temporal dimension is, however, significant to evaluating environmental performance. This can only be accomplished for TRI data by controlling for the chemicals used in analysis. Since the number of regulated chemicals has varied across time, affected most significantly by the addition of 286 substances in 1994, trends can only be assessed if the waste analysis is conducted for a set of chemicals that has remained consistent across the period of analysis. This was the rationale supporting the investigations of King and Lenox (2000; 2001) and King and Shaver (2001). Whereas these researchers performed their analyses on the basis of all TRI chemicals in consistent use through 1996, the present investigation limits analysis to a select group of seventeen TRI "Priority Toxic Chemicals" targeted by the EPA for a program of voluntary emission reductions. A list of these chemicals and their characteristics is presented in Appendix 2.

This strategy, initiated in 1991, was known as the 33/50 program for its goals of a 33 percent reduction in releases and transfers of the priority chemicals by 1992 and a 50 percent reduction by 1995, measured against a 1988 baseline. This was the first of the EPA's voluntary programs, "intended to demonstrate whether voluntary partnerships could augment the Agency's traditional command-and-control approach by bringing about targeted reductions more quickly than would regulations alone," and also "sought to foster a pollution prevention ethic…" (USEPA 1999, 1). During the program's official lifespan, from 1991-1995, approximately 1,300 companies or 13 percent of those reporting releases of targeted chemicals, made voluntary commitments towards reduction. The program is considered a success, in that a 50 percent reduction for total releases for all companies, participating officially or not, was reached a year ahead of schedule. According to EPA data, participating companies achieved the greatest reductions, but significant reductions were also made by non-participants (*Ibid*.). Accordingly, comparing firm performance using the set of seventeen priority chemicals appears to be an appropriate means to assess differences based on nationality and industrial sector across time. The present investigation does not limit the period of analysis to the 33/50 program lifespan but concerns itself with the period from 1988 to 1999.

The final phase of waste data analysis moves beyond the descriptive statistics employed in the multi-step analysis to examine statistical significance of environmental performance using an ordinary least-squares regression, based on the 1999 TRI data set. The relative environmenal performance of a facility is indicated by the standardized residual, or deviation, between observed and predicted emissions according to facility size and industrial sector.

5.5. The Mail Survey of Japanese Firms

A survey instrument was devised to solicit firm-level information concerning production operations, environmental management, and perceptions about pollution prevention at Japanese transplant firms. The instrument was mailed out to 520 Japanese-owned industrial facilities in the study area. Appendix 3 contains a copy of the survey instrument.

Information collected concerning production operations included: employment, facility size, description of products manufactured, product end use, parts outsourcing, production operations and management style, and production operations and management techniques used. "Product end use" was designed to learn connectivity to the automotive industry, using percentage categories. "Parts outsourcing" concerning the percentage of product parts obtained from other manufacturers. "Production operations and management style" asked whether the facility operations were primarily influenced by Japanese or traditional Western manufacturing methods. The survey instrument here defined Japanese Management Systems as "derived from or influenced by the Toyota Production System," and referred to the following section for examples of such methods. Traditional Western manufacturing, or Fordism, was defined on the instrument as "using mechanized technology to facilitate high-volume standardized output in long production runs, Fordism embodies a work design using unskilled and semiskilled workers performing routinized simple tasks to produce standardized products" (Taplin 1996). "Production operations and management techniques" provided a list of techniques and technologies that, from a review of the literature, appeared most often associated with Japanese production systems. These techniques and technologies included: Just-in-time, kaizen, TQC or TQM, quality circles or other small-group activities, kanban card system, pokayoke, robotics, flexible manufacturing systems, and computer-integrated manufacturing (CIM) systems. A brief definition was provided for each of these on the instrument, and the respondent was asked to indicate from a list of categories, for each technique or technology, the degree of implementation in the facility.

The primary section concerning environmental management methods and systems included queries about environmental policies, certification in ISO 14001, resposibility for environmental decision-making, and number and duties of environmental personnel. Additional sections asked the respondent to rank significance of general waste classes (airborne, wastewater, nonhazardous solid waste, hazardous waste) as components of waste generation at the facility; and to estimate waste percentages handled through specific waste management methods. The list of methods provided coincided with the reporting categories associated with the TRI program, and was intended for cross-comparison with reported quantities and to provide waste management information concerning facilities that did not generate sufficient waste to qualify for TRI regulation. Finally, under the category of environmental management, a large blank box was provided and the respondent asked to describe one or more "success stories," examples of "successful implementation of a strategy, system, process change or technology to reduce the environmental impact of this facility."

The last category on the instrument, attitudes concerning pollution prevention, consisted of two sections in which the respondent was asked to rank choices. The first of these sections, concerning “Resource conservation and pollution prevention,” provided a list of strategies with a brief description of each: process management, materials substitution, dematerialization, internal recycling or reuse, and proactive energy efficiency. The respondent was asked to indicate effectiveness of each of these strategies at the facility, if applicable. The second section asked the respondent to evaluate “Driving factors for waste reduction or better waste management” in terms of impact on company policies and practices: cost of pollution control technology, public opinion, compliance with state and federal regulations, and need to maximize economic efficiency.

The cover letter stated the purpose of the investigation and noted that the information collected would be used only for statistical analyses, without identifying either the respondent or the facility.

5.6. Case Studies of Individual Facilities

The use of case studies, involving site visitation and interviews with key environmental personnel, was intended to address the anticipated lack of specifics provided through the mail survey.   Corporate willingness to provide access to facilities and personnel in a study of this nature is often limited by a certain reticence to discuss environmental issues with outsiders, and secretiveness concerning proprietary technological or process information - trade secrets - due to a perceived threat of industrial espionage.

Despite access difficulties, which proved to be more characteristic of vehicle assembly plants than suppliers, the pilot study (O’Dell 2001) demonstrated that a personal visit can be productive. In both the pilot and present investigation, once arrangements had been made for site visitation, environmental staff were willing to discuss and demonstrate, in cases of their choice, specific measures taken to reduce resource consumption and waste production. In some instances, entry into particularly sensitive areas was not allowed, and in nearly every case, interior photography was prohibited. Despite these limitations, considerable information was obtained concerning innovations in waste reduction and management. Facilities were not selected randomly from the list of Japanese transplants in the study area; potential contacts were limited to facilities that are currently or were formerly regulated under the TRI program, so that a quantitative dimension could be added to the case studies through the analysis of waste data for each facility. Arrangements were made for case studies to be conducted for five separate facilities. The facilities were chosen for contact on the following basis: (1) at least one vehicle assembly plant, representing both destination for numerous suppliers and among the region's largest firms; (2) the majority of the facilities to be derived from sectors involved in automotive supply chains, given the importance of the transportation industry in the study area; and (3) at least one facility not involved in an automobile-related industry.

Requests for case study permission and arrangements were conducted by initially by telephone, with subsequent contacts often involving exchanges of email or faxes. The project was described verbally, and for each contact, a written proposal and copy of the case studies published in the pilot investigation was sent to the contact, even when permission had been granted immediately. The decision-making process by firms when contacted with a request for a plant visit and interviews with employees proved to be significantly different between the large assembly plants and their suppliers. For the suppliers, in every case the decision to allow the case study was either made immediately by middle-management personnel or with only a few days consideration. In contrast, the decision process at the vehicle assembly plants often involved months of deliberation as the request circulated upward through the management ranks, and, in case after case, ultimately rejected.

The first vehicle assembly plant contacted was the Ford truck plant in Louisville, Kentucky, which although not a Japanese transplant, had adopted many Japanese production methods and would provide an interesting comparison. Permission was refused on the grounds that the plant was closed to all visitors until further notice as a security measure in consequence of the 11 September 2001 terrorist attacks. This was the only facility that expressed such a concern. The Nissan plant in Smyrna, Tennessee, was next contacted, and the request forwarded to the Corporate Communications Committee. A response was received within a few days: "I am sorry to have to tell you that Nissan - Smyrna does not participate in graduate student projects due to limited resources at this point in time. Currently we are operating under a very aggressive schedule to build a new manufacturing facility in Mississippi and expand our current operation in Decherd, TN."[19] Subsequently, Honda of Ohio was contacted, and after some months of deliberatation indicated that their plants would be closed for the next twelve months as a consequence of retooling for a new model introduction. Similarly, a request to the Toyota truck and SUV plant in Indiana was ultimately rejected due to plant expansion operations. After contacting the Subaru-Isuzu joint venture in Indiana, several months passed without resolution. As the deadline for completion of the project drew nearer, the

[19] Sloan LeMauns to Gary O'Dell, email communication 20 December 2001.

decision was made to contact Toyota of Georgetown, Kentucky, even though this facility had served previously as a case study in the pilot project. Permission was readily granted by Toyota.

The five facilities for which case studies were conducted are:

1. Toyota Motor Manufacturing Kentucky. Georgetown, KY.
   Automobile assembly

2. Calsonic Yorozu. Morrison, TN.
   Metal stamping of automotive parts.
3. Madison Precision Products. Madison, IN.
   Aluminum casting of automotive parts.

4. Mitsubishi Electric Automotive America. Mason, OH.
   Automobile starters and alternators.

5. Link-Belt Construction Equipment Company. Lexington, KY.
   Heavy construction equipment.

The case studies for these facilities are based upon plant visitations, interviews with environmental staff, company public brochures and internal reports, and data from RCRA and TRI. Although specific problems vary from facility to facility since different industries have different technologies and generate waste in different ways, the firms are linked by common themes and concerns. Among these are the need to meet regulatory standards and reporting requirements and to maximize production efficiency through waste reduction.

Chapter Six

Foreign Investment in the Study Area: A Perspective

6.1. Defining the area of investigation: Japanese transplants in the eastern corridor

The area of investigation consists of four states - Indiana, Kentucky, Ohio and Tennessee – and their associated manufacturing populations, both domestic and foreign (Figure 6.1). According to Shannon, Zeile and Johnson (1999), the corridor extending from Indiana to northern Georgia represents the densest concentration of Japanese industrial investment east of the Mississippi River in North America (Figure 6.2).[1] Although by no means uniform, the Japanese transplant facilities along this Midwest corridor are generally associated with the automobile industry, consisting of vehicle

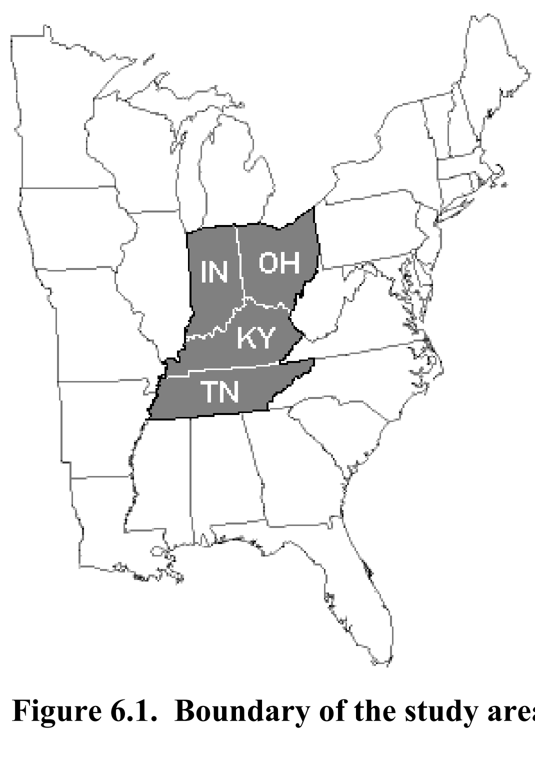

Figure 6.1. Boundary of the study area.

[1] Activity of foreign-owned manufacturing establishments in the United States is measured by employment reported in the 1992 Economic Census (Shannon *et. al*. 1999).

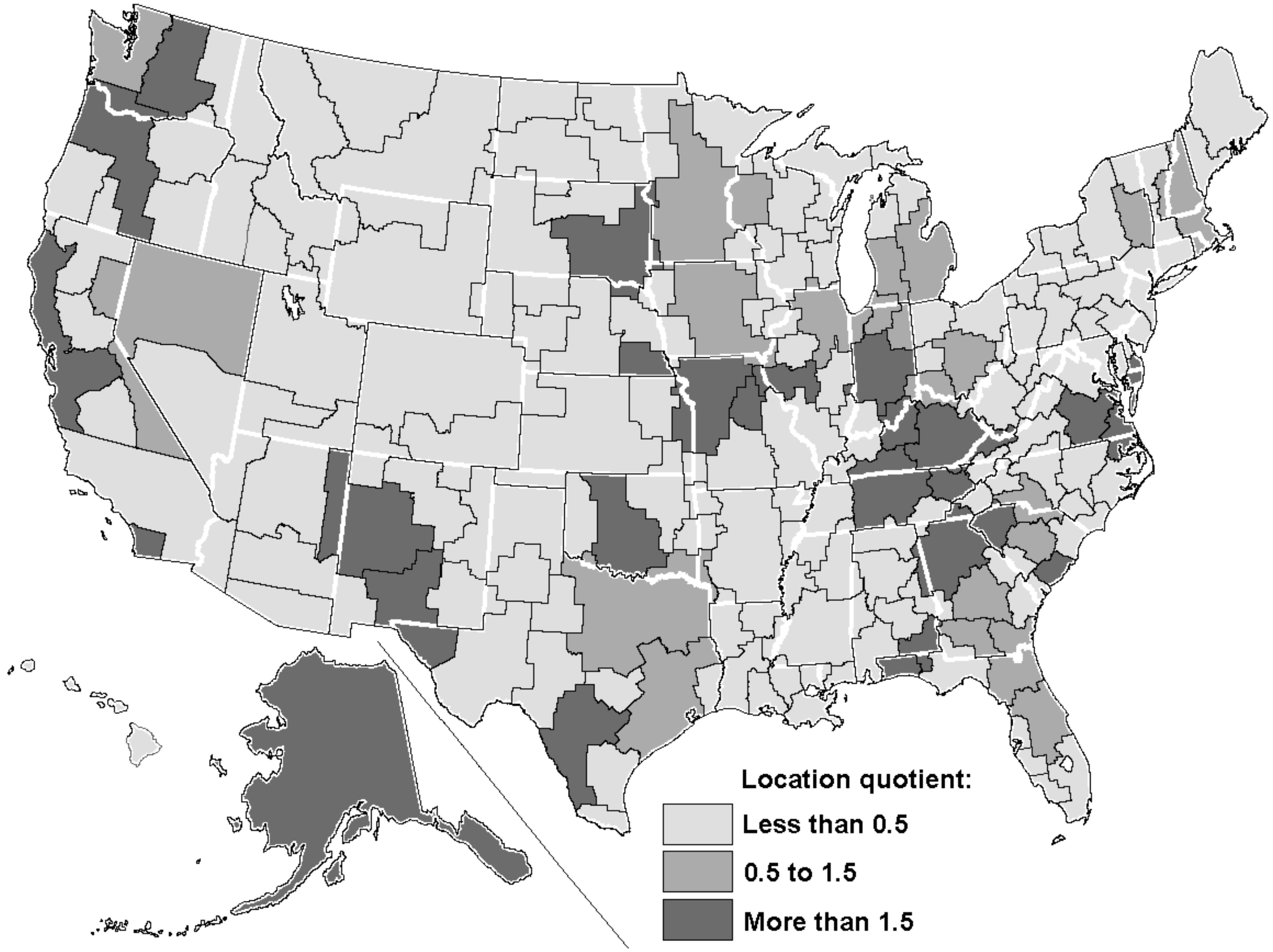

Figure 6.2. Japanese greenfield manufacturing establishments, relative concentration of employment by economic area

Adapted from Shannon, Zeile and Johnson 1999. Economic boundaries defined by U.S. Bureau for Economic Analysis. The location quotient for an economic area is calculated as Japanese-owned establishment's share of employment in the area's greenfield manufacturing establishments divided by Japanese-owned establishment's share of employment in U.S. greenfield manufacturing establishments.

assembly plants and their supplier networks. This contrasts with the character of Japanese transplants along the West Coast of the United States, where a substantial total investment is focused primarily in the electronics industries (*Ibid*.,24).

Within the eastern corridor area of concentration identified by Shannon, the states of Indiana, Kentucky, Tennessee and Georgia have a proportionately greater share of employment in greenfield manufacturing establishments. For the present investigation, however, the state of Ohio was included as part of the study area, despite a relatively lower concentration of employment in Japanese firms, rather than Georgia. This decision was made on a threefold basis:

(1) Ohio is ranked second in the nation, after California, in its percentage of both total manufacturing firms and total manufacturing employment, whereas Georgia is ranked eleventh (Harris 2002c). Although Japanese firms are a lower percentage of total manufacturing firms in Ohio than in Georgia, the actual number of Japanese manufacturers in Ohio is equal to that of Kentucky and Tennessee combined.

(2) A number of writers, including Rubenstein (1997), Klier (1999), Coughlin and Segev (2000) and others have noted a drift of manufacturing toward the southeast, a trend most pronounced for foreign-owned greenfield plants. The combination of Indiana and Ohio represents a segment of the traditional northern “rust-belt” industrial area of the United States, providing a distinct region which may be contrasted against Kentucky and Tennessee, representing the southeastern region.

(3) The inclusion of Ohio, rather than Georgia, produces a study area that is more compact and accessible.

Within the context of the defined study area, this chapter will investigate the nature of Japanese direct investment in the United States (JDIUS). Focus will be upon changes in the structure and composition of industry in the region; push-pull factors operating to attract Japanese investment; the spatial pattern of Japanese firms; and the characteristics of Japanese facilities in terms of industry structure and operating scale.

6.2. Manufacturing Profile of the Study Area

Each of the four states in the study area constitutes an important regional concentration of manufacturing industries for the United States. Ohio, Indiana, Tennessee and Kentucky respectively rank second, tenth, seventeenth and twenty-seventh nationally in the total number of manufacturing firms, together accounting for more than ten percent of all U.S. industrial firms and nearly twelve percent of such employment. In each of these states, manufacturing is a mainstay of the economy, accounting for about 20 percent of total employment (Harris 2002a,b,c,d). For descriptive and analytical purposes, Indiana and Ohio can be considered together as representing a distinct manufacturing region, the Midwest, separate from Kentucky and Tennessee which together represent the Southeast. The differences between these two regions are not so much in the present-day general structure of the manufacturing industries but in the historic factors that encouraged the development of industrialization and the time frame during which this took place, and in the modern factors promoting agglomeration and geographic redistribution.

Collectively, Indiana and Ohio are located at the core of the old industrial heartland (the Midwest) where traditional heavy industries still retain importance in the economy. Intensive industrialization of the entire Great Lakes region can be traced back to the beginnings of the American Industrial Revolution in the mid-nineteenth century. The development of a manufacturing economy here was fostered by proximity to major population and industrial centers such as Chicago, Detroit, and Pittsburgh and by a network of multiple modes of transportation. Rapid proliferation of canals, railroads and highways complemented the natural waterways of the Great Lakes and the Ohio River, along which raw materials and finished goods could be shipped in bulk.

Prior to the 1940s, Kentucky and Tennessee were primarily agricultural economies. Industrialization in these Southeastern states was a much later occurrence than in the Midwest and, initially, a consequence of the development of natural resources rather than proximity to transportation routes and urban centers. The natural resources with which this region was so abundantly blessed were not raw materials to be converted into goods but instead furnished the power to accomplish this transformation: coal and water. Industrial development in both states was stimulated by cheap electrical power. Tennessee, Kentucky, and several other states were provided with an immense power grid constructed by the Tennessee Valley Authority (TVA) during the 1930s and 1940s, based upon construction of dams along the Tennessee River and its tributaries. To meet increasing demand in the 1950s, TVA began constructing coal-fired generating plants, purchasing huge quantities of Kentucky coal. TVA early adopted a policy of extending the lowest rates to the largest users, thereby chiefly benefiting municipal and industrial consumers (Whisnant 1994, 43-64). Manufacturing industries were further encouraged in the region by the low worker wages and low unionization of the Southeast (Harris 2002b,d).

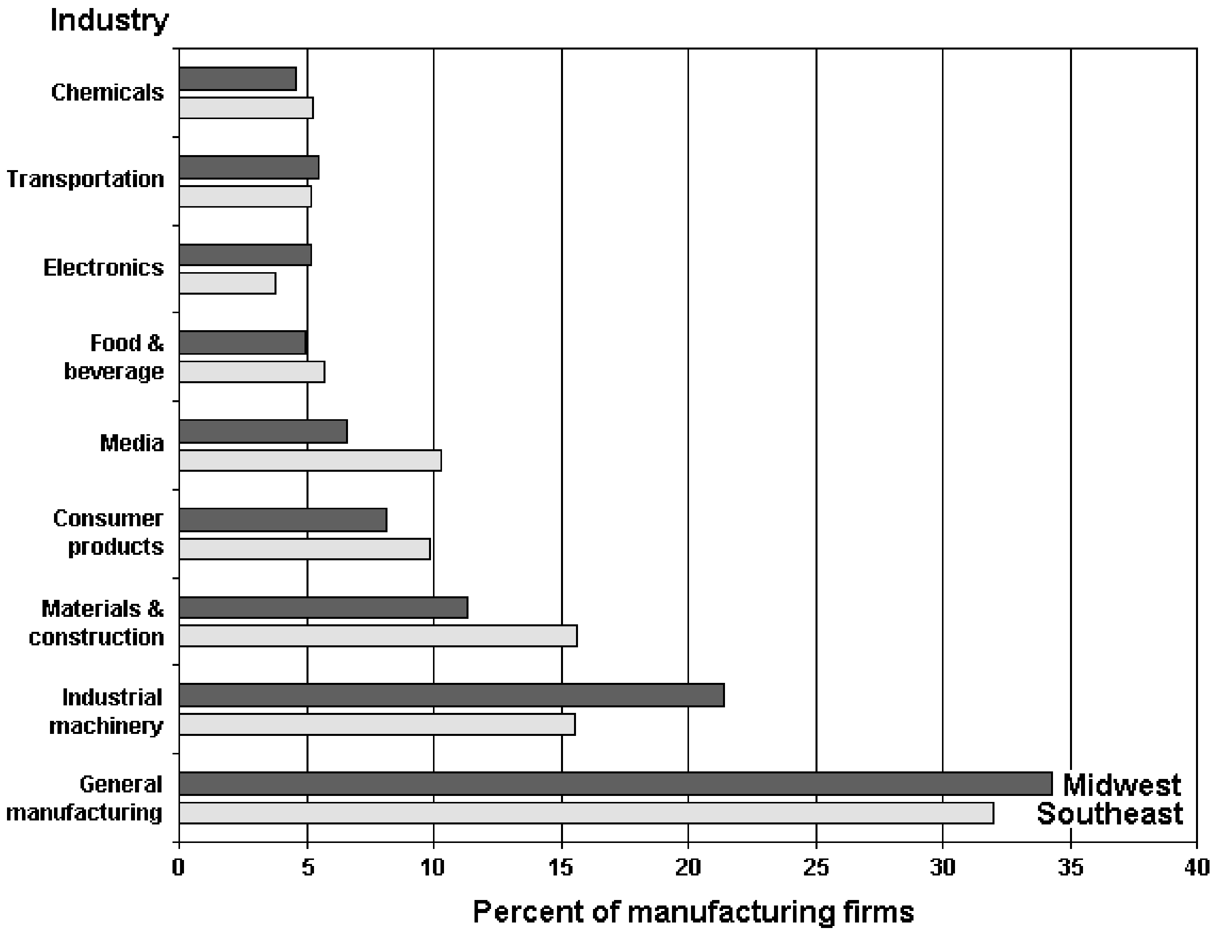

Figure 6.3. Comparative industrial structure of study area regions
Source: Harris (2002a,b,c,d)

Figure 6.3 compares the distribution of industry, based on numbers of firms, in the nine most significant industrial categories for these regions, with Indiana and Ohio representing the Midwest and Kentucky and Tennessee representing the Southeast. The categories used are equivalent to those employed by the Harris manufacturing reports for individual states, which served as the data sources for this comparison (Harris 2002a,b,c,d). In both regions, the largest firm numbers are concentrated in the general manufacturing,[2] industrial machinery, and the materials and construction[3] categories.

[2] "General manufacturing" comprises a wide variety of industries, including textile manufacturers (SIC22), packaging and containers (SIC 26), rubber and plastics (SIC 30) and metal fabrication (SIC 34).
[3] "Construction and materials" are manufactured products goods related to building and construction, ranging from concrete and lumber goods to materials used in the construction of manufactured buildings.

The relatively low proportion of firms in transportation equipment[4] belies the importance of this segment to the regional economies, for despite comprising only about 5 percent of firms in the two regions, transportation equipment accounts for more than 25 percent of total manufacturing sales in Ohio, Indiana and Kentucky and more than 12 percent in Tennessee (Harris 2002a, 2002b, 2002c, 2002d). The two Midwest states exceed the Southeastern states in the categories of general manufacturing, industrial machinery, and electronics; conversely, the Southeast leads the Midwest in the materials and construction, food and beverage, media,[5] and chemicals categories.

Table 6.1 compares the distribution of industry in the two regions, the Midwest represented by Ohio and Indiana and the Southeast represented by Tennessee and Kentucky, relative to the structure of industry in the United States as a whole. The Firm Coefficient (FC) is defined as the share of firms in an industrial category divided by that

Table 6.1. Firms by major industry categories: Study area regions compared to U.S.
Source: Harris (2002a,b,c,d)

Category	Midwest FC	Southeast FC
Industrial machinery	1.437	1.047
General manufacturing	1.206	1.127
Transportation equipment	1.183	1.117
Chemicals	1.170	1.329
Materials & construction	1.040	1.436
Electronics	0.935	0.681
Food & beverage	0.866	1.002
Media	0.858	1.335
Consumer products	0.824	0.995

[4] "Transportation equipment" consists of firms engaged in the manufacture of automobiles and trucks and components and also other transportation industries such as rail and shipbuilding.
[5] "Media" industries are involved in printing and publishing of newspapers, books, magazines and music.

industry's share of firms in the nation as a whole. At unity, the firm coefficient shows that the regional distribution of firms in an industry exactly matches the national average. Above unity, the regional distribution of firms in an industry is greater than the national average. The Midwest region contains a greater proportion of firms within the categories of industrial machinery, general manufacturing, transportation equipment and chemicals than the U.S. as a whole, substantially so for industrial machinery. The Southeast greatly exceeds the nation in the categories of materials and construction, media and chemicals. The Midwest lags the national average in consumer products, media, and in food and beverage industries, and both regions are slightly less than the national average in electronics manufacturing firms.

Over time, the geography of production in the United States has undergone a process of restructuring and redistribution.   Many factors are involved in such transformations, as suggested by the growth of manufacturing industries in the Southeastern states of Tennessee and Kentucky described earlier. One of the most basic and compelling of the forces guiding regional development is that of economic rationalization, described by Swonk (1996) as the substitution rule: One thing will eventually replace another if it is cheaper and does the job better. Swonk notes: "In the context of regional growth, it translates to competition, both domestically and abroad, for investment. Investors tend to shift their assets to regions where they believe the returns on their assets are greatest, and leave regions where they are the least" (p. 16). Shifting perspective, the factor endowment (Heckscher-Ohlin) theory predicts that regions will become more specialized in order to exploit their competitive advantages. Evaluating this model in terms of the rise and decline of manufacturing in the Midwest, Kim (1996) concludes that the Heckscher-Ohlin theory provides the best explanation for developments in this region.

According to this model, the Midwestern region experienced an initial comparative advantage based on ready access, through a well-developed transportation network, to coal, oil and ore, resulting in a manufacturing economy premised on heavy industries. Across the United States, from the mid-nineteenth to mid-twentieth centuries, regions became more specialized in various industries. From the mid-twentieth century onward, regions began to despecialize with all regions moving toward a more balanced manufacturing structure. This transition, according to Kim (1996), resulted from decreased energy and material intensity and from increased mobility of resources. Just prior to the beginning of the twentieth century, firms adopted large-scale production methods that were intensive in relatively immobile resources and energy sources, which in turn favored regional specialization. During the twentieth century, technological innovation reduced the material and energy intensity of production and greatly enhanced transportation connectivity caused production factors (petroleum, electricity, raw materials, etc.) to become geographically mobile. The decline of material and energy intensity and increasing mobility of production factors removed the comparative advantage experienced by the Midwest, leading to the decline of this region as a center for manufacturing.

The bleeding of industry away from the Midwest – in fact, from the entire northern "rustbelt" region – was also promoted by other factors, including the process of population deconcentration within the continental United States, a concentration of Midwest manufacturing in capital goods and consumer durables vulnerable to falling demand during recession, and aging facilities far less efficient than those in other regions and abroad. The manufacturing losses of the entire Midwest (Illinois, Indiana, Michigan, Ohio, Wisconsin), are reflected in a share of national manufacturing that fell from 30 percent in 1947 to 22.1 percent by 1987 (Testa, Klier and Matoon 1996). As Kim (1996) notes, however, redistribution of industry promotes increased efficiency of the system as a whole, for losses in one area tend to be offset by gains elsewhere. During the period when the Midwest was experiencing shuttered factories, the South increased its share of manufacturing industries. Testa, Klier and Matoon (1996,12) observed, "To some extent, it was inevitable and desirable that the Southeast develop manufacturing industries as its work force was released from agriculture, as air conditioning and highway transportation opened up previously isolated areas and transitory Midwest advantages of natural resources and transportation were depleted and made obsolete."

During the mid-to-late 1980s through the present time, the Midwest region began to experience a revival in manufacturing even as the Southeast continued its growth in manufacturing. The Midwest's improved circumstances are in part because the convergence of regional manufacturing structure in the United States is nearly complete; although the damage has been done, "the Midwest economy no longer looks very different from the rest of the United States….The Midwest is…unlikely to face further significant decline relative to other regions" (Kim 1996,13).

Driving the change, in part, for the Midwest has been a reconcentration of automobile assembly plants and their associated supplier plants in this region (Rubenstein 1997; Klier 1999; Testa, Klier and Matoon 1996). In the Southeast, a still-increasing share of manufacturing has been largely driven by foreign investment, focused primarily but not exclusively in the automotive industries (Shannon, Zeile and Johnson 1999; Couglin and Segev 1998; Rubenstein 1997; Klier 1999; Reid 2002).

6.3 International push-pull factors prompting Japanese investment

Although the first foreign automotive facility in North America was the relatively small-scale Nissan engine and assembly plant built in Mexico in 1966, the debut of a trend of significant Japanese investment in the United States dates to the 1982 construction of the large Honda plant in Marysville, Ohio (Womack 1990). The developing pattern of Japanese transplants owes its origin to the changes in the global economy in the 1960s and 1970s, as the United States economy declined while that of the Japanese flourished. The U.S. balance of trade showed a deficit for the first time in 1980, and in the years to follow the U.S. position changed from that of the largest creditor nation to that of the largest debtor. Various push-pull factors operated in both countries to stimulate what has been called a Japanese "investment binge" by Arthur J. Alexander (1997).[6]

Perrucci (1994) described the structural changes in the United States economy that, beginning in the 1970s, created an environment here that would encourage a dramatic increase in direct foreign investments over succeeding decades. During this period, U.S. corporate profits declined from a combination of factors, including increased labor costs, increased competition within industries and from imports, and the costs of complying with a large number of regulations imposed upon business. The response was a disinvestment and capital flight as industries downsized or shifted operations to different

[6] Arthur J. Anderson served as president of the Washington, D.C.-based Japan Economic Institute from 1990 to 2001. JEI, founded in 1957, ceased its activities early in 2001 due to reduced funding from the Japanese government.

locations within the United States or overseas. The result was a massive job loss in the industrial sector and a decreasing union presence nationwide; although an increase in service sector employment absorbed much of the loss from industry, average weekly wages were significantly lower than those in manufacturing jobs.

A further complication was a mounting trade surplus; foreign imports were relatively insignificant during the 1960s but, by 1980, represented 22 percent of goods purchased. A Reagan administration economic policy designed to deal with the trade deficit, allowing the value of the dollar to decline against international currency and thus make U.S. goods less expensive and foreign products more so, instead had wholly unforeseen consequences. As Perrucci notes, “What was not anticipated was that foreigners would take the abundance of dollars they had been accumulating from trade surpluses and buy American real estate and companies” (p. 26).

The changes in the United States economic structure that resulted in plant closings and increased unemployment led to decreased tax revenues at the state and national levels in the early 1980s. At the same time, increased military spending and tax cuts for upper-income Americans resulted in federal budget deficits and, in consequence, greatly reduced federal assistance to states. State governments were being required to take on more responsibility for the welfare of their citizens, with far fewer sources of revenue as a result of deindustrialization, recession, and cuts in federal funding. State governments were thereby forced into the role of actively seeking ways to stimulate new revenues and economic development within their boundaries.

Across the Pacific, the Japanese economy was in a state of artificial hyperstimulation, a “bubble” economy characterized by a rapid rise in asset prices, the overheating of economic activity, and a sizeable increase in money supply and credit (Okina, Shirakawa and Shiratsuka 2001). A centralized economy had been created as part of wartime mobilization prior to 1940, which, with American cooperation after the war, was further entrenched and strengthened. The postwar Japanese government established protectionist policies and a bottomless well of free-flowing cash available to favored industries, leading to an economic growth rate during the period 1950-1973 far in excess of that ever experienced by a national economy before or since. Although the growth rate slowed after 1973, it remained well above that of the United States and other developed nations. The amazing growth rate, coupled with inexpensive capital, encouraged a high rate of investment at home and abroad, often in risky ventures with little attention to rates of return or to profitability (Overholt, 2002). One of the primary factors prompting overinvestment, according to Alexander (2002), was a pledge by the Ministry of Finance that no bank would be allowed to fail.

With money readily available and the yen appreciating in value in consequence of U.S. fiscal policy, the Japanese stock market exploded, tripling in value between 1985-1990 (Alexander 1997). Corporations all but ceased borrowing from banks, able to raise money at little or no interest by granting stock options. Overholt noted, "The banks, desperate for business, poured money into mortgages, creating the greatest real-estate bubble in history. The land under the emperor's Tokyo palace came to be valued at the same price as all of California" (p. 137). With home country real estate priced out of reach, and low rates of return on domestic investments, many Japanese companies fat with surplus cash turned to foreign investment.

The Japanese had little initial interest to build automobile assembly plants in America, but were stimulated to do so by protectionist political pressures from the U.S. to resolve the trade imbalance and avert a potential trade war. The strength of the yen relative to the dollar and the large size of the U.S. market provided additional motivations (Banerji and Sambharya 1996). As soon as Japan began investment in facilities in the U.S., other advantages encouraged the trend. Production of vehicles in America allowed many tariff and non-tariff barriers to be bypassed and reduced the risks associated with trade regulations and currency exchange fluctuations. Furthermore, state and local governments began to court Japanese transplants with generous incentive packages that would aid in reducing start-up and operating costs (Bosman 1995; Perrucci 1994).

The massive outpouring of Japanese direct investment into the United States was a product of the Japanese economic bubble. The collapse of this asset bubble in 1990, plunging the Japanese economy into recession, dramatically impacted Japanese investment in the U.S. From $2.4 billion in manufacturing investment in 1991, Japanese cash inflows dropped to less than $500 million in 1992 and to $160 million in 1993.[7] Coinciding with a recession in the United States, all foreign investment plummeted, bottoming in 1992 before resuming in a new rush of FDI – except for Japan: “The recovery of Japanese direct investment outlays appeared weak in comparison to inflows from other countries” (Alexander 1997,4). Japan’s economic recovery was delayed, and remains in stagnation even today. The collapse of asset prices and the overextended banking system led to a credit crunch, shifting from a regime that encouraged extravagant lending and investment to one far more conservative. MacKnight (1996) also notes that

[7] Data from U.S. Department of Commerce, Bureau of Economic Analysis electronic data file: "FDIUS: Balance of payments and direct investment position estimates, 1987-1999"

the downturn in Japanese investment after 1991 may also be, in part, a result of the reaching of some "critical mass" by Japanese manufacturers in this country, whereby supplier networks have been all but completed for the most important industries.

Japanese manufacturing investment in the United States remained depressed until 1996, when it surged suddenly upward to a magnitude greater than had ever been experienced before, more than $9.5 billion. The reduced ability of Japanese banks to expand credit, coupled with a continued low rate of return for domestic investments, prompted Japanese industries, particularly those of large to medium scale, to invest abroad to avoid the domestic recession (Basu and Miroshank 2000). This upturn did not last long, however, for by 2000 Japanese capital flows fell into negative numbers as corporations began disinvesting in the United States. The nature of Japanese manufacturing investment also changed. From 1988-1990, one-third to one-half of all transactions were in the form of acquisitions of existing firms; in 1995, less than one-fourth of Japanese investment was for acquisitions (MacKnight 1996).

Figure 6.4 presents a dramatic visual profile of Japanese manufacturing investment in the United States that clearly demonstrates the relationship of investment to economic conditions in Japan. In summary, Japanese direct investment in manufacturing in the United States was prompted by specific and complementary circumstances in each country. In the United States, deindustrialization and associated revenue losses by state and local governments fostered a climate highly receptive to foreign investment, and weak asset prices and U.S. fiscal policies helped provide Japanese corporations with the wherewithal to finance such investment. In Japan, the availability of inexpensive capital, an attitude of reckless risk-taking, low domestic rates of return, a yen appreciating against

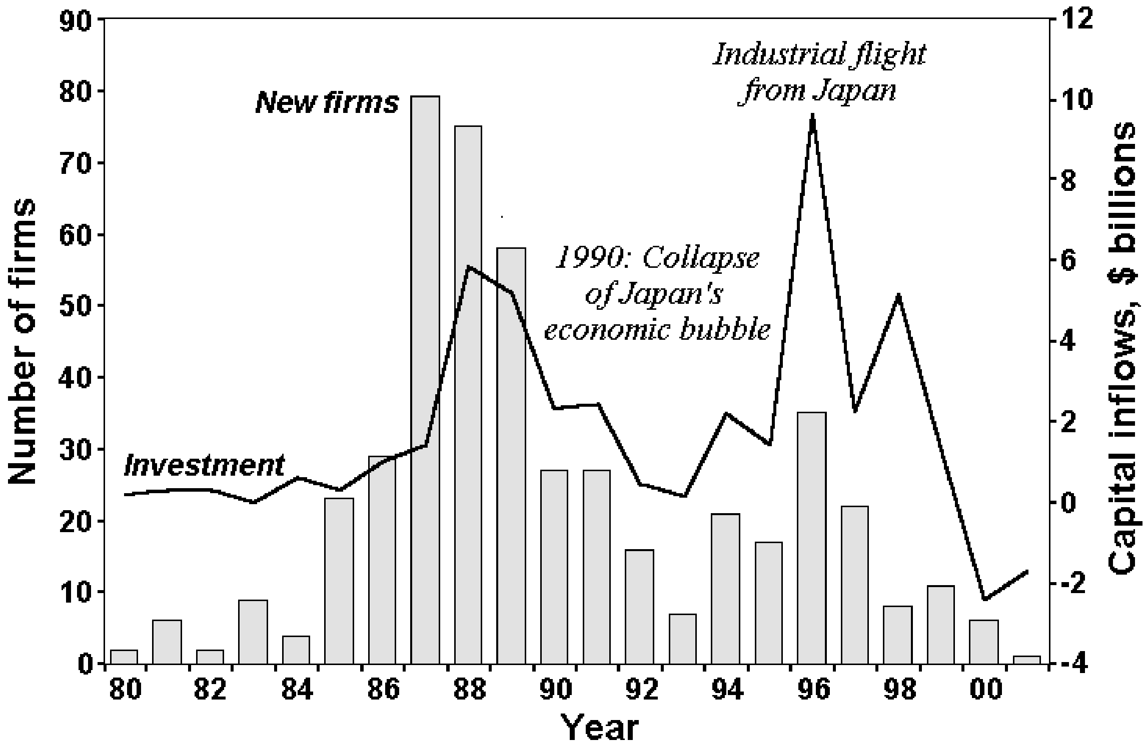

Figure 6.4. Newly established Japanese manufacturing transplants per year in study area compared to Japanese capital investment inflows in U.S. manufacturing.
Sources: Bureau of Economic Analysis and author's database. Includes greenfield plants and acquisitions.

the dollar, and the desire to avoid trade restrictions and transportation costs for imports fostered a rapidly expanding foreign investment in the U.S. until the collapse of the Japanese bubble economy. Today, although Japanese investment has dwindled to a trickle, Japan still remains as the second most significant investor, after the United Kingdom, in American industry.

6.4. Patterns of Japanese manufacturing investment in the United States

Most of the Japanese direct investment in the United States has taken the form of automotive-related manufacturing firms, and consequently most of the academic studies of the geography of JDIUS has focused upon the automotive industry. From a review of the literature on Japanese direct investment in the United States, several important common themes emerge: (1) The locational pattern of Japanese direct investment differs from that of domestic manufacturers and other foreign investors, and is concentrated in a band along the Pacific coast and along a corridor extending from Indiana through northern Georgia. The eastern concentration of Japanese investment is defined by proximity to the north-south corridor traversed by Interstates I-65 and I-75. (2) Agglomeration economies and labor force issues appear to be the most significant influences upon location choice and hence the spatial distribution of Japanese manufacturing firms. Specific factors within this context include pre-existing Japanese investment in a region, the presence of assembly plants, the demands of just-in-time supply schedules, nearness to interstate highways, and the extent of unionization.

6.4.1. Locational variations among foreign and domestic manufacturers

Shaver (1998), investigating the spatial distribution of foreign manufacturing firms to domestic firms for the year 1987, concluded that foreign firms favored coastal locations (the so-called "border effect") more than their U.S.-owned counterparts. This was attributed to a greater dependency by foreign firms upon imports and a consequent desire to minimize transport costs. Shaver's analysis concerned with foreign investment as a whole and did not consider differences among investors of different national origins. In contrast, the geographic analysis of foreign investment by Shannon, Zeile and Johnson (1999) indicates distinct differences among major foreign investors in the United States. According to Shannon and his colleagues, the overall geographic pattern for all foreign investment is similar to that displayed by U.S.-owned establishments, being mainly concentrated in areas with large populations. Canada, France, Germany, the United Kingdom, and Japan have been the leading nations in foreign investment in the United

States. There is, however, a considerable difference among countries in the locational patterns of their investments. A tendency for area clustering is exhibited by Japanese, Canadian, and German establishments, but far less so for French and British firms.

Doeringer and Terkla (1992) compared the pattern of plant locations for domestic manufacturers and Japanese transplant facilities and concluded that two distinct patterns were present. Basing their analysis upon growth rate residuals in which states were classified as high, low or average for a specific industry, they determined that the majority of Japanese firms did not locate in states that appeared to offer the greatest attractions to counterpart domestic firms. In only four industry categories – chemicals (SIC 28), plastics (SIC 30), primary metals (SIC 33) and electrical equipment (SIC 36) did Japanese plant locations correspond closely with domestic plant preferences.

Most investigators have focused primarily upon “greenfield” or newly built establishments. Greenfield investment involves a more specific choice of location than acquisition of a firm established by another company and is thus indicative of the relative attractiveness of regions to foreign investors. Exceptions to this research tendency are Shannon, Zeile and Johnson (1999) and Ó hUallacháin and Reid (1997), who compared geographic trends between greenfield plants and acquisitions of pre-existing firms. Shannon *et. al.*, comparing location distribution for all foreign investment, found that, with certain exceptions, the pattern represented by firm acquisitions is strongly correlated to that of greenfield establishments. Japanese firms were one of the significant exceptions to this general observation. The locations of firms acquired by the Japanese from U.S. companies appear to have little relation to that of Japanese greenfield establishments. Greenfield establishments were relatively concentrated in two locations: along the Pacific coast and along a corridor extending from Indiana to northern Georgia.

Focusing on Japanese investments, Ó hUallacháin and Reid concurred with the general findings of Shannon, Zeile and Johnson concerning locational differences between acquisitions and greenfield plants. To explain this difference, they determined that the availability of procurable assets was the primary constraint on location for acquisitions. During the period 1970 through 1990 acquisitions of U.S. plants by Japanese firms correlated with the general distribution of all U.S. firms: The greatest numbers of acquisitions were made in areas containing the greatest concentrations of existing plants. Acquirers participated in the formation of the automotive-based complexes during this time frame but were no longer attracted to these areas in the 1990s. Otherwise, during the early 1990s acquisitions continued to be influenced mainly by the supply of potential assets, marked by a disposition toward the Pacific coast. The establishment of greenfield plants, in contrast, while similar to that of acquisitions during the 1970s, being driven by general manufacturing distribution and a Pacific coast preference, exhibited a different investment pattern during the 1980s and 1990s. "General agglomeration forces were not constraining the location of greenfield investments," according to the authors, which "…showed an enduring attraction to the Japanese industrial complexes of the Midwest and Southeast" (p. 414).

Rubenstein (1997) specifically investigated the automotive industry for evidence of a drift of manufacturing from the Midwest region toward the Southeast and found that a southward movement predated a significant Japanese presence in the United States but has been sustained by foreign investment. The early reconcentration of assembly plants for light vehicles in the Midwest and Southeast was stimulated by the demise of the branch plant system, whereby identical vehicles were produced at assembly plants located close to population centers across the country. The branch plant system arose because the cost of shipping parts to assembly plants was less than the cost of shipping completed vehicles nationwide from a regional manufacturing center such as Detroit. Beginning in the 1960s, when automakers greatly increased the number of different models produced each year, assembly plants were converted into specialized facilities for the manufacture of one or two models for national distribution. Because the interior of the country represents the least mean distance to the majority of U.S. population, coastal facilities have been shut down and most new plants built in the optimal location for a national market – the Midwest/Southeast corridor. Rubenstein notes that, since 1990, most automotive supplier plants have been built in the Midwest, but in Ohio, Indiana and southwest Michigan, rather than in the vicinity of Detroit. The concentration of supply plants in the upper Midwest are mainly of domestic ownership, whereas those in the southern part of the corridor are more likely to be of foreign ownership.

This tendency for differential location within the corridor for domestic and foreign plants is supported by Klier's 1999 analysis of the U.S. auto supplier industry. For a set of 820 Tier 1 suppliers that opened in 1980 or since that time and remained in operation through 1997, plants of foreign ownership chose to locate in the southern part of the I-65/I-75 corridor, in the region comprised of Ohio, Kentucky and Tennessee. In contrast, domestic suppliers tended to be concentrated in the northern part. Along the corridor, Ohio was the only state in which both foreign and domestic supplier firms were represented in approximately equal proportions.

Several dozen academic papers have been published since the late 1980s as part of the effort to determine the causal factors responsible for the developing pattern of Japanese investment in U.S. manufacturing industries. Since the individual firms have themselves seldom indicated specific reasons for selecting a particular location, beyond bland assurances as to the superior qualities of the workforce, the business climate, or the regional infrastructure, researchers have endeavored to account for the spatial distribution of Japanese firms by comparing the pattern of facility locations to regional characteristics. Reviewing the extant literature, Reid (2002) grouped the investigations of locational determinants into two thematic categories: agglomeration economies and labor force issues.

6.4.2. Agglomeration economies as investment location factors

A number of researchers have focused upon the importance of agglomeration economies in promoting regional clustering of related industries; e.g., positive externalities that benefit firms in consequence of close spatial association. For example, Krugman (1991) identifies three primary advantages resulting from industry localization: development of a labor force with industry-specific skills; industry demand that creates a pool of specialized input providers; and spillovers of technology and market information. Porter (1998,81) notes that clustering fosters a higher level of productivity and innovation: “Being part of a cluster allows companies to operate more productively in sourcing inputs; accessing information, technology, and needed institutions; coordinating with related companies; and measuring and motivating improvement.” Intuition and research both support the conclusion that firms will geographically cluster where agglomeration economies exist. Shaver and Flyer (2000), however, contend that since firms vary in their individual characteristics, the most advanced firms may benefit little from clustering and in fact may contribute competitive spillovers to less able companies. More advanced firms, "possessing the best technologies, human capital, training programs, suppliers, and distributors" would wish to remain isolated and less advanced firms would desire to locate in close proximity to the advanced firm. In making location decisions, therefore, firms must weigh the benefits of agglomeration economies compared to the risks of knowledge spillovers enchancing the competitiveness of rival firms.

Reid (2002), noting that geographic research has provided mixed support for the role of agglomeration economies as a critical factor in location decisions by Japanese manufacturers, identifies three distinct types of agglomeration economies upon which investigations have focused. Type I agglomerations are defined in terms of the extent to which the spatial distribution of Japanese investment parallels the spatial distribution of domestic investment. Type II agglomerations are defined in terms of the extent to which spatial distribution of new Japanese investment parallels the spatial distribution of existing Japanese investment. Type III agglomeration is defined by the extent to which the spatial distribution of Japanese investment in a specific sector is driven by the need of customers and suppliers to be in close geographic proximity.

Research previously noted (Shaver 1998; Shannon, Zeile and Johnson 1999; Doeringer and Terkla 1992; Ó hUallacháin and Reid 1997; Rubenstein 1997 and Klier 1999) indicates that the spatial pattern of Japanese investment differs from that of domestic manufacturers. Only in the case of acquired firms are the patterns congruent; greenfield firms, which represent more than two-thirds of Japanese manufacturing investment (MacKnight 1996), are generally not found to be concentrated in the same geographic clusters, or in the same part of broader regional clusters, as U.S. firms. Accordingly, Type I agglomeration does not provide a satisfactory explanation for the spatial pattern exhibited by Japanese firms.

Type II agglomeration theory, attributing the pattern of Japanese firm locations to the attraction of preexisting Japanese firms in a region, has been addressed by Head, Ries and Swenson (1995), Ó hUallacháin and Reid (1997), and Murray, Dowell and Mayes (1999). Head and colleagues concluded that initial U.S. investments by Japanese manufacturers stimulate subsequent investors in the same industry or industrial sector to select the same states; for firms in automotive-related industries, previous investments by affiliates of the same keiretsu group were found to be significant. Ó hUallacháin and Reid determined a positive association during the 1970s between Japanese acquisitions of U.S. firms and the preexisting structure of Japanese investment, but this relationship did not continue during the last two decades of the century. They did, however, find an association between the spatial distribution of greenfield investments and existing stocks of Japanese manufacturers during the 1990s. Murray, Dowell and Mayes' survey of Tennessee automotive suppliers found that Japanese transplants are attracted to states with larger numbers of U.S. and Japanese-owned establishments in the same industry.

As Reid (2002) notes, most of the research on regional clustering effects for Japanese manufacturers has addressed Type III agglomeration effects within the automotive industry. Investigations of Type III agglomeration in the auto industry concern the significance of just-in-time delivery requirements upon the relative locations of assembly plants and their supplier networks. Although researchers such as Kenney and Florida

(1993), Perrucci and Kong (1994) and Klier (1999) note that automobile assembly plants, in their initial location decisions, exhibited a preference for regions possessing an already well-developed infrastructure of domestic automotive suppliers, most investigators of agglomeration effects have, naturally enough, focused upon the spatial distribution of the dependent suppliers rather than that of the assemblers.

Surveys of Japanese automotive suppliers in the U.S. indicate that the majority of such firms located here in order to maintain close ties to a specific major customer such as Honda or Toyota (Rubenstein 1992; Kenney and Florida 1993; Smith and Florida 1994; Murray, Dowell and Mayes 1999). An analysis of first-tier suppliers conducted by Banerji and Sambharya (1996) found that the keiretsu system[8] extended its influence even in the international environment; the core firm tends, especially in a new environment, to continue its close affiliation with proven vendors and suppliers. The study confirmed the conclusion by Florida and Kenney (1991) that major Japanese auto assemblers were able to duplicate their intricate inter-organizational network of affiliate firms in the United States. Even small firms were willing to make an investment in the United States as a consequence of the security provided by the pre-existing long-term relationship with the core firm. In some cases, Rubenstein (1991,119) noted, suppliers have been compelled to establish a manufacturing plant in the United States if they wished to continue any business relationship with the automaker; in some other cases, supplier firms are subsidiaries set up by assemblers to provide specific components such as engines.

[8] See Chapter 3 for a discussion of firm relationships within a keiretsu.

The developmental process through which Japanese direct investment created a network of transplant automobile assemblers and suppliers has been described by Rubenstein (1991) as progressing through three stages or "waves": (1) exportation by Japanese automakers in their homeland, capturing an increasing share of the U.S. market until imposition of import quotas in the 1980s; (2) the subsequent construction of assembly plants in the United States during the 1980s, first by major Japanese automakers and later by smaller companies such as the Subaru-Isuzu joint venture in 1989; and (3) a repetition of the assemblers' strategy by component suppliers, who first penetrated the U.S. market with exports and later increased market shares by constructing transplant manufacturing facilities. Kenney and Florida (1993), addressing this sequence, noted that Japanese assemblers, initially dependent upon imports and U.S. domestic suppliers for parts, encouraged relocation of supplier transplants to reduce the quality and delivery problems experienced with domestic firms unaccustomed to the Japanese production system. Over time, however, more and more domestic firms became adept at meeting the requirements of Japanese assemblers so that the supply networks today consist of a mixture of domestic and transplant firms. One consequence of the development of supplier networks has been a gradually increasing domestic content for Japanese automobiles manufactured in the United States.

At the heart of the Japanese system lies the concept of "just-in-time," developed by Toyota and widely diffused through manufacturers in Japan by the 1970s. Just-in-time (JIT) is concerned with efficiency and the balancing of process flows, and one of its most significant and best-known manifestations is in the form of just-in-time delivery scheduling. Rather than wasting space to maintain large inventories of components, Japanese manufacturers prefer to have a balanced flow of materials through the production process exactly in the quantities needed for immediate use. Internally, just-in-time supply moves steadily through a facility's production, "pulled" by the requirements of the next process step in line. Externally, just-in-time scheduling requires suppliers to make frequent deliveries; Reid (1990) notes that seats and tires arrive at the Honda Marysville, Ohio, plant every two hours. According to a survey by Kenney and Florida (1993) 80 percent of first tier suppliers and 43 percent of second tier suppliers to Japanese assemblers in the United States operated under the demands of JIT scheduling. This necessitates a relatively close geographic association between assembly plants and their suppliers, and in fact, geographic proximity was noted as one of the most important location factors for supplier firms in many studies (Kenney and Florida 1993; Smith and Florida 1994; Reid 1990; Murray, Dowell and Mayes 1999).

Although Klier (1995) found that Japanese supplier firms were grouped more closely around Japanese assembly plants than domestic suppliers around domestic assemblers, the spatial concentration of transplant supplier networks around assembly plants does not, however, appear to be as tightly clustered in the United States as is true for similar networks in Japan. Kenney and Florida (1993) noted that, in the greater spaces of the North American continent, agglomeration in the auto corridor resembles a "stretched-out" version of that found in Japan: "The transplant complex that is emerging is an adaptation of Japan's dense JIT complexes to U.S. conditions" (p. 144). In the United States, observes Klier (2000), geographic clustering in response to the demands of JIT delivery tends more to be regional in scale than in the immediate vicinity of an assembler. In part this is a consequence of greater amounts of less expensive land in the U.S. than in

Japan, allowing larger facilities to be constructed and hence more storage for components inventory (Kenney and Florida 1993; Nagao 2002).

The primary factor responsible, however, is the presence of an extensive and well-maintained network of interstate highways that allows suppliers to locate at a greater distance from the assembly plant and still keep just-in-time schedules. Klier's (2000) analysis, in fact, determined that proximity to an interstate highway was a more significant locational factor than proximity to an assembly plant. Consequently, development of the Indiana to Georgia "auto alley" corridor has taken place along two of the primary north-south arteries of the eastern United States, I-65 and I-75. Concentration has also taken place along east-west interstate links. Venable (1998) notes the emergence of a new "east-west Auto Alley" along I-64, which runs 945 miles from coastal Virginia through Missouri, facilitating JIT delivery to most regional assemblers for supplier firms locating anywhere along its length. For example, Toyota has located three major production facilities all along Interstate 64, in Buffalo, West Virginia (transmissions, 1998); Georgetown, Kentucky (auto assembly, 1987); and in Princeton, Indiana (auto assembly, 1998).

Nagao (2002) noted that most suppliers prefer to locate within 100 miles of an assembly plant; Kenney and Florida's (1993) analysis indicated that 85 percent of suppliers were located within 400 miles of their assembly plant customer, and was partly supported by Klier (1999) who found variability from 45 to 75 percent of suppliers within 400 miles; and Klier (1995) calculated mean distances of suppliers for four Japanese assembly plant networks ranging from 244 miles to 353 miles. The most detailed analyses of spatial relations within Japanese supplier networks was conducted by Murray,

**Table 6.2. Supplier plant network clustering:
Percentage of suppliers by distance from regional assembly plant**
Adapted from Murray, Dowell and Mayes (1999).
** SIA = Subaru-Isuzu.America; ** Toyota = Toyota of Kentucky*

Distance in miles	Honda	Nissan	SIA*	Toyota**
Less than 50	20.5	17.2	7.5	10.4
Less than 100	36.7	20.3	16.9	26.8
Less than 200	60.6	34.4	64.1	52.2
Less than 300	75.1	54.7	79.2	76.1
Less than 400	84.5	67.2	86.7	86.5
Less than 500	88.8	87.5	90.5	88.0

Dowell and Mayes (1999), who found that 70 percent of Japanese suppliers for each of seven different networks were located within a day's drive (500 miles) of their respective assembly plant customers. Table 6.2 presents a simplified version of their analysis, showing only the four networks located within the present study area and collapsing distance categories above 100 miles from 50-mile intervals to 100-mile intervals.

According to their analysis, the Honda supplier complex demonstrates the greatest degree of localization, with 20.5 percent of suppliers located at less than 50 miles distance from the plant, followed by Nissan with 17.2 percent. Honda, located in Ohio, and Nissan, located in Tennessee, were the first two Japanese auto assembly plants to locate in North America, and "Because the number and geographic spread of actual and potential customers was limited during the early 1980s, Japanese supplier firms were more likely to locate within close proximity of one of these two Japanese assembly plants or one of the existing Big Three [domestic] plants" (p. 21). The authors noted that many of the suppliers, however, provided parts and components to more than one assembly plant, made possible within JIT scheduling by positioning along the interstate highway system. For example, a number of suppliers to Toyota (Georgetown, Kentucky) that chose to locate in Kentucky near their primary customer also supplied the Honda plant in Ohio. Even more suggestive, Ohio contains the second-largest concentration of firms supplying the Nissan assembly plant in Tennessee. Of eleven supplier firms located in Ohio that provided parts to the Nissan plant in Tennessee, nine provided parts exclusively to Nissan and only two supplied Honda as well. In Murray, Dowell and Mayes' assessment, the nine Nissan-only suppliers preferred to take advantage of agglomeration economies available through the larger concentration of supplier facilities present in Ohio, while remaining connected on a (just-in)-timely basis with their Tennessee customer through Interstates 75 and 65.

Nagao (2002) notes that the inclination of supplier firms to locate in geographic proximity to assembly plants is not entirely due to the requirements of the JIT delivery system but also is predicated on maintenance of close business ties and knowledge-sharing. In contrast to the "arms-length" short-term, cost-based relationships inherent in Fordist production, in which proximity is of little concern, relationships between assemblers and suppliers in Japanese lean production systems tend to be characterized by high levels of interaction, joint problem solving, and long-term contracts. According to Kenney and Florida (1993), supplier networks also function as conduits for a rapid and continuous flow of information and technology transfer. Assemblers, which often have financial holdings in supplier firms, work to structure linkages and coordinate flows in the supplier network. Nearly all of the major Japanese automakers in the United States have well developed training programs in lean production methods, available free to their suppliers. Technical and management personnel from assemblers make frequent, even daily visits, to many of their suppliers to lend advice and assistance in product and process development. Geographic proximity is particularly important for firms that produce design-supplied or design-approved components, less so for producers of marketed parts. Assemblers are thus replicating externally the same characteristics of collaborative problem-solving and continuous improvement that are characteristic of their internal production methods.

This directly contradicts Shaver and Flyer's (2000) proposal that advanced firms would tend to isolate themselves from other firms to prevent knowledge spillovers that would undermine their competitive advantage. Instead, Japanese assemblers are actively promoting knowledge and technology transfer, at least within their own supplier networks. One must recall, however, that in postwar Japan, Toyota, having developed an efficient production system, undertook at their own expense to promote this methodology among manufacturers nationwide, reasoning that such a strategy would serve to improve overall quality and productivity standards for mutual benefit. In Japan today, this mentoring system is applied from the assemblers outward, with first-tier suppliers working to improve the performance of their suppliers, and hence beyond, but such tight linkages remain to be established in the United States.

6.4.3. Labor issues and other local factors

To this point assessment of the locational strategies of Japanese manufacturing investors has been conducted at the level of state or region. On the local scale, Reid (1990,49) observes, "It is argued that…the Japanese are pursuing a locational strategy which is driven by the desire to give their controversial production techniques and management practices the greatest chance of success in an alien environment." The

Japanese lean production system is premised upon a workforce where individuals are intelligent, flexible and proficient in multiple tasks, occupying far fewer and less rigid job classifications than prevails in fordist regimes. In the Japanese system, workers are expected to collaborate in teams to solve problems and accomplish production goals, rather than work in isolation. Fundamental to lean production systems is a shared philosophy and a set of values, embodied in the concept of kaizen, dedicated to continuous improvement of processes and product quality.

All these attributes together create a workplace that is structurally and socially quite different from that of traditional Fordist regimes. Perrucci (1994,44-45) notes that "Foreign firms want to create the environments to which they adapt by selecting the site they will locate – by excluding some elements of the environment and including others….Productivity and work ethic of the labor force are of critical importance to foreign companies that promote their products on the basis of quality." The academic and business literature has noted a tendency for Japanese firms to select small-town or rural locations with access to interstate highways, possessing, as Rubenstein (1996,7) observes, "…a labor force lacking the dubious experience of building cars according to Fordist production methods." Such non-traditional manufacturing locations "…offer the best chance of success for Japanese management and production techniques" (Reid 1990,56).

This tendency to favor small-town locations has led to charges that Japanese site-selection practices are both racist and anti-union, in that such environments typically have a lower proportion of blacks in the population and low unionization rates. Research findings for both cases are mixed. Nor is a pattern of investment in small-town locations uniquely Japanese. Deurbanization of manufacturing has long been occurring across the United States, so that American-owned plants are also increasingly being built in locations more rural and suburban and are hence equally open to such criticisms.

Cole and Deskins (1988) compared black employment and the percentage of blacks in the local population for Japanese assembly plants and component suppliers to U.S.-based assembly plants and found that the Japanese supplier firms and assembly plants tended to be located in areas with fewer blacks than U.S. firms. They also determined that Japanese assembly plants tended to employ black workers in a lower proportion than was represented by this segment of the local labor force where the plants were located. In an assessment of site selection factors for six Japanese assembly plants in the automotive corridor, Perrucci (1994) found a tendency for location in areas with low minority populations. Woodward's (1992) analysis of 1980-1989 establishment data similarly found that Japanese greenfield plants in the automotive corridor tended to avoid counties with high black populations, although there was no evidence of this avoidance for Japanese facilities located elsewhere in the United States. Smith and Florida (1994), however, found that Japanese greenfield plants were positively associated with areas having high concentrations of minority populations. Similarly, an analysis of location factors by Murray, Dowell and Mayes (1999) determined that Japanese supplier firms preferred U.S. locations with a high minority concentration, although Asian residents were favored. Kenney and Florida (1993) note that assembly transplants increased minority hiring in the 1990s, possibly in response to political, legal and public relations pressure. Kentucky's Toyota plant, located in a county with an 8.1 percent minority population, increased minority representation in its workforce to currently more than 12 percent.[9]

Investigation of location factors for Japanese manufacturing investment over the past decade has consistently indicated a preference for small-town or rural locations (Reid 1990; Woodward 1992; Kenney and Florida 1993; Perrucci 1994; Rubenstein 1996; Murray, Dowell and Mayes 1999). Whether or not this can be attributed to an anti-union bias is less certain. Shaver (1998) found avoidance of areas with high rates of unionization and preference for states with right-to-work laws[10] to be characteristic of all foreign firms; and Murray, Dowell and Mayes (1999) found presence of a state right-to-work law to be a positive influence for automotive suppliers' choice of Tennessee. Woodward (1992), Reid (1990), and Ó hUallacháin and Reid (1997) all found low unionization to be a significant factor for Japanese location decisions; and In contrast, Doeringer and Terkla (1992) and Perrucci (1994) did not find a strong local union presence to be a significant factor in Japanese plant siting. Although in Reid's analysis, Japanese transplants favored locations without a union tradition, he noted that only one of eight Japanese assembly plants (Nissan in Tennessee) had chosen a right-to-work state. These right-to-work laws are in effect throughout the southeastern states, but neither Kentucky nor any of the states in the northern part of the automotive corridor have any such legislation (see Figure 6.5).

Woodward (1992,696) notes: "The reasons Japanese firms desire nonunion sites may have less to do with saving on labor costs than with the organizational changes wrought

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[9] Percentages obtained from Toyota Motor Manufacturing Kentucky website and U.S. Census 2000 data.
[10] Right-to-work laws prohibit any worker being forced to join a union as a condition for employment, being forced to join in a strike, or interfering with business activities through violence or picketing. Twenty-two states currently have such legislation in effect.

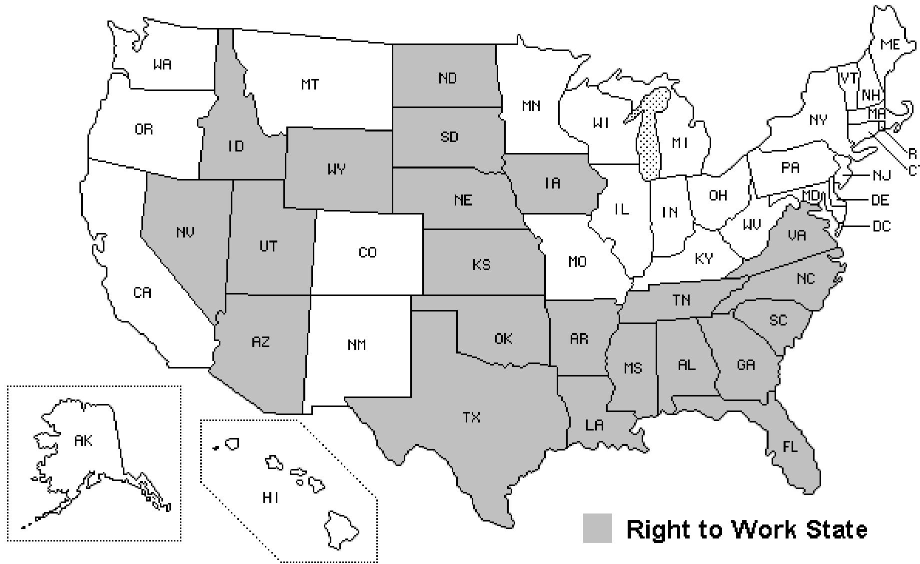


Figure 6.5. States with Right-to-Work laws.
Source: National Right-to-Work Legal Defense Foundation

by the Japanese model of production"; in other words, union resistance to the flexible work arrangements characteristic of lean production. Kenney and Florida (1993) point out that Japanese companies are not opposed to unions per se, since nearly all of the transplant parent companies in Japan are unionized, but are instead disturbed by the hegemonic and adversarial form unions take in America: "The transplants are opposed to forms of alternate worker identification, including traditional American unions, which create a separate sphere of identity for workers and disrupt the alignment between worker and company" (p. 285). Japanese transplants are, first and foremost, seeking employees who can adapt to a cooperative environment, who are flexible, loyal and capable of engaging in problem-solving as part of a team (Doeringer and Terkla 1992). American unions, where they do exist within Japanese transplant facilities, have made significant concessions to a work environment that greatly differs from fordist shops. According to Kenney and Florida (1993), those Japanese assembly plants where unionization took place demanded and secured the ability to organize the shop floor according to Japanese work principles.

Analysis of other workforce characteristics such as local wage rates, educational levels, unemployment rates, and poverty levels indicate that Japanese investors are primarily interested in a quality labor pool and are willing to pay to attain such. Japanese employers have undertaken in many cases to pay wages in excess of the prevailing local rate, partly to attract the best workers and partly to discourage efforts to unionize plants. Whereas the analyses by Shaver (1998) and Coughlin and Segev (2000) indicated that foreign firms as a whole tended to prefer areas where wages were relatively low, studies by Smith and Florida (1994) and Murray, Dowell and Mayes (1999) indicated that Japanese firms were attracted to areas where wages were relatively high. According to Murray and associates, areas with low wages and high unemployment rates were perceived by Japanese firms as reflecting low labor quality. Similarly, Woodward (1992) had previously noted avoidance by transplant firms of impoverished areas with high unemployment.

The desire for a high-quality labor pool is also reflected by studies that indicate a preference for areas where the workforce is relatively well-educated (Woodward 1992; Smith and Florida 1994; Reid 1995). Woodward (1992) and Murray, Dowell and Mayes (1999) note that specific skills, however, are not of importance, since the transplants prefer to train, or retrain, their workforce in Japanese methods. Further insight into labor characteristics favored by transplants is provided by Kenney and Florida (1993) who observe that workers in the rural areas favored by Japanese greenfield establishments are perceived as having low rates of absenteeism and low levels of occupational and geographic mobility. Doeringer and Terkla (1992) note that U.S. and Japanese firms place different interpretations upon the concept of labor quality: U.S. firms tend to emphasize education, skills and experience; Japanese firms value flexibility, adaptability, loyalty, motivation, and problem-solving skills.

Many other locational factors have been evaluated as to their role in influencing location decisions by Japanese firms, including differences in energy costs, corporate and property tax rates, and unemployment benefits, all of which were determined to have either little or no significance, or a significance less than the agglomeration and labor factors discussed above. In two separate studies, nonspecific as to nationality of ownership, on the effects of environmental regulations on plant siting decisions, both McConnell and Schwab (1990) and Taylor (1998) found that variations in regulatory stringency had no significant impact.

In summary, on the national scale Japanese transplant firms have concentrated in two locations that differ in the nature of the manufacturing industries most representative, on the Pacific coast where electronics industries are dominant among transplants and, in the eastern United States, a north-south corridor centered on I-65/I-75 that has become known as “auto alley.” Agglomeration economies related to the presence of auto assembly plants have played a role in developing this focus of automotive-related industries, although the localization is not as tightly centered as often supposed, being regional rather than local in nature. This is a consequence of the well-developed linkages of rapid transportation made possible by the interstate highway system. On the local scale, as Doeringer and Terkla (1992) concluded from their analysis of location factors, it appears that Japanese firms prefer to meet production cost targets through management practices rather than through selecting areas with the lowest factors costs. The transplant firms maximize the potential of their management practices by favoring areas having a workforce perceived as most amenable to adoption of methods of labor relations and labor organization that differ greatly from traditional fordist practice. This translates to a preference for small-town, rural or suburban locations.

Given that there are many small-town, rural and suburban locations in the automotive corridor, it would appear that there must be yet another factor that would help account in explaining why a Japanese assembly plant would select one state over another within this region, or why a supplier firm would select one community over another within range of its major customer. One possible explanation may lie in the extent and commitment with which individual states and communities promote their advantages and their willingness to host a Japanese firm.

6.4.4. The role of state and local governments in attracting Japanese investment

As noted earlier in this chapter, decreased revenues as a consequence of deindustrialization, recession, and cuts in federal funding have led states to an active role in promoting economic development within their own borders. In large part this has taken the form of fiercely competitive efforts among states and local communities to attract manufacturing investment, both domestic and foreign. Evidence as to the success of such offerings as land and building subsidies, debt and equity capital support, job training programs, infrastructure improvement and site preparation has been mixed. Regardless, as Karan (2001,3) notes, where once attracting international investment was considered a function left to national and state governments, rural communities "have been forced to break out of small-town molds and jump into new roles as global traders, translators, and negotiators."

The political system of the United States permits subnational governments the authority to undertake increased roles in international relations, the leeway to "formulate independent, if not autonomous, foreign political and economic policies" (Potter 2001,45). Perrucci (1994) conceptualizes the activity of state and local governments in promoting foreign investment as part of an "embedded corporatism" through which the state, representing the organized interests of competitive groups in the economy, undertakes an activist role in economic policy-making. The corporatist ideology pursues the goal of stimulating local economies through a partnership between government and business, and in lesser roles, labor and universities. In order to succeed, according to Perrucci, corporatism must become embedded within the institutional structure of the local community: "The process of embeddedness is facilitated by the politics of the incentive package, the selection and training of workers, media coverage of the transplant, and the personal and organizational ties established with noneconomic segments of the community" (p. 19). Embedded corporatism works to enhance the growth potential of the local community by creating a favorable business climate for the new firm, and enlisting the support of local civic, religious, educational, and cultural groups.

Analysis of the various aspects of promotional endeavors designed to attract Japanese manufacturing investment is inconclusive. Woodward's (1992) investigation of locational determinants concluded that no single program was likely to have a decisive impact upon location choice. Surprisingly, according to the nearly unanimous findings of several researchers, huge financial incentives appeared to have little effect. Potter (2001) concluded that incentives packages alone were not significant factors in location decisions by Japanese firms but only one aspect of the decision process. Rubenstein (1991) had noted that Japanese transplants expect financial incentives to be offered but that these are rarely critical factors in site selection. Similarly, Bosman's (1999) study of Toyota's 1987 decision to locate in rural Georgetown, Kentucky, noted that the incentives packages offered by competing states were the last consideration among factors evaluated by Toyota. In the words of a senior vice-president at Toyota of Kentucky (quoted in Bosman), the incentives package was "the icing on the cake"; it was the complete set of local and regional attributes that led Toyota to settle on Georgetown.

Coughlin and Segev's (2000) review of the literature found that evidence of the effectiveness of recruiting campaigns was scarce, but most researchers found a positive association between state promotional budgets and the attraction of foreign direct investment. Perrucci and Kong (1994), investigating the location decisions of six Japanese auto assembly plants, noted that states having larger international budgets, more staff for foreign recruitment, and more business incentive programs were most often chosen as sites for industrial transplants. Executives with six Japanese transplant firms, interviewed by Doeringer and Terkla's (1992) concerning their location decisions, emphasized the importance of the state government mechanism for coordinating industrial recruiting.

Reflecting the new role of the state as an actor in international negotiations, many U.S. states have established offices in Japan (and in other countries), which devote the major portion of their budgets to the attraction of foreign direct investment. Figure 5.6 shows the states which, as of 2002, have opened a trade office in Japan. The pattern displayed on this map, not surprisingly, resembles the distribution of Japanese manufacturing investment in the United States (compare to Figure 6.2, "Japanese-Owned Greenfield Manufacturing Establishments").

Woodward's (1992) analysis found that the early establishment of a Japanese office for trade and investment was a significant factor in location determination; however, Coughlin and Segev (2000), investigating location choices for foreign firms where nationality was undifferentiated, found that neither the total number of foreign offices operated by a state nor the total number of associated staff was statistically significant.

Regardless of the actual efficacy of promotional efforts designed to attract Japanese investment, state and local governments have adopted overt courting of foreign corporations as the preferred economic development policy. A recent publication by the Kentucky Cabinet for Economic Development (2002) titled *Automobile Industry in*

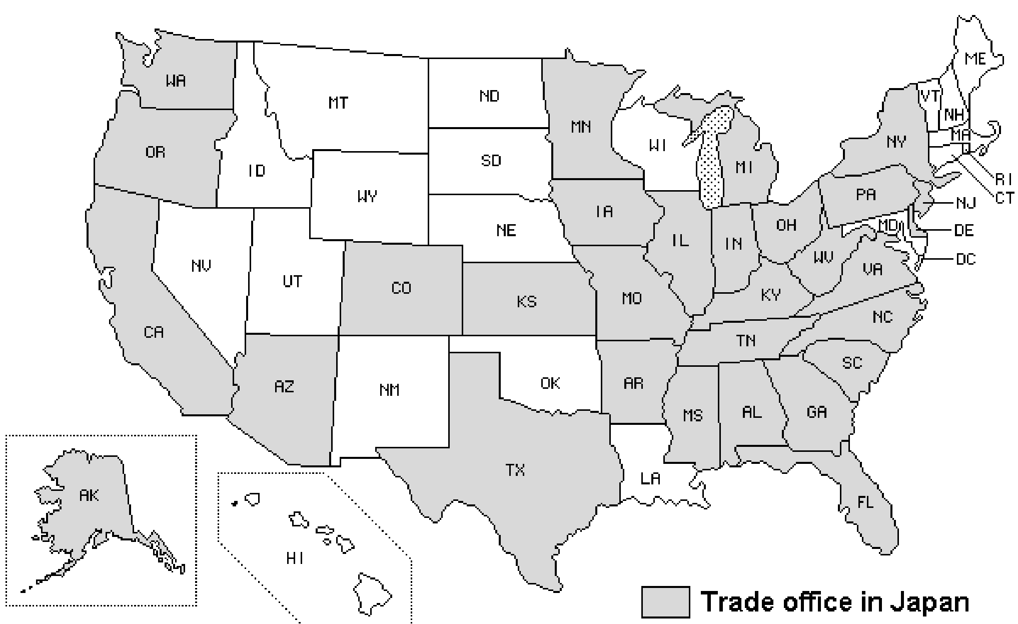


Figure 6.6. U.S. states operating foreign trade offices in Japan.
Source: American State Offices Association Japan.

Kentucky is only partly informational in nature; its alternate role is as a blatant propaganda piece extolling the virtues of Kentucky as a site for industrial location. Noting that "Kentucky continues to be the state with the lowest overall cost of doing business in the eastern United States" (p. 7), the publication favorably compares the Commonwealth to other auto-producing states in terms of wages, labor productivity, energy costs, taxes, transportation infrastructure, supplier network, and other location factors thought to be of importance to industrial site selection.

Local communities are also highly involved in promotion activities. The American State Offices Association in Japan includes several cities and counties as members in addition to states.[11] The town of Milledgeville, Georgia, (2000 population 18,757), although not a member of this association, is situated within the automotive corridor and has a Chamber of Commerce website obviously intended to draw foreign investment.[12] According to this website, Milledgeville and Georgia can offer the foreign investor:

- A pro-business attitude;
- The best-maintained interstate system in the nation;
- Ample electric power, natural gas and water supplies;
- Stable tax rates and a business rate lower than many other states;
- A large number of regional colleges and universities;
- A significant existing foreign investment in the region;
- Competitive wages;
- A low cost of living;
- A state right-to-work law;
- Low union membership, with no union presence in half of all Georgia counties. "Union losses are growing in number as compared to union wins in election results across the state. The incidence of strikes in Georgia is historically well below the average."

[11] American State Offices Association Japan website: http://asoajapan.org.
[12] http://www.milledgevillega.com/idga.htm

Ryen (1996) has observed that, for every winner of industrial competitions among states, there are several losers who must write off associated expenses. Further, he notes, "incentive packages have become so staggeringly large that critics are asking whether the jobs are worth the price" (p.530), giving the example of a package offered to a steel mini-mill recently locating in Kentucky that will cost the state approximately $380,000 per job. Whereas Kentucky's record-setting incentives package to entice Toyota's location to Georgetown in 1987 has returned many times the state's original investment, a number of investigators have suggested that such benefits are increasingly unlikely to accrue in the future (Klier 1995; Head, Ries and Swenson 1995; Murray, Dowell and Mayes 1999). This is particularly so given that that a relatively dense concentration of supplier firms is essentially complete in the automotive corridor; establishment of an additional assembly plant in the region is unlikely to draw further investment in supplier plants.

6.5. Characteristics of foreign firms

Corporations face a number of disadvantages by investing abroad. They are less familiar with the business conditions in the host country than are local firms, are often faced with language barriers, and must manage the affairs of their subsidiary from a distance. To offset these disadvantages, a foreign firm must possess specific advantages, such as specialized knowledge, advanced technology, marketing skills, production management or other organizational capabilities (Howenstine and Shannon 1996; Alexander 1997). Because firm-specific advantages are not evenly distributed across industries or countries, the particular industries in which investments are made tend to depend on the country of the investor. The foreign operation must therefore be structured to take advantage of the particular advantages of the investor, and so characteristics of the transplant are likely to differ significantly from domestic firms or those of other foreign investors. These differences may be in terms of production organization and management, as in the case of fordist versus lean production, or may be expressed in physical attributes such as plant size or employee numbers.

In a survey of the characteristics of foreign industrial transplants in the U.S., Howenstine and Zeile (1994) noted that the average plant size - based on employment - tended to be larger in specific industries than plants owned by U.S. firms. The author's analysis of 1990 data indicated that the tendency of such firms to be concentrated within industries with larger-than-average firm size was less significant. This was contradicted in a subsequent analysis of 1991 data by Howenstine and Shannon (1996), who reaffirmed the previous conclusion that foreign firms were much larger than U.S. firms, but concluded that the primary foreign investors in the United States did tend to concentrate within industries having larger average facility scale. This tendency was most pronounced for the Netherlands, Germany, and Japan, whose plants, when effects of differences in industry mix are isolated from within-industry differences, were on average twice as large as U.S.-owned facilities. These findings support the conclusion reached by O'Dell (2001) that Japanese facilities in Kentucky tended to be of larger scale than those of other ownership. Further, according to Howenstine and Zeile, foreign transplants tended to be concentrated in the industries that were most capital-intensive, paid the highest wages, and had the highest productivity levels.

Japanese transplants accounted for the largest share of production by foreign-owned establishments in four industries: primary metals, industrial machinery and equipment, electronics and other electric equipment, and in transportation equipment. In primary metals and in electronic and other electric equipment, the Japanese share was greatest for the total United States production.

Howenstine and Zeile (1996) found that the tendency to be concentrated in high-wage industries was strongest for Japanese firms, where wages averaged 23% higher than firms of U.S. ownership. Production at Japanese transplants relied more heavily on components originating elsewhere than did the establishments of other countries, that is, output reflects material purchased from others. This is consistent with the strong reliance by Japanese core companies on subcontracting to supplier networks. The authors note that this may also be because most Japanese plants are relatively new and have at present only a few production stages, planning to add more in time and substitute the use of their own products.

6.6. Chapter summary

The preceding review of the literature concerning the spatial distribution and characteristics of foreign investment in the study area indicates a number of trends:

(1) Japanese transplants in the so-called automotive corridor tend more to be located in small communities or rural areas than non-Japanese firms, provided convenient access to the interstate highway network is present.

(2) Japanese transplants tend to be concentrated in a few industries and generally are larger in scale than non-Japanese firms in the same industries.

In Chapter 7, these conclusions by previous investigators will be examined within the context of the present study.

Chapter Seven

Characteristics of Study Area Industrial Firms

7.1. Research framework

Within the study area there are three discrete populations of manufacturing firms that must be taken into account for the analytical purposes of this study: U.S.-based firms; Japanese transplants; and other foreign transplants. Because the primary purpose of the research project is to investigate comparative environmental performance based on analysis of hazardous waste data provided under federal mandate, for each of the larger populations there is also a subset of firms whose operations generate sufficient waste quantities to be regulated under the federal programs that require reporting of waste data in detail. Table 7.1 shows the total number and percentage of individual firms within each category of ownership nationality, and the number and percentage of firms in each category that are regulated under the RCRA and/or TRI programs.

In the analysis that follows, the entire population of Japanese firms will be used to examine the spatial distribution of Japanese manufacturing within the study area, concerning its proximity to urban centers and to the interstate highway system. This

Table 7.1. Industrial population groups in the study area

Source: Manufacturers News reports for 2000; Departments of Commerce for Indiana, Kentucky, Ohio and Tennessee, and RTK-NET databases.

Population category	Number of firms	Percent of entire pop.	Number of TRI/RCRA firms	TRI/RCRA as % of category
Entire population	47,937	100.0	3,712	7.7
US-based firms	46,209	96.4	3,118	6.8
Japan-based firms	525	1.1	211	40.2
Other foreign firms	1,203	2.5	383	31.8

particular analysis will not be performed for the U.S.-based and other foreign firms. All three sets and their RCRA/TRI subsets will, however, be examined on the basis of the following propositions:

1. Japanese transplants differ from other foreign transplants and domestic firms. These differences will be assessed in terms of (a) the industrial sectors represented; (b) rurality or associated community size; and (c) the scale of facility using employee numbers and area in square feet as indicators.

2. RCRA/TRI facilities differ from facilities that do not qualify for such regulatory status. These differences will be assessed in terms of (a) the industrial sectors represented; and (b) the scale of facility using employee numbers and area in square feet as indicators. The presumption involved is that certain facilities produce greater quantities of waste either because the type of operation (industrial sector) is more polluting and/or because larger facilities generate more waste than smaller ones. This proposition will be more fully explored in Chapter 9.

7.2. Spatial distribution of Japanese transplants in the study area

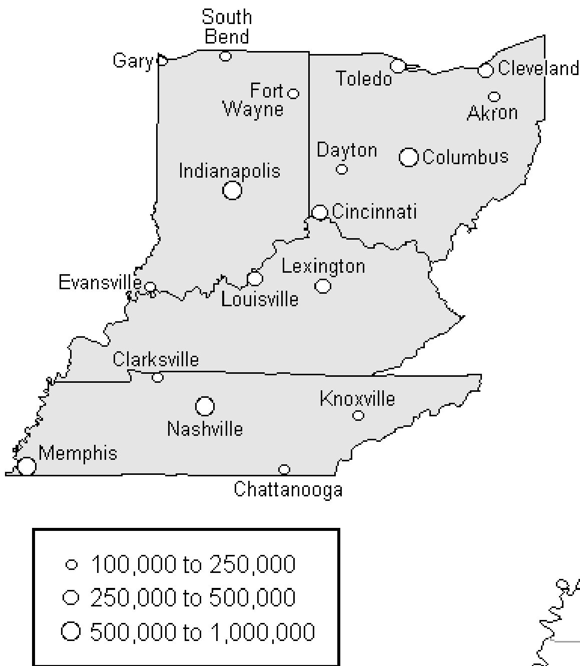
Location coordinates (decimal latitude and longitude) were obtained for all Japanese facilities in the study area through a multi-step process. For the set of facilities regulated under RCRA and/or TRI, the databases maintained by RTK NET (containing information obtained from the U.S. Environmental Protection Agency) provides latitude and longitude for each facility. Because this coordinate data proved to contain several serious locational errors that misplaced some facilities by several hundred miles, it was necessary to individually verify each location.

Verification of downloaded coordinates and derivation of locations for the majority of Japanese facilities not included in the RTK NET databases was accomplished using two separate mapping websites on the Internet: "Mapquest™"[1] and "Topozone™."[2] The Mapquest™ geographic query engine, using geocoding based on address interpolation, intersection matching, and Zip code centroids, was able to pinpoint a visual map location for nearly all facility addresses but, for legal reasons, did not provide latitude and longitude. The Topozone™ website, in contrast, provides geographic coordinates in several forms, including decimal latitude and longitude, for any point on a digital topographic map upon which an interactive set of crosshairs are focused. By using both sites together in a split screen environment, the address location found by Mapquest™ could be transferred to a Topozone™ map and the geographic coordinates thus derived. Once obtained and accuracy verified, facility coordinates were loaded into an ArcView geographic information system and a map generated (Figure 7.2) showing distribution of facilities in relation to the study area interstate highway network. Figures 7.1 ("Major cities in the study area") and 7.3 ("Automobile assembly plants in the study area") represent factors, in addition to interstate highway proximity, that have been identified by previous research as providing possible explanation for the spatial pattern of Japanese investment in the region. These figures are shown separately, rather than in combined form, to avoid an overly cluttered view.

Comparing figure 7.1 and 7.2, some relatively dense clustering of Japanese firms around urban centers is evident, particularly in the vicinity of Memphis, Cincinnati, Columbus, and the Cleveland-Akron metropolitan area. In contrast, several of the

[1] Mapquest™ website: http://mapquest.com. R.R. Donnelly & Sons' interactive mapping service.
[2] Topozone™ website: http://topozone.com. Maps a la Carte, Inc. interactive digital raster graphic maps.

Figure 7.1. Major cities in the study area



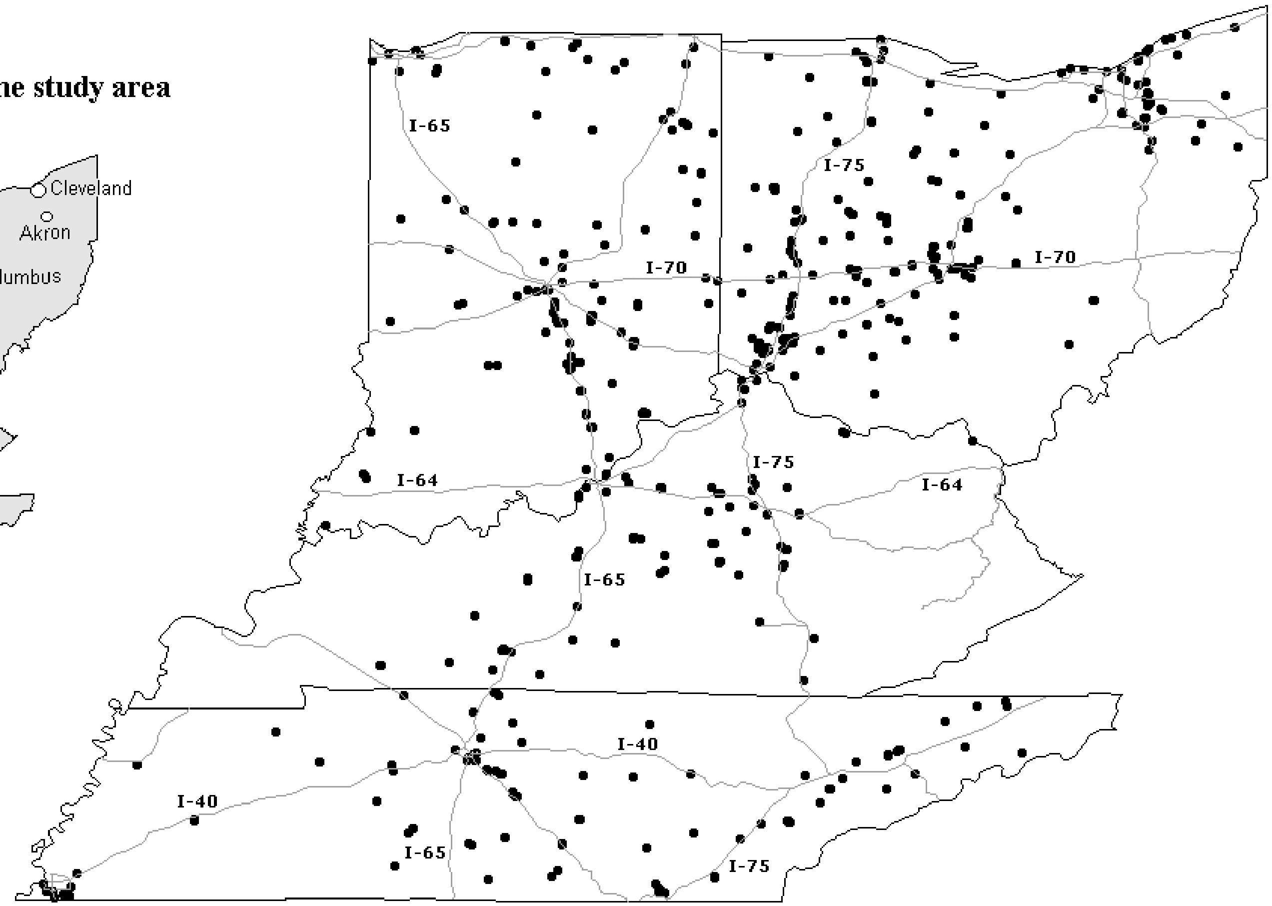


Figure 7.2. Distribution of Japanese manufacturing firms in the study area compared to interstate highway system

other larger cities within the study area, such as Indianapolis, Louisville and Nashville, show loose suburban or peripheral clustering. Japanese firms in the vicinity of Lexington, Kentucky, display a peripheral pattern that is particularly dispersed compared to other major population centers, and there appears to be little clustering effect at all at Knoxville. Throughout the study area, although urban clustering is present, the majority of Japanese firms are located at some distance away from the economic hubs in each state.

Figure 7.3 shows the locations of vehicle assembly plants, both light vehicles and heavy trucks, located within the study area. Japanese plants are identified with larger, boldface type with the year of establishment beneath the automaker's name. With eleven plants, Ohio has the greatest number of assembly plants; each of the other states has three facilities. Most of the assemblers in Ohio are older facilities of domestic ownership, reflecting Ohio's geographic proximity to Detroit and the traditional Michigan core of

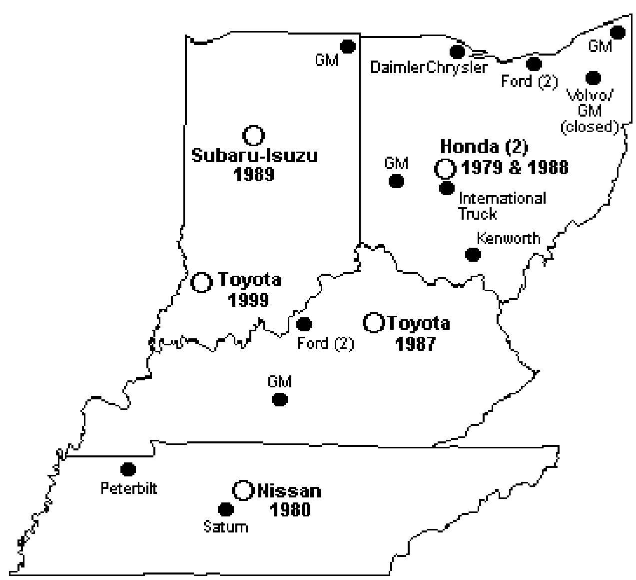


Figure 7.3. Auto and truck assembly plants in the study area.
Source: Author's database
Note: The Honda plant established in 1979 initially manufactured motorcycles only but added vehicle production in 1982.

automakers and suppliers. Ohio is the only state in the study area to possess assembly plants of non-Japanese foreign ownership, the Volvo-GM heavy truck joint venture formerly located in Orrville, and, in Toledo, the DaimlerChrysler Jeep production plant. Each was an acquisition, and each was an elderly facility at which vehicles had been produced since the early 1900s.[3] Until recently, Ohio was the only state to acquire more than a single Japanese assembly facility, although both plants were owned by the same company, Honda.[4]

The new Toyota plant in Princeton, Indiana, which began production in 1999, alters this structural insularity by its establishment in a state which already contained a Japanese assembly plant, the Subaru-Isuzu (SIA) joint venture in Lafayette. The Princeton Toyota assembly plant is, however, located at very nearly the farthest possible distance from SIA and still remain within the state of Indiana. Examination of the spatial distribution of Japanese assembly plants shown in Figure 7.3 reveals a very striking pattern, in that adjacent facilities appear equidistant from one another. Table 7.2 provides the distances between the different Japanese assembly plants; the Mitsubishi and Mazda facilities are included in the analysis because they are within the automotive corridor in states adjacent to the study area and might be expected to also reflect location choices by

[3] The Orrville plant was acquired by the Swedish company Volvo from White Motor Corporation in 1981 along with other assets of the White company. White Motor began manufacturing automobiles in 1909 and was well known for trucks, tractors and other heavy equipment. In 1988, GM acquired a stake in the Orrville plant as part of a joint venture arrangement. The Volvo-GM plant ceased operations in 1997 and was sold to Gradall Corporation, a heavy equipment manufacturer. The Toledo facility began producing bicycles in the 1890s and vehicles in the 1900s. It was transferred to foreign ownership in 1998 when German-based Daimler-Benz acquired the assets of the Chrysler Corporation.

[4] It is not clear why Japanese automakers have tended to locate in separate states. Kenney and Florida (1993) offer two possible explanations: (1) This allows the Japanese automakers to maximize their political capital by spreading investment across several states, since each state has two votes in the U.S. Senate; or (2) Each firm seeks privileged access to state and local governments, which discourages a second Japanese assembly plant from locating in a state that already contains one.

Japanese automakers contributing to the overall regional pattern. The numbers in boldface type represent straight-line distances between adjacent plants; that is, plants without an intervening facility. The mean distance between all adjacent plants in this analysis is 167 miles, with a relatively low standard deviation of 31 miles. When subjected to nearest neighbor statistical analysis, the derived value of R is 1.45, indicating a moderate dispersal; i.e., Japanese assembly plants display a pattern that tends to be more dispersed rather than random, possibly indicating that some causal factor or factors has produced this pattern.

Table 7.2. Straight-line distance (miles) between Japanese automobile assembly plants

Note: Numbers in larger, bold type represent adjacent locations.

* The Mitsubishi plant in Illinois and the Mazda (Autoalliance) plant near Detroit are not located in the study area but are in adjacent states and so included for this analysis.

** Subaru-Isuzu America joint venture.

*** This location represents two separate Honda assembly plants located about 12 miles apart.

	SIA ** Lafayette INDIANA	Toyota Princeton INDIANA	Mazda* Flat Rock MICHIGAN	Honda *** Marysville OHIO	Toyota Georgetwn KENTUCKY	Nissan Smyrna TENN.
Mitsubishi* Normal ILLINOIS	**112**	**168**	317	297	287	341
SIA** Lafayette INDIANA		**147**	**221**	**185**	**196**	306
Toyota Princeton INDIANA			344	260	**164**	**174**
Mazda* Flat Rock MICHIGAN				**129**	277	457
Honda*** Marysville OHIO					**154**	340
Toyota Georgetown KENTUCKY						**188**

The reasons for this relative uniformity in spacing for Japanese assemblers are not presently understood any better than the reasons underlying the one-per-state rationale. Mair, Florida and Kenney (1988) have suggested that, on the local scale, supply firms prefer not to locate close to one another so as not to compete for the same labor pool. Similarly, Doeringer and Terkla (1992) concluded from case study interviews that some Japanese firms prefer to locate away from other Japanese firms in order to cultivate employee loyalty by being perceived as best employer in the local market. These may have some application to interfirm spacing among Japanese assembly plants, or this pattern may be a result of the structural characteristics involved in developing a supplier firm hierarchy. Inasmuch as the Japanese automobile production complex consists of a central assembly plant, supplied by first tier component manufacturers who are in turn supplied by second tier manufacturers, central place theory may be able to provide insights into the overall spatial pattern.

Comparing the locations of the vehicle assembly plants to the pattern displayed by all Japanese firms in the study area (Figures 7.3 and 7.2), the greatest density of firms lies in the vicinity of the triangle defined by the cities of Dayton, Cincinnati and Columbus, Ohio. This is not surprising because the first of the Japanese vehicle assembly transplants – Honda – was established near Columbus in 1979 and so the first wave of supplier transplant firms chose to locate near the automaker. The second regional assembly plant, Nissan in Tennessee, although established in the following year did not likewise attract such a dense network of Japanese firms to the vicinity, instead producing a much more scattered pattern. This is most likely due to the greater number of potential customers already long established in Ohio, the domestic auto assembly plants represented by the Big Three automakers. As noted by Murray, Dowell and Mayes (1999), several suppliers who served only the Nissan plant chose to locate in Ohio and Indiana, rather than Tennessee, relying upon the interstate highway network to accommodate JIT delivery schedules.

A very loose cluster of Japanese firms is present in the vicinity of the Toyota plant at Georgetown, Kentucky, located mostly to the southward, and, in the case of the Subaru-Isuszu plant in Indiana, the concentration of Japanese firms is again to the southward rather than in the immediate vicinity. Southwestern Indiana is virtually devoid of Japanese firms since the new Toyota plant, which began production in 1999, is still too new to have attracted many suppliers. In fact, few may choose to locate here since the regional supplier network has already been built and the interstate connections preclude the need for close proximity.

The influence of proximity to the regional interstate highway system is clearly evident in Figure 7.2. This effect is particularly visible along I-65 between Indianapolis and Louisville; along I-75 from Toledo to northern Kentucky; along I-64 between Louisville and Lexington; and along the I-81 – I-40 – I-75 corridor in East Tennessee that stretches from Kingsport to Chattanooga. Where firms are not located immediately adjacent to the interstates, the influence of major subordinate highways can be seen. For example, concentrations of firms can be seen along highways that parallel interstates, such as US 411 that lies southeast and parallel to I-75 and I-40 in East Tennessee and US 22 in Ohio, associated with an interstate highway that connects Cincinnati and Columbus, and along connector routes such as the east-west alignment of Japanese firms along state highway 28 that links two interstates just north of Indianapolis, Indiana.

One of the most striking features of the pattern of firm distribution shown by Figure 6.2 is the nearly total absence of Japanese facilities in the eastern sections of Ohio and Kentucky. These areas correspond to the heart of the Appalachian region, long considered an island of economic underdevelopment surrounded by prosperity. Much of the region is characterized by rugged terrain and a poorly developed physical infrastructure lacking, in particular, good roads and adequate water supply and sewage disposal. Although high unemployment is endemic, manufacturing has long been an important part of the region's economy. Manufacturing, however, tends to be concentrated in low wage industries, and within these industries, characterized by lower wages and lower productivity than similar establishments outside the region (Jensen and Glasmeier 2001). Given the locational determinants suggested by research into Japanese site selection preferences, it is no surprise that Japanese firms have, in general, avoided most of the Appalachian region.

East Tennessee, from examination of Figure 7.2, appears to be an exception to this tendency, and in fact development is uneven throughout Appalachia. Central Appalachia, of which Eastern Kentucky is a major component, contains a higher proportion of counties considered socially and economically distressed than elsewhere in the region. The Southern Appalachian subregion, of which the area of East Tennessee containing a significant number of Japanese firms is part, has experienced a greater economic growth and prosperity than the Northern and Central subregions. In part this is due to a differing industrial basis, the Northern and Central subregions historically characterized by the declining industries of coal and steel production whereas manufacturing in Southern Appalachian has been concentrated in textiles. Southern Appalachia has also benefited most from proximity to urban centers such as Birmingham, Huntsville, Atlanta, Charlotte, Winston-Salem and Roanoke, and from federally-funded highway construction. According to Moore (1994), much of the income growth in Southern Appalachia can be linked to greatly improved highway connections.

Although each of the Appalachian segments of Ohio, Kentucky, and Tennessee is traversed by a major interstate highway, it is only along the I-75 – I-40 – I-81 corridor in Tennessee that a number of Japanese firms have chosen to locate. This corridor links three urban centers in East Tennessee, the Johnson City – Kingsport – Bristol metropolitan statistical area (2000 population 480,091) in the extreme northeast; the Knoxville MSA (2000 population 687,249) at the intersection of the three interstates; and the Chattanooga MSA (2000 population 465,161) at the Tennessee – Georgia border.[5] Furthermore, the straight-line distance from Chattanooga to Atlanta, the economic center of the entire South, is only 102 miles. The sectoral composition of industries along this corridor is quite different from that of Japanese manufacturers as a whole, however, being far less dependent upon the automotive industry. This is not surprising since East Tennessee is more remote from a major auto assembly plant than almost anywhere else in the study area. Only 44 percent of the Japanese firms in East Tennessee are involved in automotive-related production, whereas 61 percent of Japanese firms as a whole are so involved.

[5] U.S. Census 2000 data.

7.3. Characteristics of Japanese and non-Japanese firms in the study area

This section compares U.S.-based firms, Japanese transplants, and foreign firms of non-Japanese ownership in terms of industrial composition, locational rurality or associated community size; and the scale of facility using employee numbers and areal size as indicators. Except for industrial composition, where summary data was available, these comparisons are generally made using the author's database of nearly 4,000 firms in the study area regulated under the federal RCRA and TRI programs.

7.3.1. Comparison of industrial composition

Figure 7.4 shows the industrial composition for the three general populations of interest, using as a basis the industrial categories employed by Harris Infosource, Inc. in their annual manufacturing reports for each of the fifty United States.[6] The use of these categories is somewhat problematic as they do not always correspond exactly to the sectors defined in the SIC classification scheme but, in some cases, aggregate multiple sectors. For example, the Harris categories industrial machinery, food and beverage, and chemicals are compatible with the similar SIC classifications, but categories such as consumer products and general manufacturing incorporate many widely varying SIC sectors. Accordingly, the author's data had to be adapted to fit Harris categories in order to compare Japanese and foreign firms against the entire population of manufacturers. Furthermore, although the Harris reports do not differentiate according to national origin of firms, the summary data in these reports was taken to be representative of U.S.-based firms since all foreign firms, including Japanese, account for only 3.6 percent of the total manufacturing population in the study area.

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[6] The Harris categories for aerospace, computer hardware, drugs, health products, metals mining, and telecommunications were omitted since these represented a very low proportion of firms.

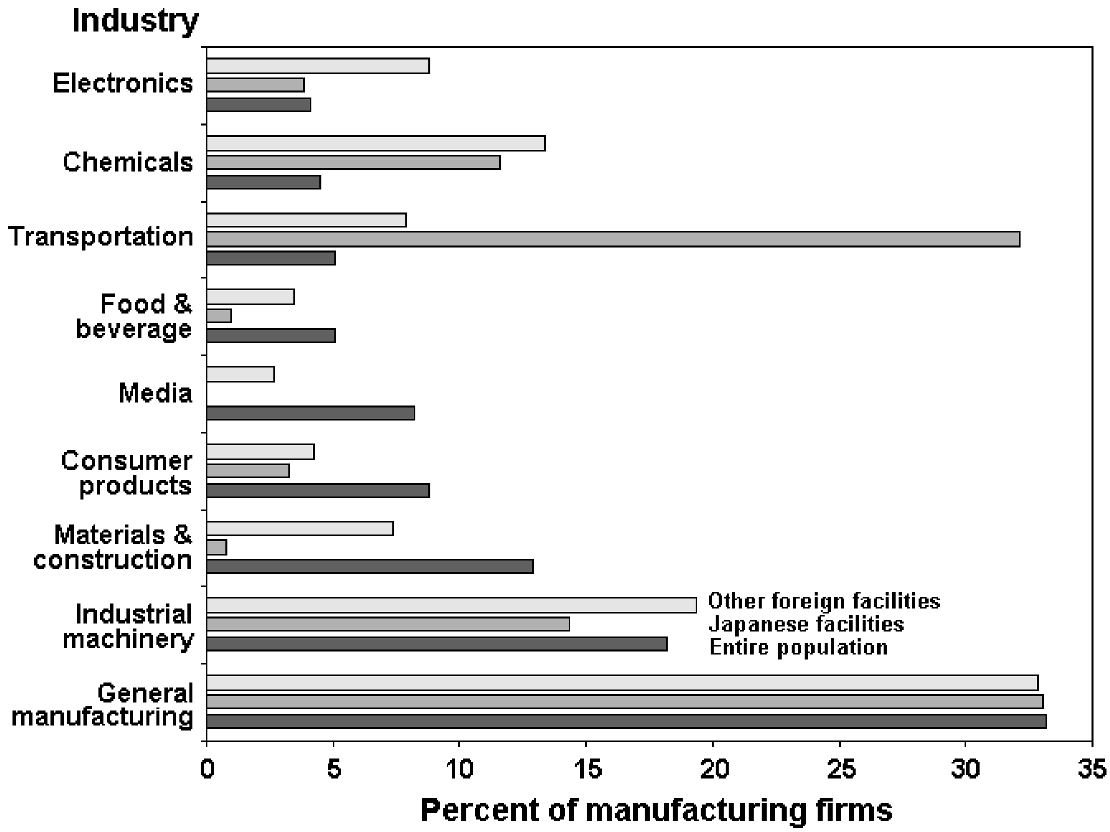

Figure 7.4. Comparative industrial composition for firms of differing national ownership
Source: Harris Infosource and author's database

Adaptation of the author's data to Harris categories was accomplished on a case-by-case basis for Japanese and other foreign firms, comparing the SIC classification to the Harris description of each category. Consumer products were defined by Harris as including: "companies that manufacture a wide range of consumer goods, ranging from apparel and furnishings to electronics and appliances." General manufacturing was described as companies that "range widely in terms of goods produced, but all share the brand of a core manufacturing industry. Included in this sector are key manufacturing such as packaging and containers, metal fabrication, rubber and plastics and textile manufacturers" (Harris 2002a).

All though all three populations are equally represented in the general manufacturing industries, considerable differences among the populations are readily apparent in every other category, both between Japanese firms and U.S.-based firms and also between Japanese firms and other foreign transplants. The most significant difference is in the transportation industries, where Japanese firms are greatly overrepresented compared to other firms; approximately one-third of all Japanese companies are concentrated in this class but only about 5 percent for the entire population and 8 percent for other foreign firms.

Firm participation in automotive-related industries for all three populations is likely to be underreported using industrial classifications as a basis. A detailed investigation of the 3,711 firms in the author's database, regulated by the federal RCRA or TRI programs, using multiple resources, revealed a much higher firm participation where all or part of the production was destined for vehicle manufacture but concealed by generalized SIC codes. For the 3,117 U.S.-based firms in the database, 29.4 percent were involved in automotive-related production; 66.8 percent of the 211 Japanese firms and 27.3 percent of the 384 other foreign firms were likewise involved. Although it is entirely possible that this reflects instead a tendency for firms in automotive industries to generate more waste, rather than more firms to be involved in automotive production, it seems rather more likely that automotive component production constitutes a greater proportion of firms than can be discovered through analysis of industrial categories alone.

Other important differences are in the food and beverage, media, and materials and construction categories, where Japanese involvement is substantially less than either U.S. or other foreign firms. Both Japanese and other foreign firms are more significantly engaged in chemical industries than are U.S. firms. The geographic specialization of Japanese industry is reflected by the relatively low participation of Japanese firms in electronics and electrical apparatus (electronics category) within the study area; as noted by Shannon Zeile and Johnson (1999), Japanese firms are concentrated in electronics industries on the Pacific coast and in automotive industries in the eastern U.S. Overall, Japanese manufacturing is focused upon general manufacturing (33.1 percent); transportation (32.1 percent); industrial machinery (14.3 percent) and chemicals (11.6 percent), with all other categories together accounting for only 9.1 percent of Japanese facilities in the study area.

Rather than using the Harris categories, it is far more convenient to compare industrial composition of the population subsets that are regulated under RCRA and TRI using the SIC classification system. Figure 7.5 compares the industrial sector distribution for

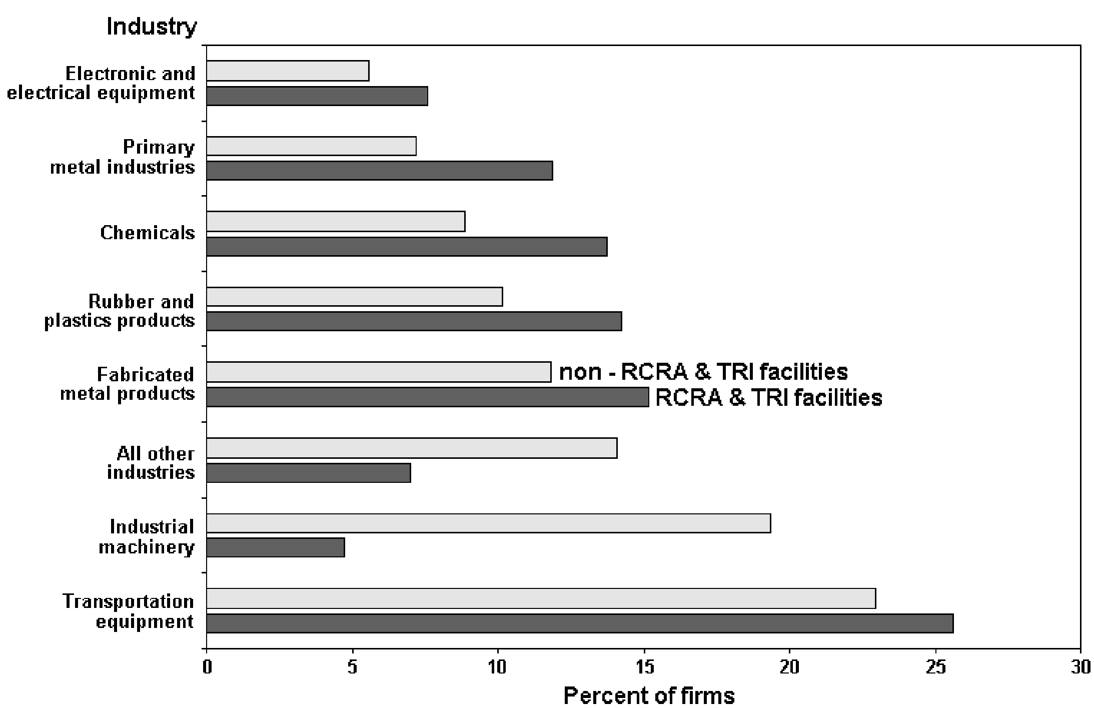

Figure 7.5. Comparative industrial composition for Japanese firms, RCRA-TRI and non-RCRA-TRI
Source: RTK NET

Japanese facilities in the study area that are regulated under RCRA and TRI (N=221) to those facilities that do not qualify for such regulation (N=305), being lesser waste generators. Overall, the majority of Japanese firms tend to be concentrated into fewer industrial categories than are U.S. firms. Almost 90 percent of RCRA-TRI firms and almost 90 percent of non-RCRA-TRI firms are each concentrated within only six industrial sectors. Although the transportation equipment sector remains of primary significance to both populations, there are major differences between them in the other sectors. The RCRA-TRI firms tend to be even more concentrated than the lesser waste generators, constituting a greater proportion of firms in all the major categories save industrial machinery. The non-RCRA-TRI firms are more diverse; a much larger percentage of such firms is found in an assortment of other industrial sectors. This comparison indicates that there are indeed important differences in industrial sector distribution between regulated firms and non-regulated firms.

The industrial composition for all of the study area firms that are regulated under RCRA and/or TRI is shown in Figure 7.6, which distinguishes among U.S. firms, Japanese firms, and firms of other foreign ownership. Major differences among these population groups are found in transportation equipment, chemicals, fabricated metal products, and the category “all other industries.” Japanese firms remain unquestionably dominant in transportation equipment, whereas other foreign firms far exceed either U.S. firms or Japanese firms in their representation in the chemical industries. Both U.S. and other foreign firms exhibit greater diversity than Japanese firms, indicated by the low proportion of Japanese facilities classed as “all other industries.” The greatest variation

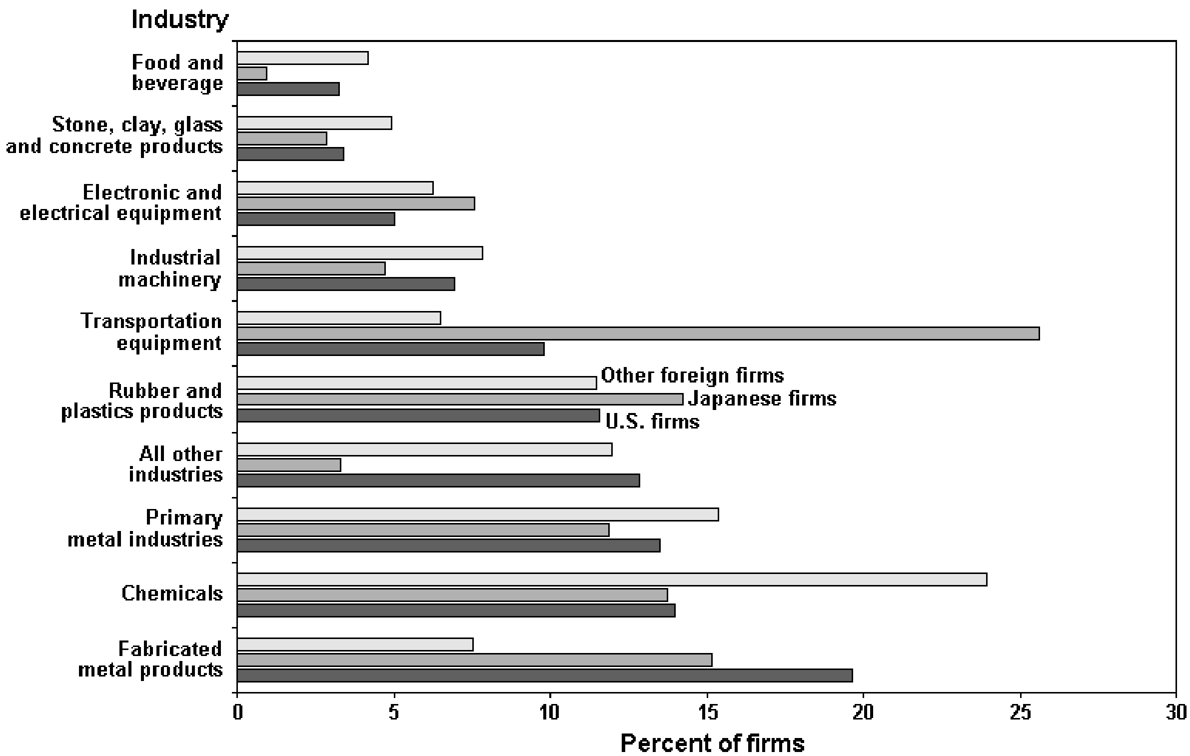

Figure 7.6. Comparative industrial composition for all study area firms regulated under the federal RCRA and TRI programs.
Source: RTK NET

among all three populations in one industrial category is found in fabricated metal products, where U.S. firms lead in representation.

In summary, examination of the industrial composition of the manufacturing populations in the study area, when differentiated by national origin and regulatory status, confirms that there are important differences. Japanese firms tend to be concentrated in fewer industrial categories, particularly in the transportation equipment sector, and become even more concentrated when only federally regulated waste generators are considered.

7.3.2. Comparison of locational rurality

Many investigators of the locational pattern of Japanese investment have concluded that Japanese firms prefer sites that are suburban, small-town or rural rather than urban. Analysis of Japanese facility locations and associated community populations (limited to auto assembly plants and component suppliers) by Reid (1990) and Florida and Kenney (1991) determined that over half were located in towns with populations less than 20,000. Using U.S. Census 2000 population data, Figure 7.7 compares the community size for Japanese and non-Japanese manufacturers. The populations are not precisely equivalent; since firm-level data for the entire population of nearly 50,000 manufacturers in the study area could not be obtained with available resources, the population of all Japanese firms was compared against the population of all RCRA-TRI firms.

Ideally, only the RCRA-TRI Japanese firms should be compared against the other RCRA-TRI firms, or the whole population of one against the whole population of the other. In order to test whether the RCRA-TRI population of manufacturers could be feasibly used as a surrogate for the general population, a matched pairs t-test was performed on the Japanese firms, assessing differences between the size of the communities associated with regulated and non-regulated firms (see Table 7.3). The test indicated no statistically significant difference between the two groups (0.941 correlation at the 0.01 level, t= -.108). The use of community size data associated with the RCRA-TRI population thus appears to be appropriate.

Because population figures were not available for certain unincorporated locales, a small percentage of firms was not included in this analysis. Figure 7.7 is based on a population of 522 Japanese firms, both RCRA-TRI and non-RCRA-TRI, compared to a

Table 7.3. Associated community size for Japanese firms in study area: Non-RCRA-TRI firms compared to RCRA-TRI firms

Source: Author's database

Community population	Nonwaste % of firms	Waste % of firms
>500K	8	5
250-500K	6	4
100-250K	3	8
50-100K	7	3
25-50K	15	15
10-25K	29	31
5-10K	14	18
<5K	18	17

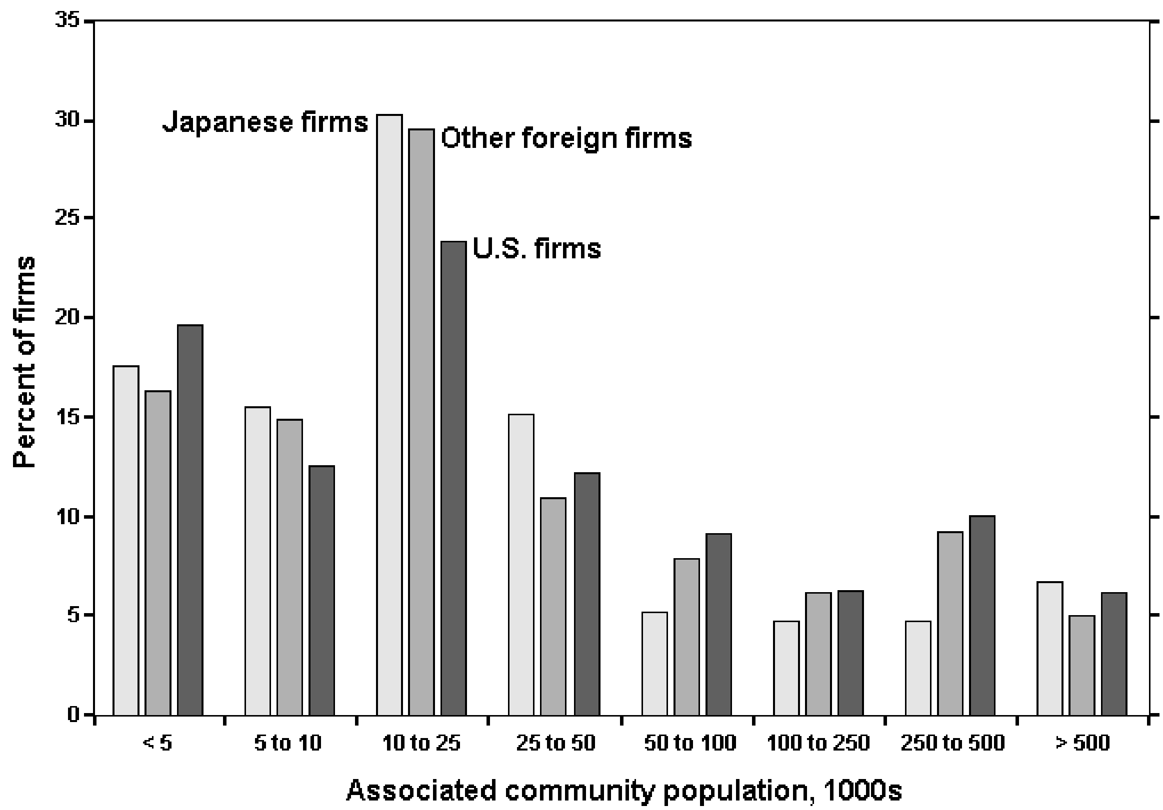

Figure 7.7. Associated community size compared to nationality of owner

Source: Author's database

population of 3,235 RCRA-TRI firms of both U.S. and other foreign ownership. This analysis confirmed, for the entire population of Japanese firms in the study area, Reid's (1990) and Smith and Florida's (1991) finding that Japanese firms in the automotive industry tended to locate in small towns. Nearly two-thirds – 63.4 percent – of all Japanese manufacturing facilities in the study area are located in communities with populations less than 25,000. Analyses of locational factors for Japanese firms have usually noted the preference of Japanese manufacturing investment for small towns but have failed to mention that this is part of an overall trend that includes domestic and foreign firms in the United States. The best that can be said is that Japanese firms are slightly more rural and slightly less urban than domestic firms, and differ even less from facilities established by other foreign investors. This is evident from both Figure 7.7 and the summary data in Table 7.4.

According to Heenan (1991), United States corporations have demonstrated a preference for smaller and relatively remote townships. This tendency, however, is not a recent phenomenon but dates back more than a half-century. Industrial migration into nonurban areas began in the late 1950s; during the period from 1960 to 1970 metropolitan areas experienced only 4 percent growth in manufacturing employment but an increase of 22 percent in nonmetro areas. The growth rate of manufacturing industries

Table 7.4. Concentration of manufacturing facilities by community size
Source: Authors database

	<25,000	>100,000
Japanese firms	63.4	16.3
Other foreign firms	60.7	20.5
U.S. firms	56.1	22.5

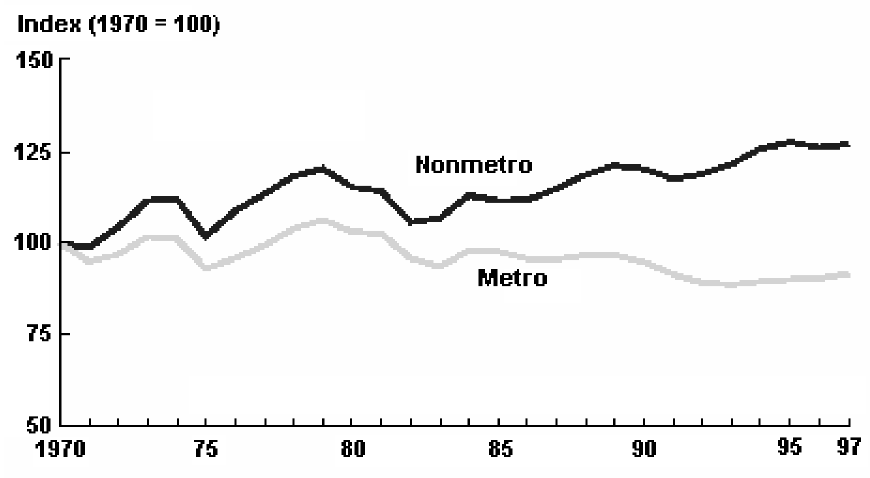

Figure 7.8. U.S. manufacturing employment, metro and nonmetro counties 1970-1997
Adapted from Roth (2000), based on Bureau of Economic Analysis data

peaked during the 1970s, declined during the recession of the early 1980s, and, recovering late in the decade, continued to climb during the 1990s (see Figure 7.8). By 1996, more manufacturing employment was located in nonmetro counties than in metro in every region of the U.S., with the greatest relative proportion of nonmetro manufacturing existing in the Midwest and South (Roth 2000). A predilection for rural sites is thus not simply a distinguishing trait of Japanese investment but applies to a large proportion of all manufacturing investment.

One further question of interest concerning the evident rurality of manufacturing firms is whether there is any association between the size of the facility and the size of the community. In other words, are large firms (in terms of employment) attracted to larger communities and smaller firms to small communities, or perhaps the converse? A Pearson correlation of facility size to the population of its associated community indicates that there is little relationship between the firm size and the community size, returning values of –0.072 for Japanese facilities (N=497) and +0.012 for non-Japanese facilities (N=3,235).

7.3.3. Comparison of operational scale

Analyses by Howenstine and Zeile (1994), based on 1990 data, and by Howenstine and Shannon (1996), based on 1991 data, of foreign manufacturing facilities established in the United States suggest that such facilities tend to be much larger than those of U.S. based firms (plant scale measured as value added per establishment) . Howenstine and Zeile's statistical decomposition of the difference indicated that 60 percent was attributable to a tendency in some industries for foreign-owned plants to be larger than U.S.-owned plants, while only 27 percent was attributable to a tendency by foreign-owned plants to be concentrated in industries with above-average plant scale.[7] Howenstine and Shannon (1996) noted that there were considerable differences in scale among different foreign investors, and identified Japanese facilities, along with those of Germany and the Netherlands, as tending generally to be of much greater size than those of U.S.-owned plants and also tending to concentrate within industries where the average plant size was larger than in the general manufacturing population.

This contention is investigated in the study area using total facility employment and areal extent in square feet as separate indicators of scale, rather than value added. Again, because firm-level data was not readily available for the general population of manufacturers, the comparison is made among facilities regulated under RCRA and TRI, for which size and employment data were obtained. The first necessary step in this analysis is to determine, as in the case of the associated community size comparison, whether there are differences in size between facilities so regulated and those that do not

[7] The remaining difference was attributable to within-industry differences and industry-mix effects. Howenstine and Zeile's statistical decomposition was based on expressing scale as a weighted average of values for individual industries (industries defined by their SIC codes), where the weight for any given industry is the industry's share in the total number of establishments.

qualify for regulation due to lesser waste generation. If there is no significant difference, then the entire population of Japanese facilities may be compared against the other foreign and U.S.-based facilities in the author's database. If, however, there is a substantial difference, then the comparison must be made using the smaller population of Japanese RCRA-TRI facilities only. The a priori assumption here is that a difference will exist; that facilities that produce more waste are likely to be larger in scale than those that do not produce sufficient waste to cross the EPA's regulatory threshhold.

Statistical and graphical analysis confirms that, for Japanese transplant firms, those regulated under RCRA-TRI are considerably larger than those that are not so regulated. Japanese firms not regulated under the RCRA-TRI programs (N=287 for which employment data was available) have a substantially smaller mean and median number of workers – 157 and 83.5, respectively – than the RCRA-TRI facilities. For RCRA-TRI facilities (N=200 for which employment data was available), the mean was determined to be 510 workers and the median as 300 workers. If the six automobile assembly plants, all of which are RCRA-TRI facilities, are removed from the analysis, the RCRA-TRI facilities are still much larger with mean and median of 379 and 293 workers. Similarly, comparing facility areal size, non-RCRA-TRI facilities (N = 212) have a mean and median size of 127,171 and 90,000 square feet respectively whereas RCRA-TRI facilities (N=159) have a mean and median of 577,020 and 194,200 square feet. Again, removing assembly plants from the analysis reduces the mean and median for the regulated facilities, but at 268,395 and 184,000 respectively are still double the size of the nonregulated facilities.

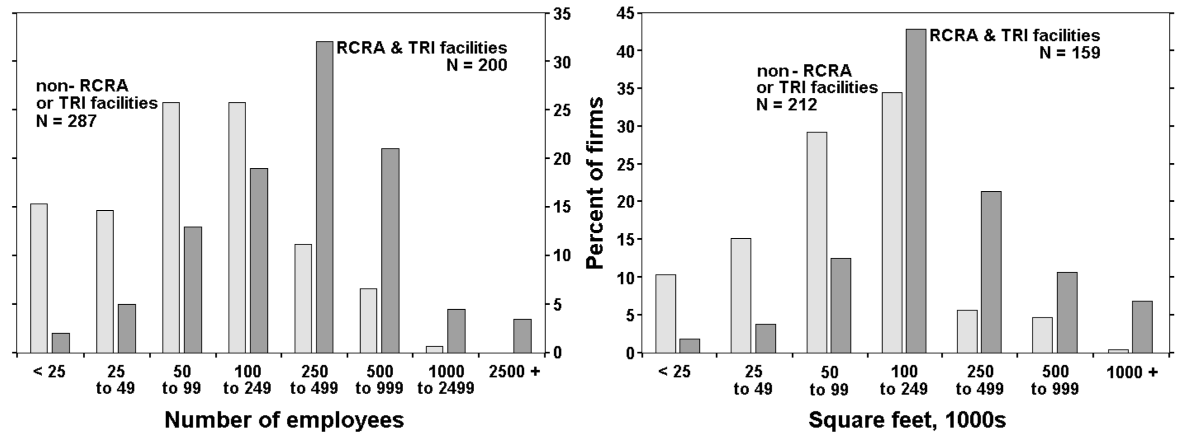

Figure 7.9. Comparison of operational scale for Japanese RCRA-TRI and non-RCRA-TRI facilities

Source: RTK NET and author's database

further analysis of facility scale will concern only RCRA-TRI populations.

Using this basis of comparison, Figure 7.10 shows the categorical distribution of facility scale for Japanese firms, other foreign firms, and U.S. firms. Differences of scale both in number of employees and areal extent are apparent, confirming Howenstine and Zeile's (1994) and Howenstine and Shannon's (1996) findings that foreign firms are, as a whole, larger than U.S. firms. Although Japanese firms also differ from other foreign firms as well, the differences are not of as great of magnitude as when either is compared

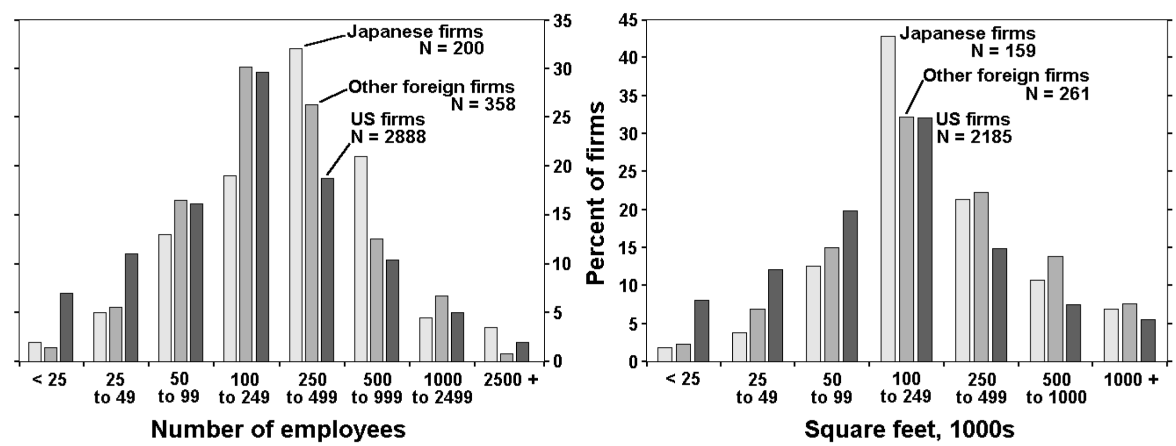

Figure 7.10. Comparison of operational scale by national ownership for RCRA-TRI facilities

Source: RTK NET and author's database

Means and medians for the overall RCRA-TRI populations by nationality are shown in Table 7.5. The slightly higher mean for Japanese facility areal size compared to other foreign firms reflects a greater number of very large facilities, notably auto assembly plants, that pull the Japanese mean size upward even though median sizes are nearly the same.

Howenstine and Shannon's (1996) analysis concluded that Japanese firms tended to be concentrated in industries having larger-than-average firm sizes. Table 7.6, based on number of employees,[8] provides the mean and median sizes of firms of Japanese, other foreign, and U.S. ownership in the nine leading SIC industrial categories (in terms of total firm numbers) and also in two derived categories, "motor vehicle production" and

Table 7.5. Comparison of operational scale by national ownership for RCRA-TRI facilities: Means and medians

Source: RTK NET and author's database

Note: Upper figure in each box is number of cases; middle figure is mean; lower figure is median.

* One exceptionally large firm omitted (31,581,000 ft^2)

** One exceptionally large firm omitted (37,000,000 ft^2)

*** Six exceptionally large firms omitted, each in excess of 10,000,000 ft^2.

	Number of employees	Size in square feet
Japanese firms	(200) **519** 300	(158)* **413,850** 197,100
Other foreign firms	(358) **390** 218	(357)** **396,819** 200,000
US firms	(2,888) **349** 150	(2,179)*** **273,114** 125,000

[8] Analysis here is based on employee numbers rather than on facility size because the extremes present in reported facility areal extent (one facility of 57 million square feet!) are less of a problem.

"part or all production related to motor vehicles." Whereas "transportation equipment" (SIC category 37) includes facilities involved in production for rail, air, and ship transport in addition to motor vehicles, "motor vehicle production" consists of ten SIC codes which are exclusively, or nearly so, concerned with production of components for and assembly of motor vehicles.[9] These codes are commonly used in sectoral analysis of the motor vehicle industry. The second category, "part or all production related to motor vehicles," includes a much wider array of manufacturers located in various SIC classifications and was determine by painstaking investigation of each individual manufacturing company in the author's RCRA-TRI database to determine whether any part of that company's production was used in vehicle manufacture.

Table 7.6 is an intermediate step to the more detailed analysis based on indexed data in Table 7.7, but highlights some relationships worth noting. First, comparing the data shown for the categories "transportation equipment" and "motor vehicle production" one striking phenomenon is evident: the number of firms involved decreases from "transportation equipment" to "motor vehicle production" except for Japanese firms, which increase in number. This may be attributed to Japanese firms not being much involved in U.S. production of rail, air/aerospace or ship transportation components and equipment within the "transportation" category, SIC code 37, so that firm participation is increased when codes from other major SIC classes involved in motor vehicle production are included. U.S. and other foreign firms are more substantially in non-motor-vehicle production within the transportation category so firm numbers decrease, rather than increase, when motor vehicles and components are considered separately.

[9] See Chapter 5, Table 5.5 for explanation of these particular codes.

Table 7.6. Comparison of operation scale for Japanese, other foreign, and US firms (RCRA-TRI) by industrial sector

Source: RTK NET and author's database

The minimum number of cases for analysis was set as 5 percent of the smallest population (Japanese firms) or 10 cases. Upper figure in each box is number of cases; middle figure is mean; lower figure is median.

Sector description	SIC class	Japanese firms	Other foreign	US firms
Food & beverage	20	insufficient cases	(16) **398** 245	(94) **366** 180
Chemicals	28	(23) **109** 50	(79) **231** 139	(389) **243** 71
Rubber & plastics products	30	(30) **378** 273	(39) **289** 190	(338) **249** 150
Stone, clay, glass & concrete products	32	insufficient cases	(18) **285** 238	(101) **241** 120
Primary metal industries	33	(23) **409** 245	(57) **419** 230	(396) **349** 150
Fabricated metal except machinery & transportation equipment	34	(30) **252** 205	(26) **170** 140	(579) **174** 100
Industrial machinery	35	insufficient cases	(30) **435** 275	(202) **539** 278
Electronic & electrical	36	(16) **694** 555	(24) **590** 397	(142) **721** 345
Transportation equipment	37	(54) **968** 438	(25) **932** 350	(281) **710** 300
Motor vehicle components & assembly	3465, 3592, 3647, 3694, 3711, 3713, 3714, 3715, 3716, 3751	(60) **957** 450	(21) **1,098** 360	(183) **862** 420
Part or all production related to motor vehicles	Numerous	(139) **611** 340	(99) **561** 300	(850) **468** 200

Secondly, in every industrial category for every ownership nationality class, the mean firm size greatly exceeds the median firm size. This may be attributed to a number of larger firms in each industrial class that pull the mean value upwards. This overbalancing tendency can be compared among Japanese firms, other foreign firms, and U.S. firms by calculating a weighted quotient representing the difference between the mean and median firm sizes for each class of firm owner nationality. For each nationality, the median plant size in an industrial sector[10] was divided by the mean and multiplied by the number of cases to provide a weighted representation for that sector. The weighted sector values were then summarized for each owner nationality and divided by the total number of cases:

$$Q^a = \frac{\sum \left(\frac{Mdn_i^a}{\bar{X}^a} * f_i^a \right)}{f_i^a}$$

where *f* equals number of facilities, *a* equals owner nationality, and *i* equals industry segment.

This resulted in weighted quotients for mean/median difference of 0.61 for Japanese firms, 0.62 for other foreign firms, and 0.48 for U.S. firms. This indicates that the overbalancing effect is strongest for U.S. firms and may be interpreted that there are a great many small U.S. firms compared to large U.S. firms, or a number of very large firms, resulting in a median that is low relative to the mean. In contrast, the lesser difference between the median and mean Japanese and other foreign firms indicates that firm size is relatively more clustered around the median. Referral back to Figure 7.10 indicates that this is the case, that there are greater numbers of small U.S. firms and Japanese firms, in particular, are more clustered around a median value.

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[10] For this calculation, the derived categories "motor vehicle production" and "part or all production related to motor vehicles" were excluded since they are comprised of overlapping categories.

Table 7.6 provides the basis to construct an index, shown in Table 7.7, that determines in which industries are concentrated the largest firms and to rank Japanese, other foreign, and U.S. firms within those industries. The mean size for all U.S. RCRA-TRI facilities was determined to be 349 employees (see Table 7.5) which becomes the index against which to compare industries. The 'Size Index" column in Table 7.7 lists figures derived by dividing the overall U.S. mean into the mean U.S. facility size in the specific industrial categories. Examination of this column shows that fabricated metals tend to have the smallest facilities, a result that is not surprising since many of these facilities are small "job shops" rather than factories dedicated to production of a few products. Also ranking below average in size measured by employment are facilities producing stone, clay, glass or concrete products; chemical industries;[11] and rubber and plastics products. Facilities in the primary metal industries equal exactly the mean for all industries, and

Table 7.7. Indexed comparison of Japanese and other foreign firms by industrial sector
Derived from Table 7.6 and author's database

Industrial group	Size Index	Japanese facilities Index - %	Other foreign facilities Index - %
Fabricated metals	0.50	0.72 (15)	0.49 (8)
Stone, clay, glass, concrete	0.69	insufficient cases	0.82 (5)
Chemicals	0.70	0.31 (14)	0.66 (24)
Rubber & plastics products	0.71	1.08 (14)	0.83 (11)
Primary metal industries	1.00	1.17 (12)	1.20 (15)
Food & beverage	1.05	insufficient cases	1.14 (4)
Industrial machinery	1.54	insufficient cases	1.25 (8)
Transportation equipment	2.03	2.77 (26)	2.67 (7)
Electronic & electrical	2.07	1.99 (8)	1.69 (6)
All/part vehicle production	1.34	1.75 (70)	1.61 (28)
Motor vehicle production	2.47	2.74 (30)	3.15 (6)

those in the food and beverage classification are very slightly above average. Industries in which facilities greatly exceed average size are industrial machinery, transportation equipment, and electronics and electrical equipment; the latter two being double the average facility size. Facilities for whom part or all production is targeted to the manufacture of motor vehicles are also larger than average. Largest of all are those plants engaged strictly in production of automotive components and assembled vehicles, though much of this effect may be in consequence of the very large size of assembly plants driving the mean upward.

Japanese firms average larger in size than U.S. firms in every category except for chemicals and electronics and electrical, although the difference in the latter category is slight. Part of the difference in the chemicals industry may be as a result of nearly a third of the Japanese chemical plants belonging to a single firm engaged in the manufacture of printing inks, which do not require the same scale of as facilities producing a diversity of chemical substances. Indexed differences between Japanese and other foreign plants are not great; Japanese facilities are larger foreign in fabricated metals, rubber and plastics, transportation equipment, and electronic and electrical; other foreign plants average larger size in chemicals and primary metals (statistically insignificant).

Table 7.7 can also be used to determine whether Japanese or other foreign firms are concentrated within industries having larger than average firm size, based on employment. The lack of sufficient cases in some categories is problematic, but for Japanese investment, at least 58 percent of firms are located within industries that where the plant size is smaller than or equal to the average U.S. plant size, and at least 34 percent are located in industries where the plant size is greater. This compares to 63 percent of foreign firms in industries where plant sizes are smaller, and 25 percent in industries with larger average size.

The investigations by Howenstine and Zeile (1994) and Howenstine and Shannon (1996) were based on analysis of single-year establishment data and evaluated facility size in productivity terms using value added as the measure . According to the results of the present study, which uses data for the entire RCRA-TRI population within four states regardless of establishment year and facility size measured in employment, Howenstine and Shannon's conclusion that Japanese facilities are concentrating within industries having larger average facility size is not supported. More than half of Japanese facilities have established in industries where the average firm size is smaller than the mean firm size for the general population of U.S. manufacturers, although Japanese plants within those industries tend to be larger than U.S.-owned plants in the same industry. Neither does this research support Howenstine and Shannon in this same conclusion about other foreign manufacturers as a whole, although no inferences can be made about specific nationalities since foreign manufacturers other than Japanese were not disaggregated in the present analysis.

7.4. Summary of the nature of foreign investment in the study area

Chapters 6 and 7 have focused upon the nature of Japanese investment in a study area consisting of four states: Indiana, Ohio, Kentucky, and Tennessee. Japanese manufacturing investment in the United States is concentrated in two regions, along the Pacific coast and along a corridor that extends from southeast Michigan through Georgia. This latter region is usually defined by proximity to the twin interstate highways, I-65 and I-75, that roughly parallel one another from north to south, and is often referred to as “auto alley” reflecting the characteristic concentration of automotive-related industries throughout.

Where historically manufacturing in general and the automotive industry in particular was once focused in the vicinity of the Great Lakes, industry has gradually drifted southward. In the automotive industry, this trend dates to the abandonment of the branch plant system by major domestic automakers, where branch plants producing identical vehicles marketed in regions were replaced by specialized plants shipping nationwide. The industry became market-oriented, concentrating its spatial distribution within the optimal geographic location providing centralized access to markets. This trend was reinforced by the arrival of major Japanese auto assembly transplants in the 1980s.

The Japanese automakers, dissatisfied with the quality and delivery of components supplied by U.S.-based firms, were initially almost wholly dependent upon imports. Over the next two decades, however, an intricate network of supplier firms developed around the pioneering assembly transplants, as traditional Japanese suppliers were attracted or coerced to locate facilities near major customers in the United States. As these networks developed and existing U.S.-based firms learned to meet Japanese requirements, domestic content of transplant-produced automobiles increased. Japanese investment was not limited to producers of automobiles and related components, for many firms in other industries also made investments in U.S. manufacturing. Japanese facilities are, however, concentrated in fewer different industries than are U.S. firms, and a detailed investigation by the author of individual facilities revealed that automotive parts and components represented part or all of the production for 66.8 percent of Japanese firms.

Investigation of the spatial pattern of Japanese transplants in the study area confirms the observations of earlier researchers that such facilities tend to locate in nonmetro areas, that is, in suburbs, small towns and in rural locations, where such locations are provided with good interstate highway connections to allow just-in-time delivery schedules to be met. This proclivity is not unique to Japanese firms, however, but is representative of a more widespread and general trend of industrial deurbanization by both domestic and foreign manufacturers.

Finally, research concerning the scale of foreign operations has indicated that foreign firms, particularly those of Japanese ownership, tend to be larger in size than those of domestic ownership within the same industries and that there is also a tendency for such firms to be concentrated in industries where overall firm size is larger. The present research concludes that the former is true, but that the latter is not completely supported. The present study also finds that facilities that meet the waste generation threshhold criteria to become regulated under the federal RCRA and TRI programs tend to be larger than plants that do not exceed the threshhold criteria; in other words, larger plants generate more waste.

The spatial pattern of Japanese investment, and of domestic and foreign manufacturing investment in general, has implications for regional environmental quality. Investigation of these implications is, however, beyond the scope of the present study but presents a fertile area for future research. In contrast, the industrial structure of Japanese investment and the scale of operations is pertinent to this investigation of environmental performance. The influence of industrial sector and scale of operations in this context are investigated in detail in Chapter 9.

In Chapter 8, which follows, additional insight on the characteristics of Japanese facilities, particularly concerning methods and systems of environmental management, is gained through analysis of the results of a mail survey sent to all Japanese firms in the study area.

Chapter Eight

Characteristics of the Survey Sample Population

8.1. Purpose of the Mail Survey

Investigation of the environmental performance of Japanese firms in the study area was designed to use three research strategies: (1) analysis of firm-specific federal waste management data; (2) a mail survey concerning environmental policies and practices sent to all Japanese firms in the area of interest; and (3) case studies of a limited number of firms. The analysis of federal waste data is essential to provide comparisons of performance at various levels between domestic and Japanese firms and among different categories of firms, seeking differences by nationality, by industrial sector, and by facility size. Quantitative analysis of this nature is often able to detect differences that may exist, but provides little in the way of explanation as to the reasons for differentation. The case studies are capable of providing considerable detail in regard to the operations and philosophy of a particular firm, but as is the nature of qualitative methods, suggest rather than demonstrate cause-and-effect.

The use of a survey questionnaire targeted to a specific population constitutes a method that lies between these two extremes and complements both. Whereas analysis of information contained in a database is completely detached from the object of study, the conduct of a case study usually requires personal contact, through interviewing and direct observation. The mail survey requires a certain degree of interaction with the respondents and is thus in a sense somewhat qualitative; a structured interview conducted through an intervening communications medium with a built-in delay. Because the results of a properly administered survey are subject to quantitative analysis, the mail survey is able to serve as linkage between hypothesis and the phenomena studied. If the researcher supposes, as in the present study, that there may be a relationship between improved environmental performance and lean production methods (and/or a higher incidence of environmental management system implementation), then a survey may be the only method to reveal the dimension of these factors within the sample population.

8.2. The Mail Survey Responses

The survey instrument[1] was mailed out during September 2001 to the 520 firms in the study area identified as manufacturing facilities of Japanese ownership. Forty-three were returned as undeliverable due to incorrect or insufficient address, or because the firm was no longer in operation. From the remaining 477 firms, a total of 59 responses were received; a response rate of 12.4 percent. Of the responses, 53 were valid forms, so that the overall survey participation represented 11.1 percent of firms who had received the survey instrument.

According to Dillman (2000, 323) mail surveys sent to businesses and other organizations have an average response rate of 21 percent. Although the response rate for the present survey is relatively low, it falls within the range of returns received in other, similar surveys. A survey mailed by Schreurs (2001, 214) to 92 Japanese firms in Kentucky concerning environmental policies and practices received only nine responses, of which only six provided the information requested. Kaynak (1997, 131) received a response of 20.3 percent to his survey investigating “the relationship between just-in-time purchasing and total quality management and the effects of this relationship on firm performance” mailed to 1,884 firms nationwide. A survey concerning environmental

[1] A copy of the form is included as Appendix 3 and is described in Chapter 5.

management practices mailed to 650 firms provided Theyel (2000, 254) with a response rate of 28.9 percent; a similar survey by Russo (2001, 15) sent to 1,004 firms in the electronics industry generated 31.3 percent returns. A mail survey concerning the regional business environment and factors influencing location decisions sent by the Tennessee Center for Business and Economic Research to 2,023 Tier I and Tier II automotive suppliers in the Southeast had a return rate of only 9.1 percent from in-state firms and insufficient responses for analysis from out-of-state firms.

One of the most successful surveys, in terms of response, was that by Florida and Davison (2001,100-101) which also concerned environmental management policies and practices. From their sample of 583 Pennsylvania manufacturers, these investigators obtained a participation rate of 36.7 percent. This high response rate may be attributed in part to his care in selecting firms to be included in his sample, which consisted in large part of companies who had participated in regional pollution prevention initiatives or had won state awards and were hence more inclined to provide information about their activities. In addition, Florida and Davison maximized their returns by a thorough sequence of follow-up steps to the original inquiry which included phone calls to all non-respondents. Had a similar program been followed for the present research survey, the response rate might have been higher. Following the initial inquiry, however, no further attempts were made to contact firms who failed to respond.

The survey was intended to provide characterization of Japanese transplant firms in greater detail than could be obtained through published statistical summaries, particularly in regard to environmental policies and innovative practices. The relatively low response rate, however, indicates that caution may be necessary in generalizing from the survey results to the general population of Japanese transplant firms. Assuming that innovative manufacturers whose environmental performance is superior may be more likely to respond to a survey inquiry than firms with poor records, some bias may be present. Even so, this is not necessarily a major problem, since a primary purpose of the research is to discover innovative practices that underlie superior environmental performance.

The survey instrument addressed three general areas of inquiry: characteristics of the production operations, particularly the extent of implementation of lean manufacturing methods; environmental management policies and practices; and attitudes concerning pollution prevention. Respondents were asked to provide their job titles, and 47 of 53 respondents did so. Forty-five percent of the survey forms were filled out by facility environmental staff; 32 percent by senior executives, including company presidents, vice-presidents, and plant managers; and 23 percent by other management and supervisory personnel.

8.1. General characteristics of respondents

The basic facility characteristics of industry segment, facility employment, and facility size (square feet) represented by survey respondents corresponded very closely to the general population of Japanese transplant firms in the study area. Survey respondents thus included a variety of different industries and ranged from very small facilities to very large facilities.

Comparison of SIC category distribution between respondents and all Japanese facilities in the study area indicates a relatively close correspondence; transportation equipment manufacturers are somewhat overrepresented and chemical manufacturers underrepresented (Figure 8.1). Seventy percent of survey responses were included in just four of the two-digit SIC industrial codes: 30 percent derived from the transportation category, and 13 percent each from rubber and plastic products (SIC 30), fabricated metal products (SIC 34), and industrial and commercial machinery (SIC 35). Also significant, but to a lesser extent, were primary metal industries (SIC 33) and electronic and electrical equipment (SIC 36), each with 8 percent of total respondents. The chemical industry, which accounts for nearly 12 percent of all Japanese firms in the study area, was represented in the survey by only a single respondent. The low response from the

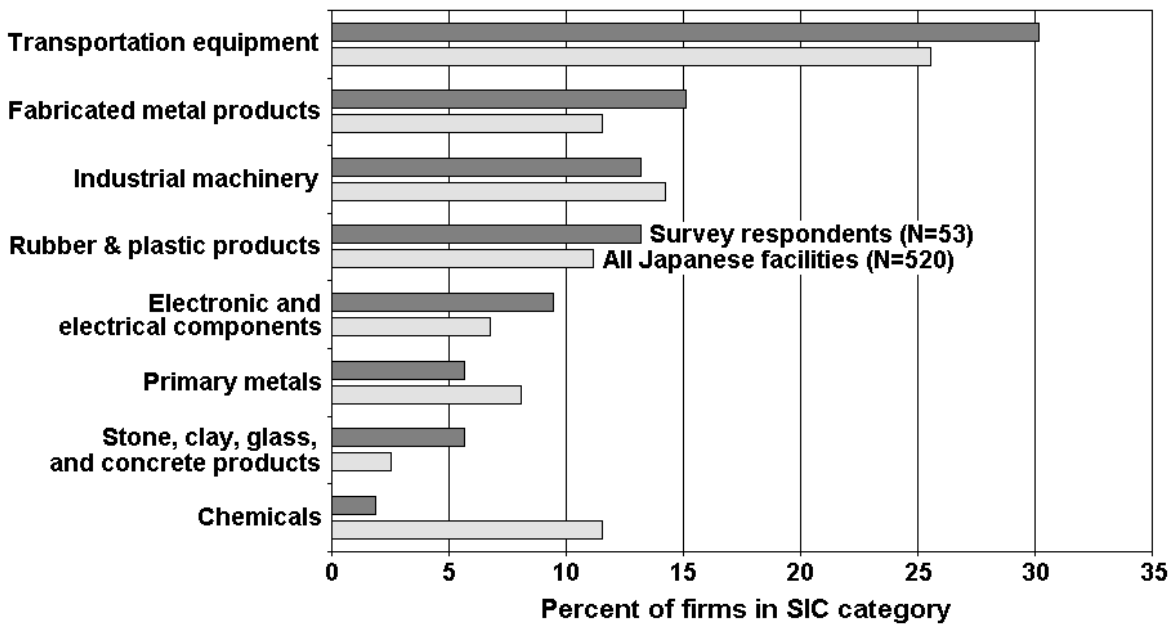

Figure 8.1. Comparison of survey respondents to all Japanese firms by SIC class.
With the exception of survey respondents in the chemical industry, categories with less than 2 percent representation are not shown.

chemical manufacturers may be because these industries typically are among the most polluting and hence less likely to voluntarily report environmental practices.

Figure 8.2 shows the size distributions for the survey respondents, where size is reported as total facility employment and total square feet of the facility. Both measures of operation scale are skewed positively (2.6 and 4.3 skewedness, respectively), as are these parameters for the population of all Japanese firms in the study area (see Chapter 7, Figure 7.9). Accordingly, median size again is a more appropriate measure than mean. Respondent firms in the survey had a median number of employees of 155 (mean of 300.5) and a median facility size of 120,000 square feet (mean of 210,984). This

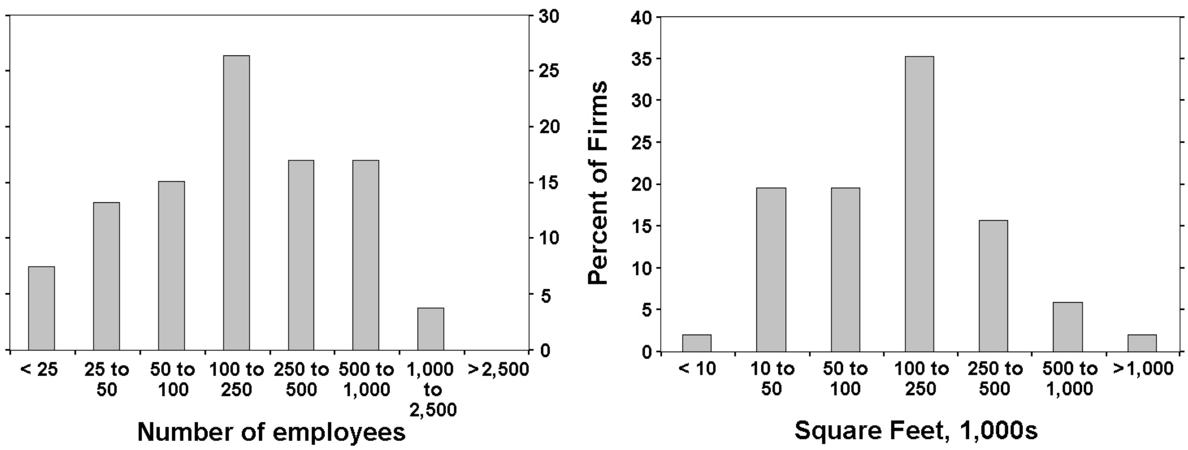

Figure 8.2. Survey respondent facility employment and size

compares to facility medians of 137 employees and 125,000 square feet for all Japanese facilities in the study area.

Like the larger population of Japanese firms in the study area, most respondent firms were engaged in production supportive of the automotive industry. More than 75 percent of respondent firms reported that at least half of their production was so utilized, compared to about 60 percent of all Japanese firms in the study area. Most of the respondent facilities manufactured components and products assembled from parts obtained from other suppliers, rather than producing such parts within their own facilities. Nearly half (47.2 percent) of all respondents reported that 100 percent of the parts used to assemble their products were outsourced from other firms, and three-quarters of all firms obtained 75 percent or more of their parts from outside. Only 17 percent of respondents did not purchase any parts or materials from external suppliers.

In summary, the structural characteristics of the respondent firms, in terms of sectoral distribution, employment, and facility size, resemble those of the entire population of Japanese transplant firms in the study area.

8.2. Production Operations

Under the heading "Production Operations and Management Style," the survey form offered three choices: Japanese, Fordist, and Other. "Japanese production systems" were defined on the form as "derived from or influenced by the Toyota Production System," and "Traditional western manufacturing, known as Fordism," was described as "using mechanized technology to facilitate high-volume standardized output in long production runs" and to embody "a work design using unskilled and semiskilled workers performing routinized simple tasks to produce standardized products." As might be expected from a sample of Japanese transplant firms, the overwhelming majority (78.8 percent) of respondent firms reported that Japanese methods dominated production operations. What is surprising, however, is the size of the proportion of firms that do not.

Six of the respondents (11.5 percent) indicated that Fordist methods exclusively were used in production operations. Five of these companies were acquisitions of previously existing American firms, some of which had been in operation for decades prior to a change in nationality of ownership, and thus had an embedded corporate culture in the Western manufacturing tradition. A representative from one of these firms, located in Kentucky, when contacted in 1999 as a possible case study candidate for the pilot research (O'Dell 2001), had stated, "Yes, we have a Japanese owner, but we don't use

Japanese methods here. The owner has bought a lot of American companies and doesn't make any changes in the way they operate." In another example, the president of one of the companies to which the survey form had been sent returned a personal letter instead of the form, noting "While we are partially owned by a Japanese firm, we are an autonomous entity. There are no Japanese at our facility and we do not practice the Japanese manufacturing methods referred to in your letter."[2]

Four companies reported using a mixture of Japanese and Fordist methods. Significantly, all four are greenfield facilities; three established during the late 1980s and one established in 1998. One facility reported using "some of both"; another indicated a "combination of American and Japanese philosophy." One firm was very specific in its assessment of production methodology, stating "80% TPS [Toyota Production System], 20% traditional." The remaining firm indicated a mixture of "Western and Japanese management," noting that the company president was an American national and the vice-president was Japanese.

Many of the firms reporting Japanese management systems as the dominant operational methodology are, in fact, most likely hybridized to some extent, as suggested by the literature review in Chapter 4. The case study for Link-Belt Construction Equipment (Chapter 12) suggests that some Japanese corporations, particularly when an acquisition has been made of a pre-existing firm, may achieve a gradual cultural transformation by implementing Japanese methods in stages. Difficulties in acclimatizing American workers to Japanese methods have been noted by several writers, in particular Graham (1995), writing about the Subaru-Isuzu automobile assembly joint venture in Indiana, and the experience of Mazda in Michigan.

[2] Since the survey form was not returned, this firm could not be included among valid responses.

The survey results indicate a partial or incremental approach to the implementation of Japanese methods by many of the respondent firms (see Figure 8.3). Kaizen and just-in-time techniques were in use by majority of firms; approximately 60 percent of firms reported full implementation throughout the facility for these methods, and about 85 percent of respondents indicated either full or partial implementation. Quality circles or other small group activities, TQC/TQM, kanban systems, and pokayoke design or mechanisms each were fully implemented in about 40 percent of firms. Of these latter methods, TQC/TQM techniques were most widely applied with full or partial implementation in 80 percent of respondents. For each of the methods, a certain proportion of facilities indicated that the method did not apply or was not compatible with the type of production at the facility. This proportion was relatively low (10 to 14 percent) for most of the management methods, but of greater import concerning

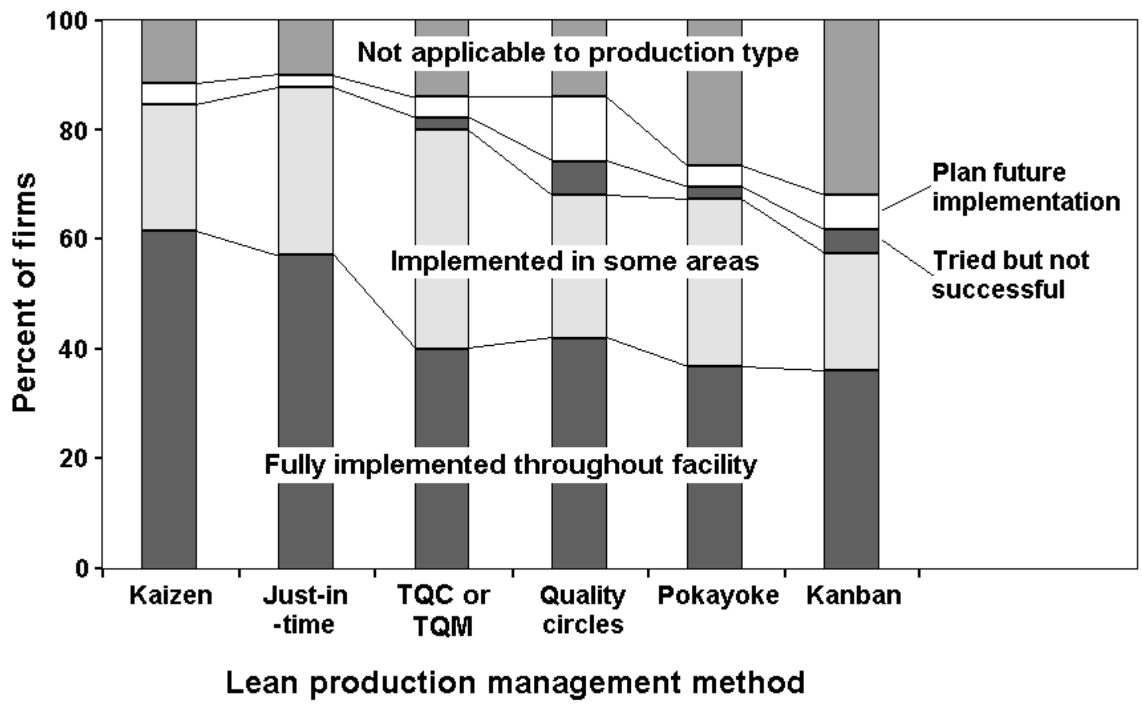

Figure 8.3. Implementation of Japanese management methods reported by respondent facilities.

implementation of kanban or pokayoke systems. For both kanban and pokayoke, nearly a third of facilities reported that these techniques were not suitable for their operations.

The design of the form also allowed an assessment of the use of multiple management techniques, thus indicating the depth of implementation of Japanese methods. Table 8.1 shows tallies for multiple methods in various combinations. Nearly half of all firms responding to the survey had fully implemented both kaizen and just-in-time methods, and three quarters of respondents reported that these two, definitive, Japanese methods were either fully or partially controlling production operations. When kaizen and just-in-time are combined with TQC/TQM quality control methods, the resulting 62 percent of the survey respondents most likely represents the proportion of this sample population that is most clearly following core Japanese methods. Only one-fourth of the respondents indicated that their facilities employed, fully or partially, all six of the methods. Overall, these results indicate a high degree of hybridization within transplant firms.

Only one-third (N=18) of survey respondents provided any information that dated the

Table 8.1. Combinations of Japanese management methods reported by respondent facilities.

Combination of Management Methods	Percent of firms
Kaizen & JIT both fully implemented	46
Kaizen & JIT both fully or partially implemented	75
Kaizen, JIT & TQC/TQM fully or partially implemented	62
Kaizen, JIT, TQC/TQM, and quality circles fully or partially implemented	46
All 6 methods fully or partially implemented	25
All 6 methods fully implemented	8

implementation of the various methods utilized, and in many cases this information appeared only partial. Only two of the 17 facilities that provided dates for multiple methods indicated that all methods had been implemented simultaneously. For the 15 facilities that indicated a phased implementation of Japanese methods, the range between earliest and most recent implementation varied from a high of 17 years to only two years compared to a range of facility ages from 18 years to 6 years since establishment. A Pearson correlation of facility age compared to implementation range returns a value of 0.38, indicating a slight linear relationship where some older facilities have taken a longer time to implement several production methods. Despite this ambiguity, some general observations can be made. In nearly every case where implementation dates are given for kaizen and/or just-in-time (N=15), it is these two methods that were implemented first, followed by other methods at later dates. Pokayoke is the method next most likely to be employed at a relatively early date. Kanban, quality circles, and TQC/TQM appear most often as the most recent implementations, with little significant difference among them.

The respondent facilities were possessed of a relatively high level of technology application, with nearly 70 percent of respondent facilities having fully or partly implemented robotics in manufacturing, 50 percent fully or partly utilizing flexible manufacturing systems, and 50 percent fully or partly employing computer-integrated manufacturing (CIM) systems. Twenty-five percent of respondent facilities fully or partly employed all three of these manufacturing system elements, and 56 percent fully or partly employed two of the three systems.

Table 8.2. Approximate technological intensity of manufacturing sectors represented by survey respondents. *Higher value = greater intensity.*

Sector	Number of firms	Technological intensity
Industrial & commercial machinery	6	2.7
Stone, glass, clay products	3	2.0
Miscellaneous manufacturing	1	2.0
Transportation equipment	16	1.9
Rubber & plastics products	7	1.4
Primary metal industries	4	1.3
Fabricated metal products	7	1.1
Chemicals and allied products	1	1.0
Electronic and electrical equipment	4	1.0
Control and measuring instruments	1	1.0
Metals service centers	1	1.0

The technological intensity of sectors within Japanese manufacturing can be crudely approximated using this information. Table 8.2 shows the technological intensity ranking of the survey respondents by sector, derived by summing the technology methods for each facility (1, 2 or 3, where a "3" represents a firm utilizing robotics + flexible systems + CIM) and determining the mean of this value for each industrial sector. Technological intensity refers, of course, to the technology used in manufacturing processes and not to the technological complexity of the items produced. A higher level of technological intensity indicates more fully automated processes. Due to the small number of cases in most sectors, this should only be considered an approximation, but suggests an intriguing area for further research such as that pursued by Klier (1996), Shapira and Rephann (1996) and Bergman *et. al*. (1999).

8.3. Environmental management

For the total survey sample, 75 percent of responding firms had developed a company environmental policy statement; 48 percent had a specific company waste reduction or pollution prevention program; and 69 percent had an environmental management system in place, either ISO-14001 or another EMS. These figures are more meaningful when assessed in the context of other factors such as type of production and facility size.

Eighteen firms (38 percent) had achieved ISO-14001 certification and 9 firms (18 percent) were engaged in the process to implement ISO-14001 and become certified. Of the 22 firms that did not possess ISO-14001 certification at the time of the survey and were not then engaged in the process to become so certified, there was an almost even split between those who intended to pursue certification (45 percent) and those who did not (55 percent). Seven of the 12 facilities (58 percent) having no plans to obtain certification were engaged in production unrelated to the automotive industry. Of the five facilities with auto-related production and no intention to become certified, only three were engaged in the manufacture of automobile components: two were metals service centers who prepared sheet metal for auto manufacturers. In contrast, 15 of the 18 facilities with ISO-14001 certification were engaged in production of automotive components; all 8 facilities who reported they were "pending" in the ISO-14001 certification process but had not yet achieved certification were engaged in production of automotive components; and 9 of the 10 facilities lacking certification who plan to undertake this in the future were engaged in production of automotive components.

Production of automotive components thus appears to be a significant factor in adoption of the ISO-14001 environmental management system; an unsurprising development given that Toyota, Honda, Ford and several other automobile assemblers either require or strongly encourage this certification from their suppliers. Facility size also appears also to be of consequence in EMS adoption. Of the 12 firms who reported no intention to seek ISO-14001 certification, half of the firms employed 50 or fewer workers, whereas only one of the 18 firms having achieved this certification employed 50 or fewer workers. Non-adopter firms had a mean of 151 workers and a median of 74 workers, compared to a mean of 512 and median of 400 for firms with current certification.

Only 3 of the 12 non-adopter firms had a company environmental policy statement and 4 had an environmental management system other than ISO-14001, whereas all certified firms and all but 2 of the 8 undergoing the certification process possessed a policy statement in addition to their ISO-14001 EMS. Only two (of 11 reporting this information) non-adopters and 3 of 10 not certified but intending to in the future had a specific waste reduction or pollution prevention program, compared to 12 of 18 ISO-14001-certified firms and 5 of 7 firms with certification pending with such a program in place.

According to research by Florida and Davison (2001,86) concerning adoption of advanced environmental practices, approximately 24 percent of manufacturing plants (undistinguished by nationality) in their survey with more than 50 employees had an EMS; 28 percent had a formal pollution prevention (P2) program, and 18 percent had both. In general, plants with both an EMS and a pollution prevention program tended to be significantly larger than other facilities, averaging 250 more employees than facilities lacking these. In the present survey of Japanese manufacturers, 64 percent of facilities with more than 50 employees possessed an environmental management system, 48 percent had a formal pollution prevention program, and 38 percent employed both an EMS and pollution prevention program. Corresponding to Florida and Davison's findings, Japanese firms with both EMS/P2 average larger than Japanese firms lacking one or both, but not to the same magnitude. Japanese EMS/P2 facilities averaged only 142 more employees than non-EMS/P2 Japanese facilities (means of 392 compared to 250 and medians of 265 versus 140). Similarly, Russo (2001) found that larger plants tend to more readily adopt ISO-14001 than smaller facilities.

Several researchers have noted that the commitment of upper management to environmental goals is essential to the successful development and implementation of policies and practices that improve environmental performance (Porter and Van der Linde 1995b; Bhat 1998; Erikson and King 1999; Nash and Ehrenfeld 2001). Others (Florida *et. al*. 2001, Theyel 2000) have emphasized the importance of the willing participation of line workers. Less has been said about the role of corporate and facility environmental staff, who are, in fact, those responsible for developing the means by which environmental goals may be achieved and monitoring, on a day-to-day basis, the environmental performance of their firm.

Florida *et. al.* (2001) noted that the presence of environmental staff is positively associated with the innovations of "environmentally conscious manufacturing," advanced manufacturing practices that include source reduction, recycling, pollution prevention, and green product design. Facilities with a high-adoption rate of such practices had larger environmental staffs than non-adopters. "All of the high-adopter plants had dedicated environmental staff," the authors observed, while noting that the tenure and experience of environmental staff were also important. This assessment was based upon research reported in Florida and Davison (2001), who found that EMS/P2 facilities had significantly larger environmental staffs compared to other plants in their survey, averaging 4.5 compared to 1.4 environmental personnel.

Because Florida and Davison did not specify how environmental personnel were classified in their survey, their results may not be directly comparable to the results of the present survey of Japanese transplant firms. The Florida/Davison survey did not, apparently, differentiate between full-time and part-time environmental duties. The survey instrument sent to Japanese facilities asked, first, how many personnel held full-time positions dedicated solely to environmental management issues. For those who did not qualify as full-time environmental staff, the survey then asked the respondent to specify which department handled environmental issues as part-time duties in addition to their primary responsibilities: health and safety, or engineering/technical staff. Alternatively, the respondent could choose "no environmental staff on site" and/or "environmental staff associated with U.S. or regional office, not resident at this facility."

Japanese manufacturers who maintained full-time environmental staff (22 of 53 respondents) averaged 1.7 such personnel per facility. Of these 22 firms, which averaged 407 workers (median 257), 50 percent were EMS/P2 facilities and 50 percent had achieved ISO-14001 certification. Of the remaining 31 facilities, 3 did not report any information about environmental staff. For the 28 facilities who did so report, indicating part-time environmental duties, 26 percent were EMS/P2 and 22.5 percent had obtained ISO-14001 certification. These firms averaged 221 workers (median 120). Larger facilities are thus more likely to have both proactive environmental policies and practices and to maintain full-time environmental staff than are smaller firms.

Full-time environmental staff were autonomous (no department specified) at 12 of 22 facilities (55 percent). At 7 firms (32 percent), environmental staff were associated with departments of Health and Safety, and were included among Engineering personnel for 3 facilities (12 percent). Out of the 28 firms that did not employ full-time environmental staff, one facility had no one at all assigned to environmental duties. Accordingly, 27 firms in the survey sample assigned environmental functions to personnel in other departments as part-time duties. For such firms, these personnel were located within Health and Safety (37 percent) and Engineering (63 percent).

Fifty firms responded to the question about the decision-level for implementation of environmental practices and innovations. Three-quarters (76 percent) of respondents indicated that such decisions were made at the local, facility level, and 14 percent indicated that decisions were made at the level of the U.S. corporate office. Only a single firm noted that environmental decisions were made by the home office in Japan. For the 4 remaining facilities (8 percent), such decisions were made at multiple levels.

8.4. Pollution Prevention

Several questions in the survey addressed waste minimization and pollution prevention practices rather than general policies. These questions concerned: (1) the significance of various classes of waste as components of the facility's total production waste; (2) the methods used for management of wastes, based in part on the TRI waste management categories; (3) ranking of the effectiveness of various waste minimization and pollution prevention strategies for the facility; and (4) ranking of internal and external factors driving adoption of waste minimization and pollution prevention strategies.

Fifty-two respondents ranked four general waste categories - airborne emissions, wastewater, nonhazardous solid waste, and hazardous/toxic waste - as to their significance as components of total waste generation by the facility. Rankings were based on a scale from 0 to 4, where 0 represented "not applicable to facility" or "not significant" and 4 represented most significant. The results are shown in Figure 8.4. Overall, nonhazardous solid waste and wastewater represented the most significant components of total production waste for most companies. Hazardous waste was the lowest-ranking component, but, with a mean value of 1.6, not unimportant. These results conform with anecdotal evidence that companies expend considerable effort to reduce overall solid waste generation, reported both in the "success stories" submitted with survey responses (see below) and through research for the case studies (see Chapters 10-12). Haulage and disposal fees for all waste categories can amount to tens of thousands of dollars annually, providing a substantial economic incentive to reduce waste quantities.

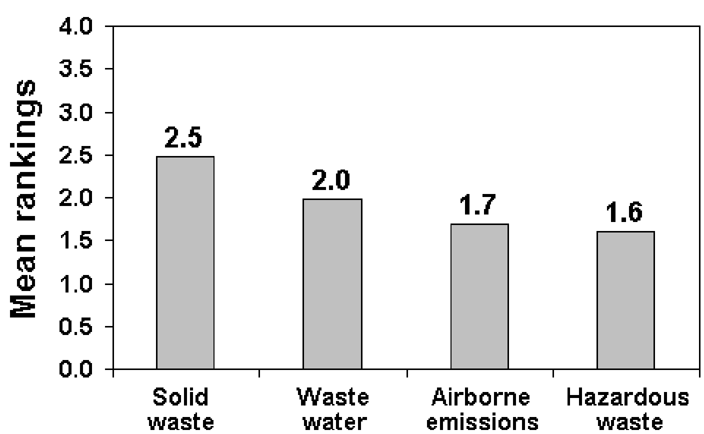

Figure 8.4. Waste generation significance rankings

The question concerning waste management practices was designed to discover which are the most common methods and whether management was primarily onsite or contracted off-site. A format similar to the TRI reporting categories was employed, but with additional categories to address all forms of production waste, not just the hazardous waste regulated under TRI. TRI management categories include "energy recovery" (combustion of flammable materials); recycling on- and off-site; treatment on- and off-site; landfill disposal; and release to the environment. Where the categories differed from TRI was in breaking down "landfill disposal" into specific waste categories: solid, special, and hazardous.

Municipal solid waste landfills accept household and commercial solid waste such as paper, yard waste, food waste, plastics, metals, glass and wood. Solid waste landfills discourage but will accept small amounts of "household" hazardous waste such as paints and pesticides but do not allow industrial hazardous wastes. Some municipal solid waste landfills have permits to accept and treat various types of "special" waste. Special waste occupies a niche between solid waste and hazardous waste and includes such materials as light bulbs, medical waste, used motor oil, asbestos, ash, petroleum-contaminated soil, and sludge from wastewater treatment plants. It is the responsibility of those disposing of the waste to separate special wastes from ordinary and hazardous wastes. Hazardous wastes are those that exhibit characteristics of ignitability, corrosivity, reactivity, or toxicity. Not all states have hazardous waste landfills and in such cases hazardous waste must be shipped out of state.

Respondents were asked to assign a percentage to each category reflecting the amount of the facility's waste managed using that method. In those relatively few cases where

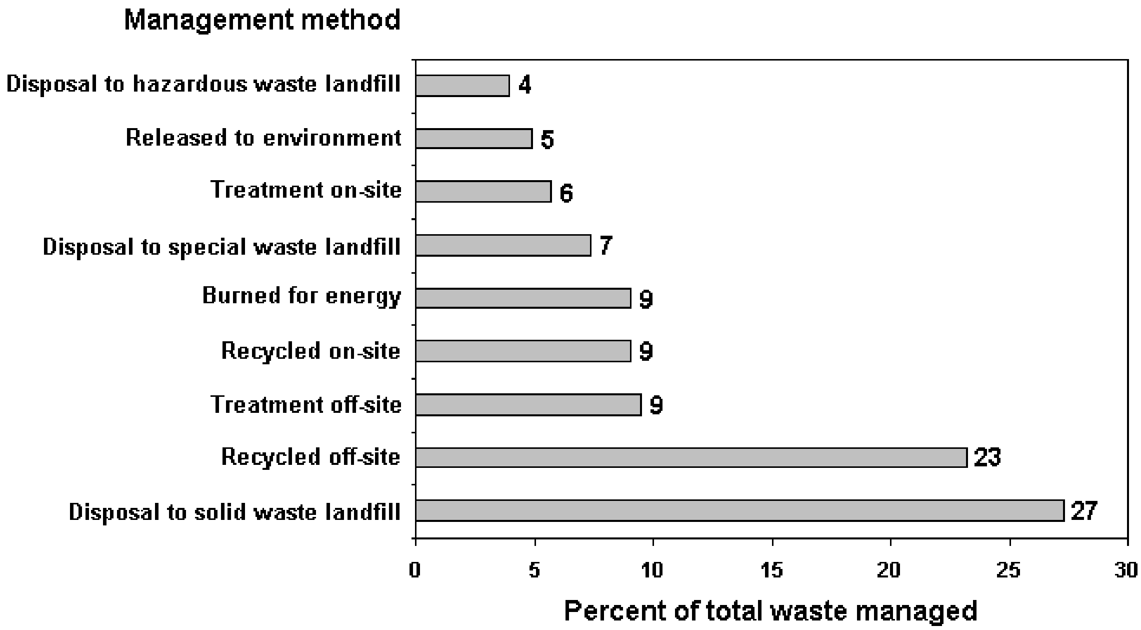

Figure 8.5. Waste management methods utilized, facility means.

estimates provided by the facility produced a total slightly more or less than 100 percent, the error was adjusted proportionately across the percentages reported for that facility. Totals in excess of 100 percent were generated by a respondent's careless math or when a facility did not provide an exact percentage for one or more categories but instead indicated, for example, "less than 5 percent." Where discrepancies in the totals exceeded ±5 percent, the data for that facility was discarded and not included in the analysis. Valid waste management method information was thus obtained for 44 facilities. The results are summarized in Figure 8.5.

Accounting for an average of 27 percent of all waste, disposal to a solid waste landfill clearly stands out as the single most important management method for industrial wastes. When combined with hazardous and special waste, landfill disposal comprises 38 percent of all waste generation. Given the high cost of this method, this explains why solid waste reduction is often a high priority for facilities. Off-site recycling is the next most significant management method; off-site and on-site recycling combined account for about a third of all waste. Large firms (workforce>250) differed significantly from smaller firms in several of the management methods. Larger firms (N=17) tended to recycle more of their waste, a mean of 48 percent combined off-site and on-site, compared to only 22.4 percent for smaller facilities (N=27). Smaller firms tended to burn more waste for energy (12.4 compared to 3.7 percent) and to treat more on-site (7.8 compared to 2.4 percent).

In summary, relatively less detrimental management methods such as recycling, treatment, and energy recovery amount to 56 percent of industrial wastes for all respondents whereas land burial (landfill disposal) and environmental release averages 44 percent of such wastes. Each of these methods represents, in the order given, increasing inefficiencies in the production process. The most efficient - and the most effective - waste management method is invisible by this accounting technique: source reduction, or pollution prevention.

Resource conservation and pollution prevention were addressed by the next section on the survey instrument, which asked respondents to rank five different strategies in terms of their effectiveness at their facility, on a scale of 0 to 5 where 0 is "not applicable" to the facility.[3] The strategies to be ranked were listed and described on the form:

- *Process management*: The design of process layout and/or waste stream flows to minimize resource consumption and waste generation.
- *Materials substitution*: Replacement of a hazardous substance with a less-hazardous or non-hazardous material.
- *Dematerialization*: Product redesign for a lower material content.

[3] The use of a 0 to 5 ranking scale, rather than 0 to 4 as used for the other two ranking questions, was an inadvertent error in the survey instrument design but does not affect the outcome.

- *Internal recycling and/or reuse*: For example, the reuse of plastic scrap produced by injection molding processes so that the finished product contains recycled material generated during the manufacturing process.

- *Proactive energy efficiency*: Use of most energy efficient machinery, lighting, HVAC equipment, etc.

Figure 8.6 shows the mean rankings assigned to these strategies by respondents.

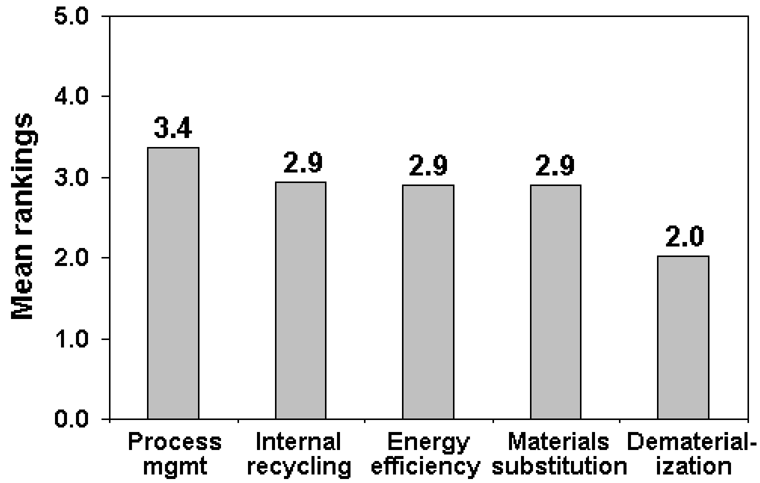

Figure 8.6. Resource conservation and pollution prevention strategies.

Process management was considered to be the most effective of the pollution prevention strategies (3.4) and dematerialization the least effective (2.0). The other three strategies were all rated about equally: energy efficiency (2.9); internal recycling (2.9); and materials substitution (2.9). With the exception of dematerialization, larger companies (workforce >250) tended to rate all strategies as more effective overall than did smaller companies (workforce <250). The most significant difference between larger and small companies was in their perception of internal recycling as an effective pollution prevention strategy. The larger firms (N=21) assigned internal recycling/reuse a mean value of 3.5 whereas the smaller facilities (N=29) averaged only 2.5. For these larger firms, internal recycling (3.5) was as important as process design and management

(3.5). In contrast, for smaller firms materials substitution (2.8) ranked second after process (3.2), and internal recycling ranked fourth of the five strategies.

The role of waste disposal costs, based on anecdotal evidence, in promoting waste reduction strategies has already been noted. Waste is expensive, both in terms of inefficient use of the initial resource - purchased materials that do not become part of the manufactured product - and in costs incurred in managing the residuals of production. Consequently, when asking respondents to evaluate the factors that "have the greatest impact for your facility" in their influence on waste reduction strategies, the need to maximize economic efficiency was included as a factor along with the cost of pollution control equipment, the importance of public opinion about the firm, and the need to comply with state and federal regulations. The respondents' (N=51) ranking of these factors, on a scale of 0 to 4 where 0 is "not applicable," is shown in Figure 8.7.

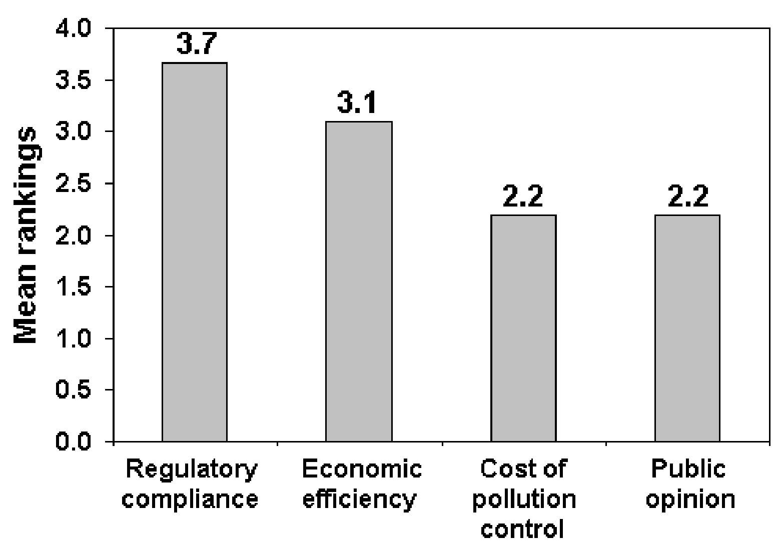

Figure 8.7. Factors driving waste minimization

Regulatory compliance was strongly identified by nearly all firms as the primary factor driving waste reduction efforts (3.7), followed by economic efficiency (3.1). Cost of pollution control technology and public opinion were rated considerably less, each averaging close to a 2.2 ranking. Very little variation was exhibited between the responses from large firms (workforce >250) and smaller firms. Only in terms of the cost of pollution control technology was a minor difference registered, with larger facilities ranking this factor less than the mean at 2.0 and smaller facilities, presumably less able to afford such, ranking it at 2.3.

A large box at the bottom of the form was left blank, and respondents were invited to describe, in general terms, "an example of successful implementation of a strategy, system, process change or technology to reduce the environmental impact of this firm." The cover letter sent with each form gave an example of such an innovation, using the case of Universal Fasteners from the Kentucky pilot study (O'Dell 2001). Universal Fasteners had reduced its hazardous waste by 90 percent through the simple expedient of separating a combined wastewater stream from two operations into two different streams, only one of which contained hazardous waste. Thirty-two firms responded by providing examples of "success stories," ranging from a few lines to very detailed descriptions. One firm simply replied "too many to list," and another, surprisingly, stated "We have many success stories. I don't share success stories with strangers." One would think that a firm might be reluctant to discuss failed efforts, not successful environmental strategies. A sampling of the "success stories" follows:

- A yard equipment firm acquired balers to recycle cardboard and reduced their landfilled solid waste by 85 percent.

- A producer of automotive suspension parts reduced hazardous waste by 75 percent in 2001 through materials substitution.

- A manufacturer of industrial batteries reduced hazardous waste disposal by more than 600,000 pounds annually through recycling.

- A hard chrome plater of automotive stamping dies eliminated all hazardous waste through installation of a chrome recovery system.

- A supplier of manual and powered seat adjusters to Honda eliminated all hazardous waste from their processes by changing from leaded to non-leaded paint in a dipping system. The company noted that they had sought and received Honda's approval to make the change.

- A maker of power transmission belts, whose primary generated waste was rubber dust, made an arrangement whereby another company accepted and used the rubber dust as a raw material in their own manufacturing processes.

- A manufacturer of automotive and flat glass products worked with customers to reduce the amount and type of packaging materials, and changed the packaging specifications to recyclable components and materials.

- At a facility producing steel fasteners for the automotive industry, "American staff pushed for replacement of solvent cleaning processes with water-based cleaning."

Many of the firms noted that, along with reductions of waste generated or waste disposal, they had achieved substantial savings often amounting, in individual cases, to tens of thousands of dollars. Much of the savings resulted from reduction or elimination of hazardous waste disposal charges. A further benefit, not explicitly stated but implied, was that many of these firms, through complete elimination of hazardous waste, were able to remove themselves from constant and intense regulatory scrutiny by the EPA and state and local environmental agencies. One firm stated, as a result of recent measures taken, "we generate *no* hazardous waste into the environment. We are very proud of this situation."

Chapter Nine

Environmental Performance Assessment

9.1. Analytical framework

Because the actual environmental impact of a firm's manufacturing operations is extremely difficult to assess accurately due to the complexity of external factors, performance evaluation is a more practical undertaking. Performance assessment can be applied to a single firm by examining some environmental indicator across time, or to multiple facilities by comparing relative performance either for a single year or across several years. In Chapter 5, three factors were proposed – magnitude, efficiency and toxicity – that can be used to evaluate the environmental performance of firms in regard to waste generation and management. Although each of these factors provides information about performance when analyzed alone, the analysis becomes more meaningful when these factors are combined and evaluated in the context of other considerations.

The analyses performed in this chapter are intended to assess the environmental performance of Japanese-owned manufacturing firms compared to that of other firms in the study area. The concept of eco-efficiency provides the basis for this evaluation. Eco-efficiency is measured as a ratio of some indicator of economic output compared to one or more indicators of environmental influence. The most satisfactory way to achieve this would be to measure economic output as units of production or as value added in relation to the combination of resources consumed (inputs) and non-recovered waste (outputs). For this purpose, only one potential environmental indicator – federal RCRA and TRI waste data – is readily available in quantitative form at the firm level for a large number of companies. Information concerning resource consumption per unit of production is difficult to obtain, so that environmental impact assessment is necessarily limited to waste management parameters. For the economic output side of the ratio, products manufactured vary so greatly (automobiles versus VCRs, for example) that standardization of a unit of production across industries is virtually impossible. Even when products are superficially the same, as in automobiles, there are often significant differences in size and complexity.[1]

In consequence, comparative assessment of eco-efficiency for a large sample of manufacturers can only be partial, or must resort to the use of proxy indicators. For the present study, facility size and labor force size have been chosen as two indirect economic proxies that indicate operational scale. These are compared against two environmental indicators, annual waste generation and waste releases. Eco-efficiency is therefore measured in terms of waste, in pounds or tons, generated or released annually per facility square foot or person employed. Since RCRA data concerns hazardous solid waste, off-site shipment is substituted for releases as an indicator.

Industry sector, facility size and nationality of ownership are proposed as significant factors influencing the generation of industrial hazardous waste. There is substantial evidence that certain industries are more pollution intensive. For the United States, Mani and Wheeler (1998) identified Iron and Steel, Non-Ferrous Metals, Industrial Chemicals, Pulp and Paper, and Non-Metallic Minerals as the “dirtiest” sectors whether ranked by intensity of emissions or by abatement expenditures per unit of production. Larger operations are likely to generate greater quantities of waste; the analysis presented in

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[1] This issue is addressed by MacDuffie and Pil (1995) and Pil and MacDuffie (1999) concerning the difficulties inherent in assessing labor productivity among different vehicle manufacturers.

Chapter 7 indicated that large waste-volume facilities regulated under the federal TRI and RCRA programs tended to be substantially larger than facilities whose waste production did not cross regulatory thresholds. Different systems of industrial production are reflected by nationality of ownership; although lean production methods are being adopted by firms in many countries outside Japan, evidence from various studies indicates that Japanese transplant firms in North America tend to establish more complete versions of lean production systems.[2] Lean systems have been widely promoted as more efficient than traditional Fordist mass production; therefore, if operational efficiency translates to eco-efficient results, this should be empirically demonstrable for Japanese transplant firms.

As outlined in Chapter 5, efficiency is not the only factor involved in a consideration of environmental performance. Critics of eco-efficiency point out that increasing efficiency in industrial operations in terms of resource conservation and pollution reduction is negated if the overall scale of operations also increases. Eco-effectiveness, in contrast, refers to the extent to which firms engage in reinventing processes to eliminate, not simply reduce, ecological impacts. Materials in an eco-effective production system circulate in closed loops of production, use, and recycling. An eco-efficient strategy reduces the amount of a toxic material used in production; an eco-effective solution replaces such substances with those that are harmless, recoverable and/or biodegradable.[3] Accordingly, this study also includes a measure of eco-effectiveness by measuring the toxicity of materials both used and released into the

[2] See Chapter 4 for a review of the pertinent literature on this subject.
[3] See Chapter 2 for a more detailed comparison of eco-efficiency and eco-effectiveness.

environment by manufacturing firms, based upon a method of toxicity weighting described by King and Lenox (2000).

Using the author's database consisting of information about TRI and RCRA firms in the study area, the analysis will begin by testing the proposed factors in a series of simple regressions for pairs of dependent and independent variables. This is followed by a set of multiple regressions that assess the functional relationships of the independent variables that relate to or explain the dependent variables. The next section, building upon the discussion in Chapter 7, provides a general description of the facilities in terms of firm size and industrial sector in relation to the federal programs under which they are regulated. This is followed by a series of data analyses of increasing sophistication based upon the factors identified as potentially significant, beginning with an assessment of the relative magnitude of waste generation but evolving to include considerations of toxicity and efficiency as influenced by factors of industrial sector, firm size, and nationality of ownership. Concluding sections will focus first upon performance over time using the limited number of chemical substances featured in the EPA's 33/50 program, and finally upon an analysis and discussion of the automotive industry.

9.2. Evaluation of variable significance using regression analysis

Regression analysis is used to determine the influence of one or more independent variables upon a dependent variable. The dependent variables represent outcomes of production and waste management practices: production waste magnitude, waste releases magnitude, production waste toxicity, and waste releases toxicity. Independent variables are derived from the discussion in Chapter 5 and above and represent factors that may determine the amount and form of waste for a given firm: facility size measured by worker numbers, facility size measured by enclosed square feet, nationality of owner, industrial sector, and type of federal program under which the firm is regulated. Owner nationality was coded as dummy variables to indicate either Japanese or non-Japanese, and industrial sector is represented by 20 separate dummy variables. Since TRI and not RCRA data was used for regression analysis, federal regulatory program was limited to two dummy variables, representing firms that are either TRI only or both TRI and RCRA. In order to avoid skewing the results, the uppermost one percent of waste generators, measured by production waste volume, was eliminated from the analysis.

Table 9.1 presents the results of a two-tiered multiple regression analysis conducted for each of the four dependent variables. This format was chosen because two of the independent variables, worker numbers and enclosed square feet, are each measuring the same characteristic – plant size – in two different ways. The first stage compares the influence of these two independent variables alone; the second stage represents the complete model for the dependent variable testing all of the independent variables.

Facility size measured as enclosed square feet was found to have a statistically significant relationship for every case with the exception of releases toxicity; this was a stronger relationship than exhibited by any other variable and was of greatest influence for production waste magnitude and production waste toxicity. The number of facility workers was statistically significant only for the magnitude of releases, and, more weakly and in a negative direction, for production waste toxicity. Industrial sector was significant for only one case, where a weak, negative effect was indicated for the magnitude of releases. Program type (single or double regulation) had a significant weak to moderate effect upon production waste magnitude, and a weak effect upon releases

Table 9.1. Two-tiered multiple regression analysis of TRI waste and facility variables

	Independent variables (Beta and significance)					
Dependent variables	**Size by workers**	**Size by sq. ft.**	**Owner**	**Sector**	**Prog.**	**R^2 (sig.)**
Production waste magnitude	0.10	.307***				
	-.004	.299***	.034	-.049*	.121***	.113 (.000)
Releases magnitude	.137***	.068**				
	.137***	.064**	-.008	-.042	.051*	.033 (.000)
Production waste toxicity	-.046*	.169***				
	-.048*	.166***	.041	-.030	.025	.029 (.000)
Releases toxicity	.011	.007				
	.009	.008	-.008	.026	-.010	.001 (.833)

*$p < .05$. **$p < .01$. ***$p < .001$.

magnitude. Surprisingly, no significant effect was observed for owner nationality in regard to any of the dependent variables. Overall, none of the models were very satisfactory in explaining differences among firms for the waste outcomes; the model based upon production waste as the dependent variable was the best model fit, but only provided a weak explanation.

In summary, one may expect to find some readily apparent differences among firms that can be explained in terms of facility size, and possibly by the program categories under which the firms may be regulated. Industrial sector has some potential influence, but requires a more detailed analysis to interpret this. Whether a firm is Japanese or not does not appear to have much significance in explaining the characteristics of firm waste generation. The sections that follow in this chapter will explore the relationships among these variables in greater detail.

9.3 Characteristics of TRI and RCRA firms

The analysis of facility characteristics in Chapter 7 found that there were some significant differences in size between facilities regulated under the TRI and RCRA programs and those that were not, and between Japanese and non-Japanese facilities. Furthermore, for TRI and RCRA facilities, differences were also apparent between Japanese and non-Japanese firms in comparison of industrial sector distribution. These comparisons were made on the basis of aggregated TRI and RCRA facilities; the analysis that follows examines differences between facilities according to which program they are regulated under, TRI or RCRA. For comparative purposes, foreign companies other than Japanese are grouped with U.S.-based companies as utilizers primarily of Fordist methods; thus the analysis will concern only two groups, Japanese versus non-Japanese.

The population for which performance analyses are conducted in this chapter consists of a total of 3,712 facilities whose waste generation is of sufficient magnitude to bring them within the regulatory authority of either the federal TRI or RCRA programs, depending upon the characteristics of the waste. Of these, 3,074 facilities are regulated under TRI, 1,894 facilities under RCRA,[4] and an overlap of 1,256 facilities that qualify for regulation under the provisions of both programs. Differences exist between facilities within these three categories, and also between Japanese and non-Japanese firms in each regulatory category.

Forty-three percent (N=90) of Japanese facilities and 49 percent (N=1,728) of non-Japanese facilities are regulated solely under the TRI program without also qualifying

[4] Under the RCRA program, only those firms that qualify as large-quantity generators (LQG) are included in the analysis in this chapter. See Chapter 5 for definition of the criteria that determine classification of firms under the TRI or RCRA programs.

under the purview of RCRA. Thirteen percent (N=27) of Japanese and 17 percent (N=611) of non-Japanese firms qualify only for RCRA regulation and not TRI. Of those firms that are regulated under both the TRI and RCRA programs, 44 percent (N=94) of Japanese companies and 33 percent (N=1,162) of non-Japanese ownership so qualify.

Industrial composition in each of these categories is similar in that most firms are concentrated in the same few sectors, although there is considerable variation in the concentration of firms within these sectors and between Japanese and non-Japanese firms within regulatory categories (see Table 9.2). The variation in sectoral distribution is most apparent between RCRA-only firms and those in the other categories. RCRA firms tend to exhibit a far greater concentration in fabricated metals (SIC 34) than is true for TRI-only firms or those regulated under both programs, and far fewer RCRA firms are found in rubber and plastics (SIC 30) and primary metals (SIC 33). This is true for both Japanese and non-Japanese firms in these regulatory categories. The percent of total

Table 9.2. Industrial composition by federal waste program and nationality, in percent

Source: RTK NET

	TRI only		RCRA only		Both TRI & RCRA	
Sector	**non-JPN**	**JPN**	**non-JPN**	**JPN**	**non-JPN**	**JPN**
Chemicals	12.3	12.2	15.9	33.0	18.8	9.6
Rubber & plastics	15.5	21.1	5.1	0.0	9.1	11.7
Primary metals	15.1	14.4	8.0	3.7	14.6	11.7
Fabricated metals	14.2	13.3	28.8	25.9	18.8	13.8
Machinery	7.3	2.2	8.5	14.8	5.9	4.3
Electronic	5.2	7.8	4.7	7.4	5.6	7.4
Transportation	8.3	20.0	10.1	11.1	10.8	35.1
Percent of total facilities	**77.9**	**91.0**	**81.1**	**95.9**	**83.6**	**93.6**

regulated facilities in each category represented by these few sectors is shown at the bottom of Table 9.2.; the much higher proportion, in each case, for Japanese firms indicates relatively less diversity in types of production than is true for non-Japanese.

Sectoral variations between Japanese and non-Japanese firms within a single regulatory category are more distinct than differences among programs. Japanese firms are far more concentrated in the transportation sector (SIC 37) than non-Japanese firms in both the TRI-only and combined categories, but, surprisingly, there is little difference by nationality for this sector for RCRA-only firms. In the RCRA-only category, Japanese firms tend to be more concentrated than non-Japanese in the chemicals (SIC 28) and industrial machinery (SIC 35) sectors. The large proportion (33 percent) of RCRA-only Japanese firms in the chemical industries is somewhat surprising, since Japanese representation in this sector is considerably less in both of the other regulatory categories.

Transportation appears as a particularly significant sector for regulated Japanese facilities, less so for non-Japanese, if the analysis is based strictly upon the primary SIC code reported for the facility. The analysis in Chapter 7 indicates, however, that manufacturing components for the transportation industry includes a much larger proportion of industrial firms than is indicated by the SIC codes alone. If the analysis is extended beyond the boundaries defined by sector definitions to address all firms identified as suppliers of parts or materials to automotive manufacturing, variations according to nationality and program are again apparent. Such variations are greatest for the Japanese firms, of which 27 percent of TRI-only facilities, 41 percent of RCRA-only, and 69 percent of facilities regulated by both programs were involved in production for the automotive industry. In contrast, representation by non-Japanese firms in automotive-related production was consistent across all three program categories at about 30 percent of firms.

Facilities regulated under federal waste programs also differ considerably in terms of operational scale, measured as number of employees or size in square feet. These differences exist both among programs, and between Japanese and non-Japanese manufacturers. Table 9.3 illustrates these variations. Mean size differences, by either measure, are not great between the individual TRI and RCRA programs for either Japanese or non-Japanese firms. The medians for employee numbers in Japanese firm, in contrast, show a significant difference in that Japanese TRI firms have a median size nearly twice that of Japanese RCRA firms. Furthermore, the mean for Japanese RCRA firms is nearly 2.5 times the median, but among Japanese TRI firms the mean is only about 40 percent larger than the median. This would appear to indicate that there is a greater variation in firm size among the Japanese RCRA firms than among the TRI, that the mean is possibly skewed upward by a number of very large firms. This same pattern of a larger difference between RCRA employee mean and median is also evident for non-

Table 9.3. Facility size by federal waste program and nationality

Source: RTK NET and author's database.

Upper figure in each box is number of cases; middle figure is mean; lower figure is median.

	TRI only		RCRA only		Both TRI & RCRA	
Factor	**non-JPN**	**JPN**	**non-JPN**	**JPN**	**non-JPN**	**JPN**
Number of workers	(1,606) **251** 130	(86) **354** 255	(520) **316** 150	(22) **327** 132	(1,120) **518** 240	(93) **712** 400
Size in square feet	(1,196) **230,400** 105,000	(62) **252,940** 148,000	(369) **165,115** 100,000	(14) **210,350** 146,000	(871) **627,593** 200,000	(83) **947,500** 256,000

Japanese firms. In contrast, when firms are compared using square feet as the measure, there are no great differences whether mean or median is used as a basis. When we use worker numbers or areal size to compare Japanese to non-Japanese firms within the same program, either TRI or RCRA, there do not appear to be large differences except in terms of employee numbers under TRI.

Significant differences are evident, however, when single-program firms are compared to firms regulated under both TRI and RCRA. Both Japanese and non-Japanese facilities which qualify to be regulated under both programs simultaneously are approximately twice as large as their single-program counterparts in terms of employee numbers, with an even greater difference evident for facility areal extent. Within the combined program category, Japanese firms tend to be nearly 50 percent larger than non-Japanese firms. The difference between mean and median for both Japanese and non-Japanese firms is quite large. The mean is about twice as large as the median for both Japanese and non-Japanese firms in terms of employee numbers, and an even greater variation exists for plant areal size. The apparent explanation for this difference would again seem to be a consequence of a number of very large firms that drive the mean upwards.

Table 9.4 provides information on the number and proportion of very large firms in each regulatory category by ownership nationality. It is immediately apparent that, for both Japanese and non-Japanese companies, very large firms are particularly concentrated in the category that includes both programs. If a very large firm is defined as one with 1,000 or more employees, 14 of the 16 Japanese transplants (87.5 percent) of this size are regulated under both TRI and RCRA, and 120 of 229 non-Japanese facilities (52 percent). Similarly, using plant size equal to or greater than 1,000,000 square feet as

Table 9.4. Number of very large firms by federal waste program and nationality
Source: RTK NET and author's database.
Upper figure is total number of firms that match the qualifier. Figure in parentheses is the total number of firms in that regulatory category for which data is available on the specified parameter. The last number in each group represents the number of matching firms as a percentage of the total firms in each category.

	TRI only		RCRA only		Both TRI & RCRA	
Parameter	**non-JPN**	**JPN**	**non-JPN**	**JPN**	**non-JPN**	**JPN**
Number of firms >1,000 workers	70 (1,606) 4.4	1 (86) 1.2	39 (520) 7.5	1 (22) 4.6	120 (1,120) 10.7	14 (93) 15.1
Number of firms >1,000,000 square feet	34 (1,196) 2.8	1 (62) 1.6	14 (369) 3.8	0 (14) 0.0	92 (871) 10.6	10 (83) 12.0

a measure, 91 percent of the largest Japanese firms and 66 percent of the largest non-Japanese firms are under the authority of both TRI and RCRA. Thus the supposition that large firms unbalance the means is borne out; a truncated mean or median would appear a better method to characterize firm size. The results depicted in Table 9.4 do not, at first, appear to support the earlier conjecture that the mean value for employee numbers for Japanese RCRA firms had been similarly skewed, since there was only one firm with greater than 1,000 employees in this category. Examination of the Japanese RCRA data, however, reveals a particularly large firm of nearly 3,000 employees has unbalanced the mean for a relatively small number of cases (22).

A number of general conclusions can be drawn from the preceding analyses of industrial composition and firm size for the three separate programs. First, Japanese and non-Japanese firms exhibit a concentration in the same few industrial sectors. Most of the variations between program categories and between nationality of ownership are relatively minor. The major program difference is a much greater concentration of metal fabrication facilities in the RCRA-only category; the most significant firm nationality differences are a far higher proportion of Japanese firms than non-Japanese in the transportation industry generally, and of Japanese firms in the chemical industries under the RCRA program.

In terms of firm size differences under the three program categories, there was little significant difference between firms in the single-program categories, when measured either by number of workers or facility square feet; Japanese firms tended to be somewhat larger than non-Japanese but not extraordinarily so. Differences were much more apparent for firms regulated under both TRI and RCRA. Facilities tended to be much larger, both for Japanese and non-Japanese firms, and the Japanese firms were larger in this category than non-Japanese. This tendency is indicated by both the means and medians, and also by analysis of the distribution of the largest firms by program and by nationality. The analysis of firm size presented in Chapter concluded that TRI/RCRA facilities tended to be larger than facilities that did not qualify to be so regulated. Because the TRI and RCRA programs address different waste classes, plants that qualify to be regulated under both programs are likely to generate more waste, and more diverse kinds of waste, than facilities in single regulatory programs. Based on this evidence, one might reasonably propose that Japanese facilities, being larger than non-Japanese facilities, are thus likely to generate more regulated waste.

Before turning to analysis involving waste generation and management, which will address this supposition, an examination of the proportional representation of Japanese facilities and non-Japanese facilities in federally regulated programs is in order. Table 9.5 shows the number of Japanese and non-Japanese firms regulated under the federal

TRI and RCRA waste programs as a percentage of the total population of Japanese and non-Japanese manufacturers. In all regulatory categories, although exact percentages are highly variable, Japanese firms are proportionately represented by magnitudes five to seven times as great as non-Japanese firms in their respective populations. TRI firms are in the greatest number and percentage of facilities for both ownership categories, constituting nearly 6 percent of non-Japanese firms and 35 percent of Japanese firms. Overall, more than 7 percent of non-Japanese and more than 40 percent of Japanese facilities are regulated by one or both programs. The 211 regulated Japanese firms comprise 5.6 percent of the 3,712 total TRI/RCRA firms but only 1.1 percent of the total

Table 9.5. Proportion of Japanese and non-Japanese firms regulated under federal waste programs

Sources: Manufacturers News reports for 2000; Departments of Commerce for Indiana, Kentucky, Ohio and Tennessee, and RTK-NET databases.

Upper figure is number of firms; figure in parentheses is percentage.

	non-Japanese	Japanese
Total facilities	49,140	525
TRI only facilities	1,726 (3.5)	90 (17.1)
RCRA only facilities	611 (1.2)	27 (5.1)
All TRI facilities	2,890 (5.9)	184 (35.1)
All RCRA facilities	1,773 (3.6)	121 (23.1)
Both TRI and RCRA	1,164 (2.4)	94 (17.9)
Either TRI or RCRA	3,501 (7.1)	211 (40.2)

manufacturing population;[5] thus, a fivefold greater proportion of Japanese firms were producing hazardous or toxic waste than in the general population of industrial facilities. These figures indicate that a large proportion of Japanese transplant firms tend to be waste generators of sufficient magnitude to qualify for the highest categories of federal regulation. This may be because Japanese facilities tend to be larger in size than non-Japanese, or because Japanese investment may tend to be in industries that generate more waste.

Over time, formerly nonregulated firms may cross the regulatory threshold as a result of expanded production to become a TRI or RCRA facility, or conversely, may drop beneath the threshold criteria in consequence of reduced production or more effective waste management practices. It is greatly to the advantage of any firm able to reduce its waste so as to lessen the amount of paperwork, number and complexity of regulatory requirements, and intensity of state and federal agency scrutiny. The population of regulated firms in any given year is thus inherently dynamic, subject to additions and deletions of firms. Adapted from the pilot study (O'Dell 2001) and updated with 1999 data, Figure 9.1 shows the trend over time for Japanese RCRA facilities in Kentucky in relation to the increase in Japanese transplants in that state.[6] Although the number of Japanese transplants in Kentucky greatly increased in total numbers and, individually, in production capacity, the number of Japanese RCRA firms has remained fairly stable. The percentage of Japanese RCRA firms as a percentage of transplants in Kentucky has actually declined during the period shown, from 33 percent of firms in 1991 to 24.5

[5] See Chapter 7, Table 7.1.
[6] A comparison of this sort is relatively difficult to produce, since the RCRA facility list for each year must be carefully examined to determine which facilities are of Japanese ownership and which are not; due to limited resources this comparison was not undertaken for all four states in the study area.

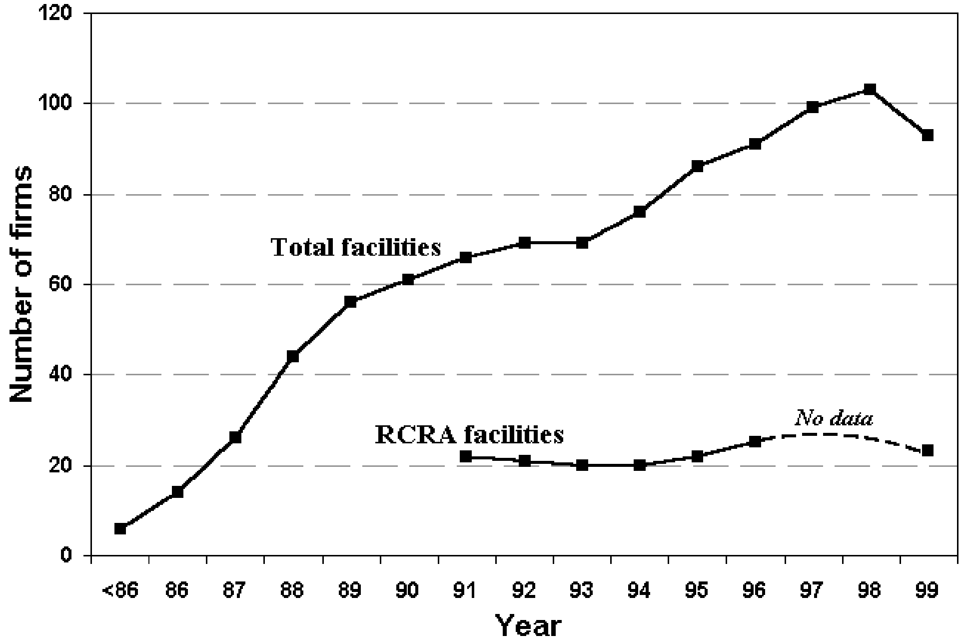


Figure 9.1. Rate of increase of Japanese RCRA compared to total number of Japanese transplants, Kentucky.
Sources: Kentucky Division of Waste Management; Kentucky Department of Commerce

percent in 1999. The stability in numbers of transplant RCRA firms despite a substantial increase in total Japanese transplants may be a consequence of the earliest transplants being larger than later firms, located within more polluting industries, or from improved waste management efficiency over time.

Analysis of Kentucky data in this regard is inconclusive. The mean firm size, whether measured in terms of worker numbers or areal extent, is nearly identical for RCRA firms before and after 1991; the same is true for non-RCRA firms. The distribution of industrial classifications for current RCRA firms shows no significant variations across the period of firm establishment from 1980 through 1999. As nearly 70 percent of the Japanese RCRA firms and 82 percent of Japanese TRI firms in Kentucky for 1999 were established prior to 1991, there may be a relatively stable core of older transplants that have remained within these program. Only 48 percent of Japanese firms that are not regulated under RCRA or TRI were established prior to 1991. The more recently established firms may have been able to take advantage of more advanced and effective pollution control technology to remain outside of the federal regulatory programs.

The number or proportion of firms generating waste is not in itself necessarily significant, however; of greater import is the Japanese share of the total waste generated in the study area, the toxicity of this waste and the manner in which it is managed. These are the relevant issues which are examined through the remainder of this chapter.

9.4. Magnitude, toxicity and sectoral distribution of waste outputs

Simple magnitude of waste generated is the least sophisticated of the measures that can be used to compare environmental performance of firms, and therefore has only limited applicability. Waste generation data alone does not address subsequent waste management and so, while providing some indication of the effectiveness of resource utilization, discloses little concerning potential environmental impact. For example, waste that is internally recycled back into the production process is transformed from waste into raw materials, yet in its initial manifestation is counted as part of a firm's total waste burden. More effective indicators are those wastes which are not or can not be managed in some manner to allow full or partial recovery and are disposed of to landfills or released to the environment as discharges or emissions. These can be measured by magnitude, or, more significantly, as percentages of generated waste. If generated or released wastes (TRI only) are adjusted to reflect relative toxicity, this provides more significant criteria by which potential environmental hazard may be evaluated.

During 1999, the total population of facilities in the study area generated 2,743 million pounds of TRI waste, of which the Japanese share was 178 million pounds or 6.5 percent.

Since 6.4 percent of all TRI firms are Japanese transplants, the quantity of waste produced is almost exactly proportional to the number of Japanese firms. If the generated waste is weighted by toxicity in the manner described in Chapter 5, the factored value derived for total production waste for all firms, Japanese and non-Japanese, is 167 million, of which the Japanese share is slightly less than 1.5 million or 0.9 percent. Thus the population of Japanese facilities generated waste that is, proportionately, one-seventh as toxic as the waste produced by the overall manufacturing population (i.e., 6.4 percent of TRI firms are Japanese, producing 0.9 percent of total toxicity).

Comparisons of this sort are valid only when applied to aggregate populations and should not be taken as representative of individual firms, because examination of the data indicates that most of the waste is being generated by a very few very large firms. The case of the U.S.-based, Oxy-Vinyls firm, located in Louisville, Kentucky, is illustrative. Regulated only under TRI, Oxy-Vinyls is the single largest TRI waste generator in the study area, at 142 million pounds accounting for eight percent of total TRI waste. This is nearly twice the amount of the next largest generator and nearly equal to the entire waste quantity for all of the Japanese transplants combined. Given that the total waste generation for all firms in the study area is 2,743 million pounds, even the immense waste quantity of Oxy-Vinyls has only a minor effect in the comparison of proportionality of shares of total production waste between Japanese and non-Japanese firms. Because, however, Oxy-Vinyls' waste is highly toxic, it has a very significant effect in skewing the toxic-weighted comparisons.

Nearly all of the waste generated by Oxy-Vinyls consists of the extremely toxic substance, vinyl chloride. This material is considered so toxic that it is assigned a hazard ranking of “1” based on the EPA’s RQ assessment. As a consequence, the toxicity-weighted waste for this facility has the same magnitude as its production waste. The next largest toxicity weighted value for non-Japanese firms is only four percent of this, and the largest toxicity value for a Japanese firm is but one-half percent that of Oxy-Vinyls. If we repeat the assessment of toxicity shares with Oxy-Vinyls data omitted, the weighted toxicity for total production waste in the study area is reduced by 142 million pounds from 166 million to only 24 million pounds of factored toxic weight. The Japanese share of total toxicity, 1.5 million pounds, thus increases from 0.9 percent to 6.2 percent, which is almost exactly proportionate to the number of Japanese firms in the manufacturing population. The contribution to the overall waste profile by a very few firms is thus highly significant.

Waste releases, e.g. discharges or emissions to the external environment, represent the least desirable fate for hazardous or toxic waste. Industrial waste releases reported for 1999 under the TRI program constituted 293 million pounds; the Japanese share of releases was 11.8 million pounds or about 4.0 percent. Releases for Japanese firms were therefore proportionately a little more than half the level of those for the entire population. When relative toxicity of these releases is calculated, the resulting factored value for all facilities is 1.5 million, compared to a value of 0.05 million for the population of Japanese manufacturing firms. The Japanese share of total toxicity of releases, at 3.3 percent, is greater than their share of total production waste toxicity (0.9 percent), but still no more than half of the expected proportion of total toxicity of releases when based upon the relative representation of Japanese firms within the industrial population.

For environmental waste releases there are several very large contributors of approximately equal magnitude, unlike waste generation, where a single firm stands out from all others as a major source. Four firms each contribute about five percent of total waste releases among non-Japanese firms; interestingly, Oxy-Vinyls is not among these. The Oxy-Vinyls firm manages its TRI waste so well that only 0.004 percent of the vinyl chloride waste escapes to the environment.[7] Among Japanese firms, the largest producer of waste releases is the Nissan automobile assembly plant in Tennessee with 15 percent of total Japanese waste releases, followed by three other facilities whose waste releases are approximately of equal magnitude and together account for an additional 25 percent. Thus only four facilities are responsible for more than 40 percent of all Japanese toxic waste releases.

If we eliminate the uppermost five percent of firms contributing the most waste releases from both Japanese and non-Japanese firms, the resulting profile may be considered more representative of manufacturing firms in each category. The top five percent of Japanese release sources includes nine facilities (out of 184) whose combined releases account for 60 percent of the total for transplant firms. The top five percent of non-Japanese release sources includes 144 facilities (out of 2,890) whose combined releases account for 75 percent of the total for non-Japanese firms. The remaining 95 percent of firms in each ownership category together released 74 million pounds of toxics into the environment, of which the Japanese share is 6.3 percent; slightly less than the proportion of Japanese firms in the total manufacturing population.

[7] Even so, this small percentage constitutes 5,524 pounds of highly toxic vinyl chloride releases and thus a significant health risk.

If toxicity of releases is reevaluated to examine the role of very large producers, 17 percent of total toxicity can be attributed to only two non-Japanese firms. The next most significant firm accounts for less than half as much release toxicity as either of these. For Japanese firms, the toxicity of releases for the top two producing facilities constitutes 24 percent of total release toxicity. Unlike the situation with unweighted production waste generation, however, where the Oxy Vinyls facility generates waste an order of magnitude above other large firms, for toxicity of releases there is a fairly even graduation of increasing toxicity along a continuum. There is no single facility or handful of facilities, neither among the Japanese transplants nor non-Japanese firms, whose contributions to toxicity are substantially larger than those firms ranked immediately below.

This is not to say that the firms with the largest releases are not significant, merely that the profile is not skewed by one or two anomalous firms but represents less variability at the upper end (greater magnitude of toxicity) of cases. The greatest proportion of total toxicity of releases is, in fact, contributed by a relatively small number of firms. The top five percent of Japanese firms whose release toxicity is greatest account for 75 percent of total release toxicity, compared to 85 percent of total toxicity for the upper five percent of non-Japanese firms.

Similar comparisons can be undertaken for wastes generated and managed under the RCRA program, although, due to the more generalized classification of waste types, toxicity assessment is not practical. Japanese firms constitute 6.8 percent of all RCRA firms within the study area. RCRA solid waste generated by all LQG facilities in the study area amounted to 77.8 million tons in 1999 (note the change in units to tons), of which the Japanese share was quite disproportionate at 13.2 million tons, about 17 percent. The RCRA waste generation is also considerably skewed, however, by the tremendous quantities of waste generated by a relatively few plants. Fifty-eight percent, more than 45 million tons, of the RCRA waste for non-Japanese facilities is generated by just two plants, the Tenn Eastman facility in Tennessee and the Catlettsburg Refinery in Kentucky. Eighty-two percent, nearly 11 million tons, of Japanese RCRA waste is produced by a single facility, the National Steel Corporation in Ohio.

If we remove these extreme outliers from the data, a more representative picture of relative RCRA waste generation emerges. Total hazardous waste generation is reduced to a total of 21.4 million tons, of which 19.1 million tons were produced by non-Japanese firms compared to 2.3 million tons for Japanese. The Japanese share in this case becomes 10.7 percent, approximately 50 percent greater than the representation of Japanese firms (6.8 percent) within the total population of RCRA firms. To evaluate RCRA waste shipped off-site, the same three firms will again be eliminated for consistency although the quantities shipped by these firms are minor. The majority of RCRA waste is managed on-site at facilities, with only about 0.98 million tons or 4.5 percent shipped offsite, primarily to hazardous waste landfills. Of the amount shipped, the Japanese share is about .04 million tons or 4.5 percent. Since RCRA waste generation is greater than the proportion of Japanese firms in the manufacturing population but RCRA waste shipped is substantially less, this implies that Japanese firms may be managing this waste more effectively.

Table 9.6 uses 1999 TRI data to compare total production waste and total releases, both as raw data and weighted by toxicity, for Japanese and non-Japanese facilities in two program categories, firms regulated only under TRI and firms regulated under both the TRI and RCRA programs. This evaluation is intended to test whether those firms that qualify to be regulated simultaneously under both programs are, in fact producing greater quantities of hazardous or toxic wastes. Before this comparison could be undertaken, a serious anomaly in the TRI data had to be addressed. For the comparison shown in Table 9.6, the Oxy-Vinyls data were eliminated to reduce the severe imbalance in toxicity-weighted total production waste created by this anomaly.

The data in this table strongly support the proposal that firms regulated under both programs generate more waste than single-program firms. This is indicated for both Japanese and non-Japanese firms, although the tendency is most pronounced for the transplant facilities. Approximately half of the Japanese firms in this comparison are TRI-only (N=90) and half are regulated under both programs (N=94), yet by far the

Table 9.6. Waste indicators compared to federal waste program and nationality

Source: RTK NET

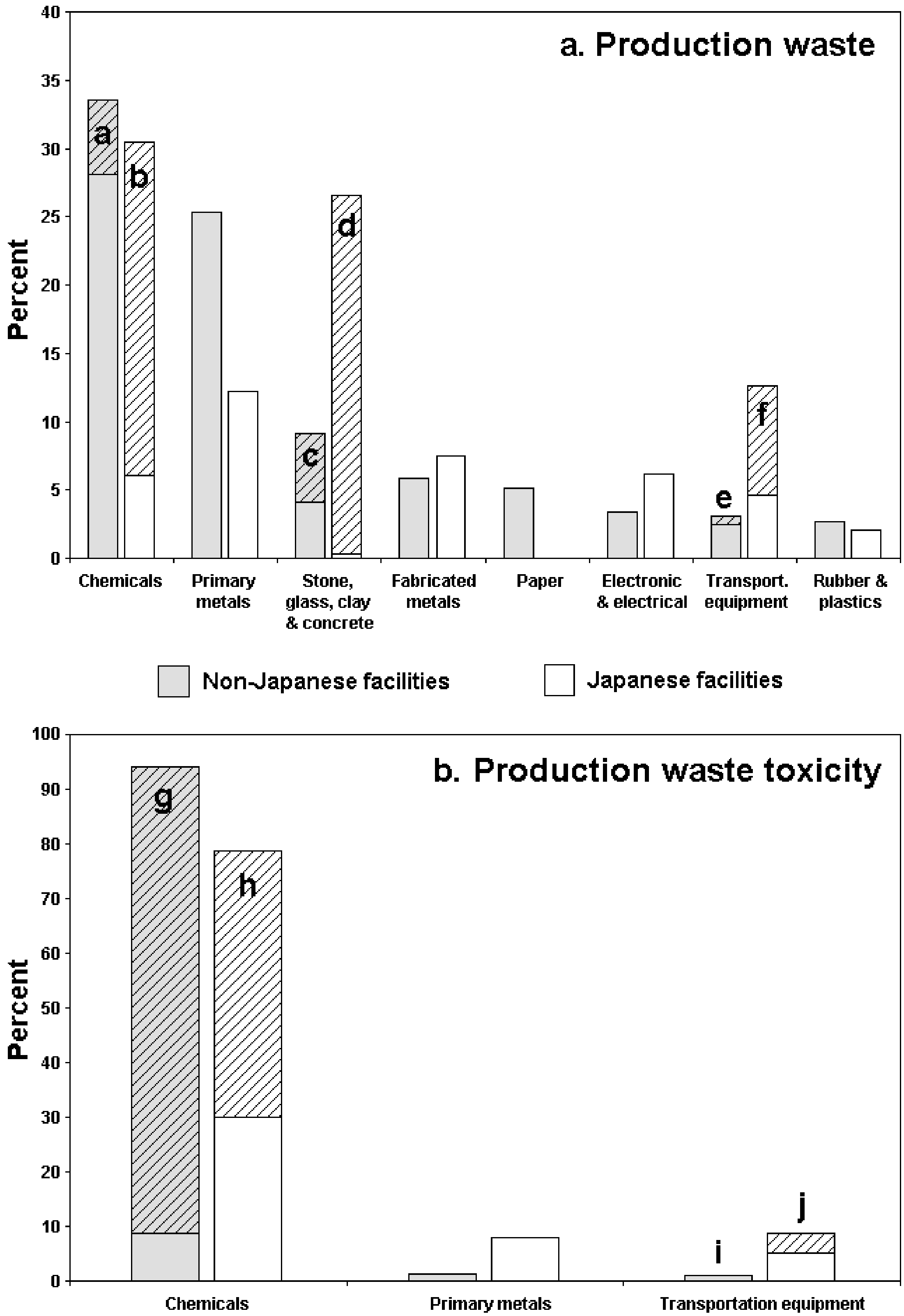
Figures apply to TRI waste only. Upper figure in each cell is waste in millions of pounds. Figure in parentheses is percentage of total TRI waste for the category of owner nationality, derived from the sum of the waste weight for that nationality for both program categories.

	TRI only		Both TRI & RCRA	
Waste indicator	non-JPN (N=1,726)	JPN (N=90)	non-JPN (N=1,164)	JPN (N=94)
Total production waste	779.4 (32.2)	24.7 (13.8)	1,643.1 (67.8)	153.7 (86.2)
Total production waste, toxicity weighted	7.1 (30.0)	.06 (3.8)	16.3 (70.0)	1.5 (96.2)
Releases	103.1 (36.7)	2.6 (21.9)	177.8 (63.3)	9.2 (78.1)
Releases, toxicity weighted	.62 (57.6)	.004 (6.3)	.81 (42.4)	.06 (93.7)

greater proportion of total waste and releases are generated by those firms operating under the combined jurisdiction of TRI and RCRA. The contrast is even more striking in terms of toxicity, since 96 percent of production waste toxicity and almost 94 percent of the toxicity for releases by transplant firms can be attributed to dual-program facilities. The trend is similar but less pronounced for non-Japanese facilities, where TRI-RCRA facilities, representing about 40 percent of non-Japanese TRI firms, generate about two-thirds of the production waste, releases, and production waste toxicity. The only deviation from the tendency is in the case of the toxicity of releases for non-Japanese firms, where approximately 60 percent of total toxicity resides in the TRI-only firms.

A more detailed profile of waste generation and environmental release can be obtained through analysis of sectoral distribution of waste, using both raw waste data and waste adjusted for toxicity. Figures 9.2a and 9.2b compare total production waste and production waste toxicity for eight industrial sectors in which the majority of manufacturing for both Japanese and non-Japanese firms is concentrated. These sectors represent almost 98 percent of the production waste generated by Japanese facilities and 88 percent of that produced by non-Japanese facilities. The graphic does not show relative magnitude of waste generation but is instead intended to represent the distribution of waste across sectors and within each sector according to ownership.

Superficially, Figure 9.2a indicates chemicals (SIC 28), primary metals (SIC 33), and stone, clay and glass products (SIC 32) as industrial segments which constitute the greatest concentrations of production waste for both Japanese and non-Japanese firms. Additionally, a substantial proportion of total waste is concentrated in the transportation equipment sector (SIC 37) for Japanese facilities.



Figures 9.2a and 9.2b. TRI production waste and toxicity according to nationality and industrial sector.

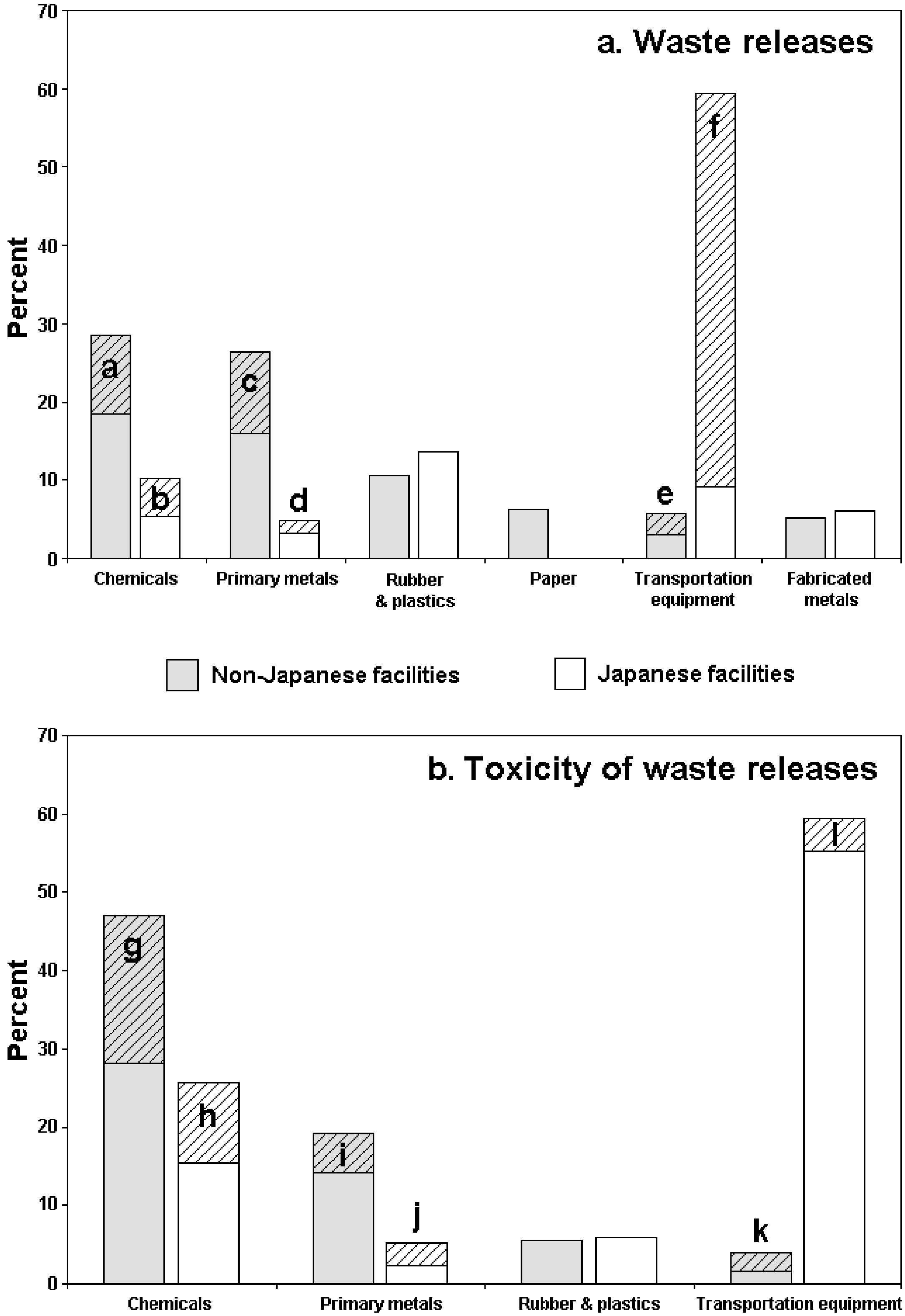
Source: RTK NET

These relative distributions are, however, misleading, because of the influence of a handful of firms that generate tremendous quantities of waste; the cross-hatched areas are intended to highlight the significance of such firms to the pattern of waste concentration. In Figure 9.2a, the sections of the bars for the chemical industries that are marked “a” and “b” indicate the influence of large waste generator. One Kentucky firm, Oxy Vinyls, accounts for 16.5 percent of waste for non-Japanese facilities in this sector, indicated by the area shaded “a”; similarly, a single Ohio firm shown as “b”, Aristech Chemical, is responsible for 80 percent of all waste generated by Japanese chemical firms. In the primary metals category there are a great many firms generating large quantities of production waste, but no single firm stands out in this regard for either Japanese or non-Japanese facilities. The bar segment marked “c” for the stone, glass and concrete products represents two non-Japanese facilities, LaFarge Corporation in Ohio and Lone Star Industries in Indiana, that together produce 56 percent of the waste in this category. Amazingly, the bar segment marked “d” is the proportion of production waste contributed by a single Japanese firm in Ohio, Techneglas, which constitutes 99 percent of waste for Japanese firms in this sector. The segments marked “e” and “f” indicate the waste generated by automobile assembly plants. Nine non-Japanese automobile plants generate 22.6 percent of production waste in the transportation equipment sector, and seven Japanese automakers generate 65 percent of the waste in their sector. This most likely reflects a much greater number of domestic automobile suppliers that generate waste and thereby reduce the relative contribution of non-Japanese assembly plants.

Figure 9.2b indicates that most of the production waste toxicity is concentrated within only three industrial sectors: chemicals, primary metals, and transportation equipment.

More than 95 percent of the toxicity for Japanese facilities and more than 96 percent of toxicity for non-Japanese facilities is generated within these sectors alone. Again, the influence of a few large generators heavily skews the distribution. The bar segment marked “g” represents the proportion of total toxicity for a single non-Japanese firm, Oxy-Vinyls, within the chemical sector; this same firm was also responsible for a significant part of total production waste. Among Japanese firms in the chemical sector, Aristech Chemical Corporation of Ohio, marked “h”, accounts for 62 percent of total toxicity. Too small to depict graphically but indicated by the letter “i”, toxicity from the nine automobile assembly plants amounts to 4.3 percent of transportation equipment waste for non-Japanese firms, compared to 39 percent of total production waste in the sector for the seven Japanese automakers. Note that the relative size of the columns is not related to the actual magnitude of waste but only to proportional distribution within the sectors. For example, the actual magnitude of weighted toxicity in the transportation sector is 1.6 million pounds for non-Japanese firms and 0.13 million pounds for Japanese.

Figures 9.3a and 9.3b use the same format to illustrate sectoral distribution of waste releases and toxicity according to owner nationality, and again a limited number of facilities exert substantial influence on the pattern that develops. Environmental releases are of far greater concern to human and ecosystem health than production waste. Production waste may be managed in several different ways, including recycling, that either eliminate the material as a waste or reduce its ecological liability; uncontrolled releases of toxic substances in the form of discharges or emissions comprise the greatest potential class of risk. Releases are thus a much more significant indicator of potential environmental risk.



Figures 9.3a and 9.3b. TRI waste releases and toxicity according to nationality and industrial sector.
Source: RTK NET

Environmental releases shown in Figure 9.3a are concentrated in six industrial sectors that in aggregate account for most of this form of waste: chemicals, primary metals, rubber and plastics, paper, transportation equipment, and fabricated metals. The sectors shown represent more than 94 percent of releases for Japanese facilities and nearly 83 percent of releases for non-Japanese facilities. Significant differences in sector distribution are present according to nationality of the firm owner; releases for Japanese facilities tend to be more concentrated in the transportation equipment sector and releases for non-Japanese facilities are more concentrated in the chemicals and primary metals sectors.

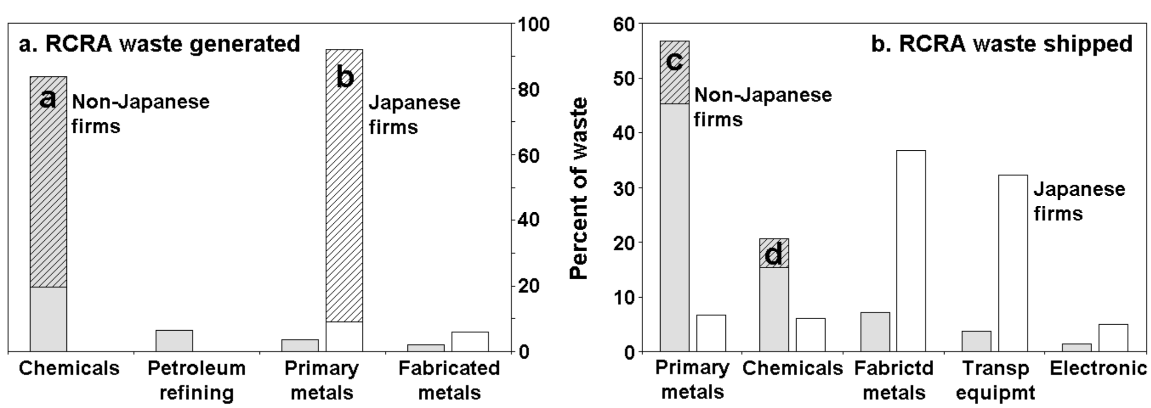
In the chemicals sector, two non-Japanese firms, BP Chemicals Inc. in Ohio and Lenzing Fibers Corporation in Tennessee, account for more than 35 percent of total releases, represented by the shaded area marked “a”. A single facility marked “b”, Aristech Chemical Corporation in Ohio, is responsible for 47 percent of all releases for Japanese firms in this industrial sector. In the primary metals sector, Eramet Marietta Inc. in Ohio and United States Steel’s Gary, Indiana, works account for 39 percent of emissions and discharges for non-Japanese firms, whereas a single facility, National Steel in Indiana, produces 35 percent of releases for Japanese firms in the sector. The nine non-Japanese automakers are responsible for 43 percent of releases in their sector, and the seven Japanese assembly transplants account for 84 percent of releases in transportation equipment.

Relative toxicity of releases is depicted in Figure 9.3b, which indicates that total toxicity of releases is concentrated in four sectors: chemicals, primary metals, rubber and plastics, and transportation equipment. Strong differences in sectoral distribution according to nationality of ownership are again apparent, closely resembling the pattern for releases shown in Figure 9.3a. Other similarities also exist: the same two firms responsible for a significant proportion of releases for non-Japanese firms in the chemical sector are also responsible for 40 percent of toxicity, and the same Japanese firm, Aristech, that accounted for a large part of Japanese releases in that sector also contributes 40 percent of toxicity. In primary metals, Eramet Marietta in combination with New Boston Coke, also of Ohio, generate 26 percent of total release toxicity for non-Japanese firms. One firm in the primary metals sector, Trutec Inc of Ohio, is responsible for 53 percent of release toxicity for Japanese facilities. In transportation equipment, the non-Japanese automobile assembly plants account for 55.4 percent of toxicity of releases in the sector, compared to just 7 percent of sector release toxicity for the Japanese automakers.

This latter circumstance is of particular interest; one would be inclined to think that the Japanese automakers would be responsible for a much greater proportion of total toxicity simply because they represent a far greater numerical proportion of firms in that sector for the Japanese. Non-Japanese automakers constitute nine firms out of 269 total non-Japanese firms in transportation equipment, whereas transplant assembly firms are seven out of 51 Japanese firms in the sector. Among possible explanations: (a) Japanese assembly plants release substances that are less toxic than non-Japanese plants; (b) Non-Japanese assembly plants release much greater quantities of equal or lesser toxicity than Japanese assembly plants; (c) Other non-assembly Japanese firms in the transportation sector release substances that are in greater quantities or toxicity than assembly plants; or (d) Other non-Japanese non-assembly firms in the transportation sector release substances in less quantities or less toxicity than Japanese non-assembly plants. Since most of these explanations contradict one another, it becomes apparent that waste toxicity and magnitude alone do not provide adequate comparisons among plants.

Turning now from toxic wastes regulated under TRI to the RCRA program, Figures 9.4a and 9.4b depict, respectively, generation and shipment of solid hazardous wastes according to industrial sector and owner nationality. The resulting graphic profile indicates substantial differences in sectoral distribution of waste magnitude between Japanese and non-Japanese firms in both categories. As shown by figure 9.4a, nearly 98 percent of all RCRA waste generated from Japanese firms is concentrated in just two industrial sectors, primary metals and fabricated metals, of which primary metals accounts for the greater share by far. Similarly, 96 percent of RCRA waste for non-Japanese firms can be attributed to just four industrial sectors, dominated by the chemicals sector. Thus, waste generation for Japanese and non-Japanese firms is concentrated within two entirely different sectors; 92 percent of total RCRA waste for Japanese firms derives from primary metals alone, and 84 percent of non-Japanese waste

Figures 9.4a and 9.4b. RCRA waste generation and shipment according to nationality and industrial sector.
Source: RTK NET



from the chemicals sector alone. As was the case for TRI wastes, this profile is largely determined by the activities of large generators rather than the host of smaller firms. The Tenn Eastman facility ("a") in Tennessee accounts for 76 percent of all RCRA waste for non-Japanese plants in the chemicals sector. Similarly, National Steel ("b"), a Japanese-owned facility located in Indiana, accounts for 90 percent of all RCRA waste generated by Japanese firms in the primary metals sector. Minus the contributions of just these two firms, variations between owner nationality in the pattern of generated waste are greatly diminished.

Nationwide, about 98 percent of RCRA is managed on-site by the facilities responsible for generating it; these are generally larger companies able to afford treatment equipment and possessing sufficient space for storage and disposal. Small firms and those in urban locations are more likely to ship RCRA waste off-site to a commercial firm or public facility for treatment, storage and disposal (USEPA 1997). Figure 9.4b shows the profile for off-site RCRA waste shipment in the study area. The industrial sectors depicted respectively represent 86.5 of waste shipped by Japanese firms and 93 percent of waste shipped by non-Japanese firms. The sectoral distribution pattern again varies significantly between Japanese and non-Japanese firms, but does not correspond very closely with the pattern of distribution for RCRA waste generation.

Although most of the waste for non-Japanese firms was generated by firms in the chemical industries (even if the contribution of Tenn Eastman is discounted), this sector takes second place to primary metals for the proportion of waste shipped off-site. This appears to support the EPA's generalization about firm size, since the results of indexed firm size analysis reported in Table 7.7 (Chapter 7) indicates that facilities in the primary metals and chemical industries tend to be of about equal or smaller size than the mean. Waste shipments from Japanese firms, in contrast, are concentrated in the fabricated metals and transportation equipment sectors. Although the calculated size index for fabricated metals firms was the lowest of all sectors examined, the transportation equipment sector had nearly the highest size index. Furthermore, locational analysis of Japanese firms reported in Chapter 7 indicates a distinct tendency toward rural or small-town sites.

The relative influence of a few firms responsible for large proportions of waste is less apparent for RCRA waste shipments. For non-Japanese firms, Nucor Steel in Indiana is responsible for 20 percent of shipped waste in primary metals ("c"), and the B.F. Goodrich facility in Kentucky ("d") accounts for 26 percent of waste shipments in the chemical sector. For Japanese facilities, however, there are no single or few firms whose waste shipments are substantially greater than the firms ranked immediately beneath.

This rather lengthy and complicated exercise has served to illustrate the problems inherent in using any single or simple indicator as a basis of environmental performance comparison among industrial firms. Neither waste magnitude, waste releases nor waste toxicity are sufficient in themselves. Simple magnitude of waste generation, which potentially has implications concerning resource utilization, is the least informative, because this parameter alone provides no indication of internal or external management practices that may recover waste. Comparison of waste releases, particularly when adjusted for toxicity, has implications for ecological risk or hazard but alone does not address firm performance. The use of either of these parameters as indicators is complicated by the influence of a few firms that, in most of the preceding analyses, strongly skewed comparative summaries. It is evident that a meaningful comparison of firm performance must be based on an indexed value such as that represented by the concept of eco-efficiency. In the following sections, indicators are created that take into account operational scale and relative effectiveness of waste management practices.

9.5. Assessing eco-efficiency

9.5.1. Waste management practices and operational efficiency

The generation of waste is a reflection of inefficiencies in the production system, and the options available to facilities to minimize production waste and pollution are influenced by both external and internal factors. External factors include public opinion about environmental quality, customer expectations as to product quality and features, and the effectiveness of available pollution control technology. Internal factors include the commitment of management to environmental goals, products manufactured, characteristics of the production system, existing pollution control technology, and resources available to implement process or technological change. The best way to manage waste is not to produce it; accordingly, source reduction was established as national environmental policy by the 1990 Pollution Prevention Act (PPA).[8] Source reduction was defined by the Act as "any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment." Production practices which may assist in waste reduction at the source include equipment, process or technology modifications; reformulation or redesign of products; substitution of materials; and improvements in maintenance and inventory controls.

[8] Public Law 101-508, Nov. 5, 1990; 104 Stat. 1388, 42 U.S.C. 13101 et seq.

Source reduction is considered to be the most desirable form of waste management, followed in ranked order by recycling, energy recovery, treatment, and as a last, undesirable alternative, disposal. Companies have been required to report these waste management practices in some detail since passage of the 1990 PPA. Source reduction cannot be measured using single-year data and must be assessed over some period of time. "Environmentally sound" recycling, according to the EPA (1997), shares many of the advantages of source reduction: "Like source reduction, recycling reduces the need for treatment or disposal of waste and helps conserve energy and natural resources." On-site recycling is recovery of the toxic material for further use. Off-site recycling is transfer of the material to a facility beyond the plant boundaries for recovery or recycling. The same on-site/off-site distinction exists for treatment and energy recovery operations. "Treatment" is the destruction of the toxic material in waste treatment operations. "energy recovery" is concerned with materials that are combustible and release energy, not those that require energy to be incinerated.

With a few significant differences, Japanese and non-Japanese facilities appear to use similar waste management strategies. Table 9.7. shows the percentage of firms employing specific waste management activities and the percentage of total waste managed by these methods according to owner nationality. Because many of these firms employ multiple methods to handle waste, firm percentages total in excess of 100 percent. Japanese firms exhibit a greater tendency to utilize off-site waste management strategies including disposal, shipping waste to recycling centers and TSDFs (treatment, storage and disposal facility) or arranging for it to be picked up by contractors. However, the overall proportion of total waste managed by these methods does not differ greatly

Table 9.7. Waste management methods by owner nationality
Source: RTK NET

	Percent of firms		Percent of total waste	
	Japanese (N=160)	non-Japanese (N=2,207)	Japanese (N=160)	non-Japanese (N=2,207)
Recycling on-site	15.2	16.0	31.5	27.7
Recycling off-site	52.2	37.7	20.3	14.4
Energy recovery on-site	2.7	2.4	12.9	14.1
Energy recovery off-site	31.0	21.6	1.8	1.9
Treatment on-site	22.8	20.3	7.7	17.1
Treatment off-site	37.5	31.7	1.3	2.5
Disposal	92.9	76.9	24.6	22.3

according to owner nationality. Japanese firms exhibit a slight tendency to favor recycling more, both on- and off-site, in terms of total waste managed, than non-Japanese firms, but are less likely to employ waste treatment.

Environmental emissions and discharges of toxic materials are the least desirable outcomes for a facility's waste management program. Uncontrolled waste releases can be economically damaging to the firm as well as harmful to human and ecological health. Such releases can result in negative public perceptions about the firm, fines and increased regulatory oversight, and even possible litigation. Furthermore, materials that escape from the production process are unrecovered resources. The ratio of environmental releases to production waste alone represents a crude measure of the efficiency of the production process and a reflection of the internal and external influences previously mentioned. More effectively, as employed in section 9.5.2, the release ratio should be combined with an economic indicator to estimate the eco-efficiency of production.

Table 9.8. Waste management efficiency compared to program type and nationality
Source: RTK NET and author's database

Parameter	TRI only		Both TRI & RCRA	
	non-JPN (N=1,726)	JPN (N=90)	non-JPN (N=1,164)	JPN (N=94)
Releases as percent of production waste	13.2	10.5	10.8	6.0
Release toxicity as percent of production toxicity	8.7	6.6	4.9	4.0

The concept of release ratio as efficiency indicator was used to construct Table 9.8, which compares waste management efficiency as a function of regulatory program and owner nationality. The release ratio is measured by two different methods: releases as a percentage of unadjusted production waste, and release toxicity as a percentage of production waste toxicity. Differences between regulatory programs are similar for both Japanese and non-Japanese facilities, in that TRI-RCRA facilities exhibit a lower proportion of released waste than the TRI-only facilities. Since facilities regulated under the combined programs tend to be larger, this may possibly be interpreted as economies of scale and greater availability of resources to deal with environmental concerns.

Japanese facilities, both in the case of the lower-volume TRI-only generators and the higher-volume combined TRI-RCRA generators, appear to be more effective at minimizing environmental releases than are non-Japanese firms. Differences by nationality of owner are greatest concerning unadjusted waste for the higher-volume firms regulated under both TRI and RCRA. This may reflect a tendency for a more complete application of lean production systems and environmental management systems in larger Japanese firms. Less variation is apparent in the case of waste releases adjusted for toxicity, although Japanese firm performance still exceeds that of non-Japanese.

Interestingly, the pattern reverses if the very largest facilities, those with more than 1,000 employees, are compared to those of lesser size in terms of unadjusted waste. Table 9.9 provides this comparison. For unadjusted waste, the gap between Japanese and non-Japanese firms is greater still, but the largest firms are less successful than the smaller firms at minimizing releases. This implies that the middle-size firms, those that are less than 1,000 employees but still produce waste in sufficient volume and kind to qualify under both TRI and RCRA, are more effective in reducing waste releases than either the very large firms or those firms of smaller size. In addition, there are some surprising developments in terms of toxicity. The calculated percentages for toxicity show still another reversal from Table 9.8, in that non-Japanese firms are superior in reducing the toxicity of waste releases. Although the Japanese firms are performing better at managing waste in volume terms, toxicity is more concentrated in Japanese releases than non-Japanese and particularly for the very largest Japanese facilities.

One problem with the concept of release ratio is that it does not address the issue of

Table 9.9. Waste management efficiency compared to facility size and nationality
Source: RTK NET and author's database

	< 1,000 workers		1,000+ workers	
Parameter	**non-JPN (N=2,536)**	**JPN (N=164)**	**non-JPN (N=190)**	**JPN (N=15)**
Releases as percent of production waste	10.3	5.3	16.1	8.9
Release toxicity as percent of production toxicity	0.93	3.2	15.4	36.3

operational scale. For example, the M.A. Hanna Color Company and the WCI Steel Company, both of Ohio, each have a release proportion of five percent of production waste. Yet environmental releases by M.A. Hanna totaled 125 pounds in 1999, compared to more than 500,000 pounds for WCI Steel. This is a primary problem with the eco-efficiency concept, in that it is capable of measuring performance but not potential ecological harm. The concept of operational scale is further addressed in the following section.

9.5.2. Eco-efficiency based on operational scale and toxicity

Eco-efficiency is defined as a ratio of an economic indicator to an environmental indicator (or the inverse). Economic indicators are typically conceptualized as involving some measure of value added or production output. Because such information can be difficult to obtain on a firm-level basis, or difficult to standardize in the case of production outputs, these indicators are not suitable for comparisons involving a large number of firms in different industries. In contrast, information about workforce size and areal extent is readily available for many firms. The questions involved are whether worker numbers and plant areal size are in fact appropriate for use as economic indicators in the eco-efficiency equation, and if so, which would best for this purpose.

Facility size, whether measured by number of employees or number of square feet, is an indicator of the operational scale of the establishment. Operational scale, while not a direct measure of economic output, is nevertheless closely linked to a facility’s production volume. Assessing operational scale in terms of areal size is, however, problematic. Facility size in square feet (not including grounds) is a fixed capital investment and thus not very responsive to fluctuations in the firm’s economic output.

Capital construction may take place to increase production capacity, but once built, is seldom removed to accommodate reduced production but is instead likely to remain in place but underutilized. Worker numbers, on the other hand, are far more closely related to changes in production volume. Addition to or downsizing of a plant's workforce can result in increased or decreased outputs; worker numbers are, to a certain extent manipulated to reflect the establishment's current economic situation. Worker numbers are also tied to the labor intensity of specific industries and to improvements in productivity resulting from process change or the introduction of new technology. Thus worker numbers can also be said to reflect operational efficiency as well as operational scale within particular industrial sectors. Worker numbers constitute a more effective indicator of plant dynamics than areal size and are accordingly a more appropriate indicator to use in assessing eco-efficiency.

The waste-related indicators discussed in previous sections of this chapter were all shown to have certain limitations in their applicability to evaluation of facility environmental performance. Production waste magnitude is misleading, because without reference to its management subsequent to initial generation it is not possible to assess how this magnitude is related to either resource conservation or environmental pollution. The same is true for environmental releases; lacking context, magnitude alone is a poor indicator. Context can be provided for releases in two ways; by adjusting total release weights for toxicity or by calculating the release ratio. Toxicity-weighted releases reflect the ability of the firm both to reduce quantities of environmental releases and to reduce the toxicity of materials used in production. The release ratio, or proportion of releases or release toxicity to production waste are indications of waste management efficiency.

Ideally, both the quantitative aspects of total toxic releases and the waste management aspects of the toxicity-weighted release ratio would be combined in some way to construct an environmental variable; in practice this becomes problematic.

Based upon these findings, this section derives values for eco-efficiency using operational scale, measured by worker numbers, as a proxy for the economic variable and toxicity-weighted releases for the environmental variable. The eco-efficiency construct, termed "release toxicity per worker" can then be applied to comparisons of manufacturing firms in the study area. Eco-efficiency determined in this manner thus provides an both an indication of firm performance and of the potential ecological liability of the firm's production, since the way in which magnitude and toxicity are combined provide a measure of toxic intensity for the firm. Low calculated values for eco-efficiency would indicate the best firm performance.

This method can only be applied to firms regulated under the TRI program, and for which information on worker numbers is available. From the original database consisting of 3,712 firms, all RCRA-only firms and those without worker numbers were eliminated. An additional 36 firms were eliminated for which toxicity-weighted determinations could not be made. The remaining data set was comprised of 2,869 TRI and TRI-RCRA facilities. Of these, 177 firms were Japanese and 2,692 were non-Japanese, with other foreign firms comprising 10.9 percent of the non-Japanese firms. Calculated values for eco-efficiency ranged from zero, for those firms that had no releases of production waste, to a value of 2,683. The histogram in Figure 9.5 shows the overall distribution of eco-efficiency (EE) scores, using a log scale on the x-axis.

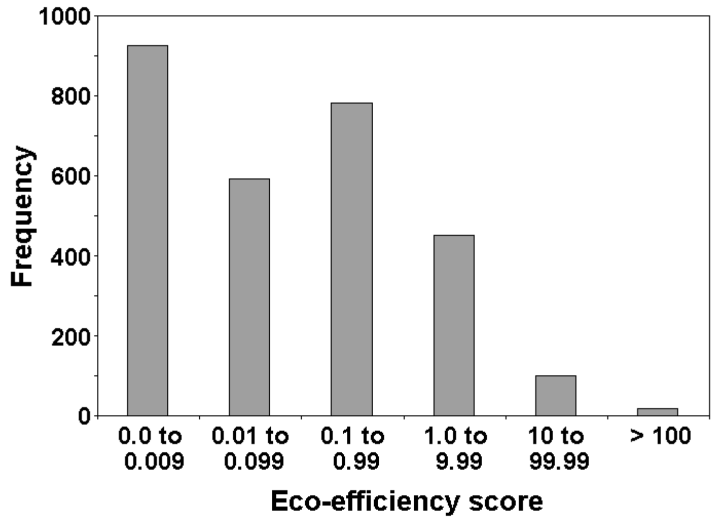


Figure 9.5. Distribution of eco-efficiency scores by firm

The distribution shows a very strong positive skewedness, with more than 80 percent of cases below the mean of 4.24. At the upper end, a very few firms exhibit very high scores, with a rapid drop-off in value below these. The median score of 0.078 is equivalent of one pound of toxicity-adjusted releases per year for every 13 employees; that half of the facilities scored this well or better is encouraging from the perspective of human and ecological risk. About seven percent of the firms exhibited zero released toxicity, some because the substances involved are unrated as to acute toxicity but most because they had no environmental releases at all from the facility. The eco-efficiency median score for the sample population of Japanese firms was roughly half (0.043) that of the non-Japanese firms (0.081). Tables 9.10 and 9.11 provide categorical analysis of the eco-efficiency results. Table 9.10 compares eco-efficiency between Japanese and non-Japanese firms according to facility size. Japanese firms in the middle size ranges exhibit better scores than non-Japanese firms, but inferior performance at the extreme upper and lower ends. The higher values for very large Japanese firms with more than

Table 9.10. Eco-efficiency score by firm size and owner nationality
Upper figure in each cell is EE score; lower figure is number of firms.

Firm size (workers)	non-JPN	JPN
>1,000	0.045 (N=185)	0.1479 (N=15)
500 to 999	0.0802 (N=301)	0.0239 (N=40)
250 to 499	0.0539 (N=531)	.0345 (N=61)
100 to 249	0.0779 (N=799)	.0160 (N=27)
50 to 99	0.1403 (N=459)	0.0683 (N=24)
< 50	0.1286 (N=426)	0.5909 (N=10)

1,000 employees and for small Japanese firms of less than 50 employees may reflect the relatively small number of cases upon which these respective figures are based.

Table 9.11 compares the eco-efficiency scores for Japanese and non-Japanese firms on the basis of industrial sector. The table has been sorted vertically so that the worst scores for non-Japanese firms appear at the top and improve downward. There were few or no Japanese firms operating in several of the industrial sectors, and so these are shown as insufficient cases for comparison. Where comparative data exists, Japanese firm performance is superior in every case, by a minimal two-to-one margin except for the chemicals sector in which Japanese performance is only slightly better. Although the differences between the values in these cells appears small, they are actually rather significant given that four-fifths of the entire sample population scored less than 1.0.

Table 9.11. Eco-efficiency scores by industrial sector and owner nationality
Upper figure in each cell is EE score; lower figure is number of firms. Minimum cases = 10.

Sector	non-JPN	JPN
Lumber & wood products except furniture	0.3912 (N=52)	insufficient cases
Chemicals	0.1983 (N=395)	0.1535 (N=18)
Paper	0.1884 (N=63)	insufficient cases
Food & kindred products	0.1636 (N=105)	insufficient cases
Rubber & plastics	0.1481 (N=343)	0.0787 (N=30)
Furniture & fixtures	0.1299 (N=65)	insufficient cases
Stone, clay, glass & concrete products	0.1223 (N=113)	insufficient cases
Transportation	0.0925 (N=248)	0.0459 (N=50)
Primary metals	0.0651 (N=410)	0.0331 (N=22)
Fabricated metals	0.0315 (N=434)	0.0100 (N=25)
Electronic & electrical equipment	0.0150 (N=139)	0.0084 (N=13)
Industrial & commercial machinery	0.0048 (N=185)	insufficient cases

The concept of eco-efficiency, when measured as a ratio of plant size to release toxicity, appears to have potential as an indicator of a firm's environmental performance, useful as a benchmark to track performance across time for that firm or in comparison with other firms. This is an indicator that is responsive to changing conditions. If production increases or decreases, the indicator responds in the same direction as the change. Any change that affects the magnitude of waste generation and how it is managed will be reflected in the eco-efficiency value, whether the change is driven by internal or external factors that influence capacity, efficiency and productivity.

9.6. Temporal analysis: EPA's 33/50 "priority" chemicals

Analysis of facility performance across time using TRI data is problematic because there have been both additions to and deletions from the list of chemicals regulated under this program. In order to evaluate a temporal trend, the analysis must employ a selected set of chemicals that have been in consistent use during the period of investigation. Although there are several hundred substances on the TRI list that meet this criteria, this investigation focuses upon a group of seventeen "Priority Toxic Chemicals" targeted by the EPA for a program of voluntary emissions reductions.[9] The EPA strategy was initiated in 1991 and referred to as the 33/50 program because it set goals of a 33 percent reduction in releases and transfers of these chemicals by 1992 and a 50 percent reduction by 1995, measured against a 1988 baseline. The EPA initiative was considered a signal success, having reached its 50-percent goal by 1994, a full year ahead of schedule (USEPA 1999). Although the 33/50 program officially extended only from 1991-1995, the following analysis will track these chemicals, as releases, over the period 1987 through 1999.

The period from 1987 through 1991 was the peak for Japanese manufacturing investment in the United States, with transplant numbers rapidly increasing in the study area through both acquisitions and greenfield establishments. It is against this context of rapid growth and facility expansion that the data must be considered. In 1987 there were

[9] See Appendix 3 for a list and description of the seventeen chemicals.

only 14 Japanese facilities in the study area using any of the seventeen chemicals on the priority list, compared to 387 non-Japanese firms. The number of Japanese firms using these chemicals climbed steadily until 1992, remained constant for a few years, and then resumed increase to a peak of 69 firms in 1999. This peak represents 37.5 percent of all Japanese TRI firms. In contrast, non-Japanese firms using these chemicals climbed to a peak of 603 firms in 1994 and has slowly declined since to 562 firms in 1999, or 19.4 percent of TRI facilities.

Figure 9.6 compares the reduction in environmental releases for the seventeen priority chemicals for Japanese and non-Japanese firms over the period 1987 to 1999. Both groups show a substantial reduction but surprisingly, given that Japanese firms have exhibited, in most instances, lower release rates and reduced toxicity of releases, the performance of Japanese firms in regard to this particular set of substances has been poor compared to non-Japanese firms. Release rates for these chemicals have dropped precipitously for non-Japanese firms throughout the period of investigation, from a

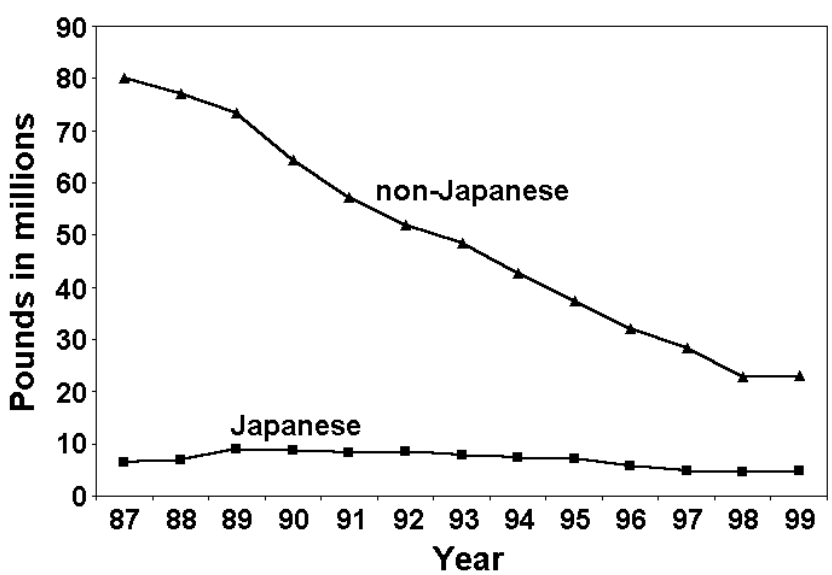


Figure 9.6. Releases of TRI priority chemicals by owner nationality, 1987-1999
Source: RTK NET

maximum of 80 million pounds in 1987 to a minimum of 22 million pounds in 1998. Japanese releases climbed to a maximum of 9 million pounds in 1989 and have dropped year by year since then, but at a far lesser rate of decrease than the non-Japanese facilities. For Japanese firms, the increase up to 1989 was undoubtedly the result of newly established operations during the peak investment period. During the next few years, the relatively slow rate of reduction may have been a result of continued, if lesser, investment that partially offset any progress made by existing firms. The single greatest reductions in releases for the priority chemicals made by Japanese firms occurred in 1996 and 1997, for those years alone exceeding the rate of reduction of non-Japanese firms. The following year, 1998, progress again slowed; the minimum releases quantity was achieved by Japanese firms in that year, amounting to 4.6 million pounds. From 1998 to 1999, releases for these chemicals increased for both Japanese and non-Japanese firms.

Overall, Japanese firms were able to reduce environmental releases of the 33/50 priority chemicals by 49.4 percent from the peak in 1989 to the minimum reached in 1998. In comparison, non-Japanese firms achieved a reduction of 70 percent during the same time period. The key to the difference may lie in the industries involved. The transportation equipment sector is more heavily involved in the use of the 33/50 chemicals than any other individual sector, for both Japanese and non-Japanese firms, but to a far greater extent for the Japanese. This is simply a reflection of the basic industrial composition of Japanese transplants, who have tended to invest more in this sector. During the period of investigation, the transportation equipment sector remained responsible for a little less than a third of releases of the priority chemicals for non-Japanese facilities. In contrast, the transportation sector was strongly dominant at the beginning of the period for Japanese firms and increased that dominance in terms of priority chemical releases, from 64 percent in 1989 to 76.5 percent in 1999.

Based on anecdotal impressions gained during case studies conducted for the pilot study (O'Dell 1991) and for the present investigation, a substantial proportion of the usage of these priority chemicals appears to have been associated with painting operations, as solvents. Firms involved in manufacturing components for the automotive industry, including body parts made by assembly plants, appear to have been reluctant to switch from solvent-based to water-based paints. This reluctance has been prompted by quality considerations, in the perception that water-based paints have not, in the past, been able to meet customer expectations for quality and durability. Many firms are, however, beginning to make a changeover to paints that pose less environmental hazard improved paints of this nature become available to manufacturers. These include powder coatings as well as paints with a water base or other, less toxic base.

9.7. Sector focus: The automotive industry

Because the automotive industry is such an important component of the overall pattern of manufacturing in the study area, and most particularly for Japanese firms, it appears worthwhile to conclude the analysis of environmental performance in this chapter with a focus upon this industry. The detailed, firm-by-firm investigation described in Chapter 5 revealed that about a third of all non-Japanese TRI or RCRA firms in the study area were involved in supplying parts or materials to the automotive industry, even though this might not represent their primary activity. Participation is double this level for Japanese firms, with 66.8 percent of Japanese manufacturers so involved.

In the subsections that follow, the investigation begins with automobile assembly plants and then moves to supplier firms. Supplier firms are divided into two classes: (1) those whose SIC codes apply strictly to automotive component manufacture; and (2) other firms involved in the auto industry as suppliers whose codes are not specific to the industry but were identified as participants by the author's research. In a very rough sense, the former group of suppliers may be considered equivalent to first-tier suppliers and the second group as tiers more distant in the supplier hierarchy.

9.7.1. Automobile assembly plants

The study area contains 16 vehicle assembly plants, not counting those dedicated to heavy trucks or equipment. Seven of these plants are Japanese, and nine are non-Japanese. Table 9.12 lists the assembly plants along with indicators of operational scale, plant size measured in worker numbers and in square feet enclosed. There is little distinction by size between Japanese and non-Japanese facilities. Japanese plants average 4,157 workers compared to 4,364 for non-Japanese and have a mean areal size of 3.6 million square feet compared to 3.5 million for non-Japanese facilities. The largest automaker in the study area is Toyota in Kentucky, with 7,000 employees and nearly 8 million square feet under roof. The smallest facility is the GMC plant in Kentucky, which manufactures Corvettes with about 1,000 employees and 1 million square feet of plant area.

Table 9.13 lists a number of environmental indicators for these assembly plants, including total production waste, total releases, the release ratio, release toxicity and the eco-efficiency score calculated as the ratio of toxicity-adjusted waste releases per worker. In terms of waste unadjusted for toxicity, again there is little difference by nationality of

Table 9.12. Characteristics of automobile assembly plants in study area
Source: Author's database

Firm	City	ST	Owner	Workers	Sq. Ft.
Saturn	Spring Hill	TN	USA	8,400	6,200,000
Toyota	Georgetown	KY	JPN	7,000	7,850,000
GM SCG	Lordstown	OH	USA	6,650	2,650,000
Honda	Marysville	OH	JPN	6,500	3,300,000
Nissan	Smyrna	TN	JPN	5,700	5,100,000
Daimler/Chrysler I & II	Toledo	OH	GER	5,600	5,180,000
Ford Truck Plant	Louisville	KY	USA	4,500	4,330,460
GMTG	Moraine	OH	USA	4,300	3,235,595
Ford	Louisville	KY	USA	3,800	3,049,075
Ford-Nissan joint venture	Avon Lake	OH	JPN/USA	3,100	3,300,000
Subaru-Isuzu joint venture	Lafayette	IN	JPN	3,100	2,300,000
GMTG	Roanoke	IN	USA	3,100	2,600,000
Honda	East Liberty	OH	JPN	2,400	1,500,000
Ford	Lorain	OH	USA	1,875	3,200,000
Toyota	Princeton	IN	JPN	1,300	2,000,000
GMC	Bowling Green	KY	USA	1,050	1,000,000

owner. Japanese assembly plants average 2.1 million pounds of production waste compared to 2.0 for non-Japanese facilities, and 0.83 million pounds of unweighted releases to 0.75 million.

The anomalous Ford Lorain facility is a special case and is omitted from these and further analyses. Production at this facility has suffered from nearly constant disruption since the mid-1990s. In 1997 two assembly lines producing Thunderbirds and Cougars were permanently closed, leaving only a single line for Ecoline vans. Employment dropped from over 3,000 to about 1,875, with the plant being described by company officials as being on "warm idle." The Loraine plant continues to assemble vans, but bodies are trucked in from the Avon Lake facility, where they are manufactured and painted. The Lorain plant is thus very atypical since it does not even produce body parts; the waste that would normally be associated with the production of van body components at Lorain is instead outsourced to Avon Lake.[10] The TRI database shows a dramatic drop in waste releases from 1.43 million pounds in 1994 to 0.02 million in 1999 as a consequence of these changes.

Outsourcing is a thorny problem to deal with in any consideration of Japanese assembly plants, whether the issue at hand is environmental performance, productivity or value added. According to Kenney and Florida (1993), Japanese auto assembly plants typically obtain as much as 70 percent of vehicle components from supplier firms, compared to 30 to 50 percent of inputs obtained by U.S. firms from suppliers. Any parts that are manufactured external to the assembly plant also generate waste externally. Florida (1996, 93) notes "manufacturers have at times used their suppliers as a vehicle for improving their own environmental records by out-sourcing toxic elements of the production processes, essentially pushing waste and toxins down the supply chain." During the 1990s' however, U.S. firms, lead by the Big Three automakers, have rapidly and substantially increased the proportion of outsourced components, narrowing the gap between Japanese and non-Japanese firms.

The relative proportion of component outsourcing certainly has implications for comparisons of environmental performance among firms, since major differences in outsourcing dependence would skew the basis of comparison. There does not appear to any easy way to resolve this problem, since even an accurate determination of the amount

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[10] See *Blue Oval News*, 24 December 2000, and the *Cincinnati Enquirer*, 1 June 1999 for discussion of changes at the Lorain facility.

of outsourcing is problematic. Defining a percentage of outsourcing faces the same ambiguity as defining "domestic content" of manufactured goods, a closely related concept. The Federal Trade Commission defines domestic content on the basis of cost, where the percentage of U.S. content equals the proportion of a good's value that does not derive from a foreign source. The environmental cost of manufacturing a good is not, however, necessarily comparable to its economic cost.

There does not seem to be any clear consensus as to what defines a unit of outsourcing, whether this should be measured as value, units, or mass. Kenney and Florida (1993, 206) state: "Domestic content refers to the direct material inputs such as steel, rubber, automotive parts, engines, and transmissions that are used in the manufacture and assembly of automobiles." If we consider outsourcing as the percentage of parts, then does a transmission count the same as a stainless steel bolt? If in terms of mass, does a hundred pounds of complex electronics equate to a hundred pounds of stamped sheet metal? The same equivalency considerations apply to environmental issues such as resource use and pollution generation associated with manufacturing different components. Nor did plant managers and production supervisors interviewed during the case studies have any clear idea how to measure outsourcing; most seemed to feel that this applied to the number of parts in a product.

One cannot dismiss an issue simply because it is ambiguous or difficult to resolve; it remains a pitfall for the investigator. When comparing Japanese assembly plants to non-Japanese, we must be aware that the outsourcing issue may be creating a situation in which the playing field has not been leveled. This issue cannot be easily resolved at the level of the assembly plant, but can be addressed further out in the supply chain. Many suppliers also outsource some of their components, but not to the extent of assembly plants. Firms that supply parts of a similar nature should constitute a reasonable basis for comparison of environmental performance.

While acknowledging the potential significance of outsourcing, a number of environmental indicators can be applied in assessing comparative environmental

Table 9.13. Environmental indicators for automobile assembly plants in study area
Source: RTK NET and author's database

Japanese facilities								
Firm	**City**	**ST**	**Prod Waste**	**Releases**	**Release toxicity**	**Release ratio**	**Release toxicity ratio**	**Eco**
Honda	Marysville	OH	1,455,199	970,265	189	66.7	45.7	0.02
Toyota	Princeton	IN	2,487,318	86,455	352	3.5	16.7	0.27
Toyota	Georgetown	KY	3,864,447	1,060,888	4,239	27.5	32.2	0.54
Honda	East Liberty	OH	619,687	429,295	1,960	69.3	76.6	0.81
Ford Nissan JV	Avon Lake	OH	1,781,845	544,951	3,220	31.7	31.7	1.04
Nissan	Smyrna	TN	2,626,939	1,757,902	6,640	66.9	62.1	1.16
Subaru Isuzu JV	Lafayette	IN	1,864,648	968,685	5,730	52.0	53.1	1.84
non-Japanese facilities								
Firm	**City**	**ST**	**Prod Waste**	**Releases**	**Release toxicity**	**Release ratio**	**Release toxicity ratio**	**Eco**
Ford	Lorain	OH	57,689	24,744	23	42.9	44.05	0.01
GMTG	Moraine	OH	1,788,632	108,459	386	6.1	10.42	0.09
Saturn	Spring Hill	TN	1,590,474	825,033	2,605	51.9	45.3	0.31
GM	Lordstown	OH	1,560,806	707,755	3,992	45.3	46.4	0.60
Ford	Louisville	KY	3,409,189	1,179,552	3,318	34.6	38.7	0.74
Daimler/ Chrysler	Toledo	OH	1,368,231	924,662	4,569	67.6	69.8	0.82
GMC	Bowling Green	KY	1,179,814	261,647	1,020	22.2	25.6	0.97
GMTG	Roanoke	IN	3,263,160	1,265,303	5,187	38.8	39.6	1.67
Ford	Louisville	KY	3,633,226	1,611,996	9,820	44.4	52.5	2.58

performance among automakers. The automobile assembly facilities in Table 9.13 are rank-ordered by their eco-efficiency scores ("Eco" in the table heading) from best to worst performance, separated as to nationality of owner. There is little direct correspondence apparent between the eco-efficiency scores and the other environmental indicators; this is because none of the other indicators address operational scale. These indicators are nonetheless useful in assessing either waste management efficiency or potential environmental risk. In terms of the release ratio (releases as a percentage of total production waste), the Toyota plant in Indiana and the GM plant in Ohio stand out above the rest for effectiveness in reducing releases. Although the mean release ratio (excluding these three facilities) for Japanese assembly plants is 52.1 percent and 43.5 for non-Japanese, the Toyota plant has achieved an astounding 3.5 percent and GM has attained 6.1 percent uncontrolled releases derived from production waste.

As the newest automobile assembly plant in the study area – established in 1998 – the Toyota facility has been able to take advantage of the latest advances in pollution control technology to reduce its environmental impact. The GM Moraine Assembly facility, on the other hand, is an older plant but has a TRI record that shows constant environmental performance improvement, year by year since 1996.

In terms of the release toxicity ratio (weighted toxicity of releases divided by total releases), non-Japanese facilities appear, on average, to do a slightly better job of ensuring that releases are less toxic than do Japanese firms. Japanese firms exhibit an average release toxicity ratio of 45.4 percent compared to 41.0 for non-Japanese assembly plants. Toyota of Indiana, with 29.5 percent, shows the best performance among Japanese automakers, but is eclipsed by the very low 10.4 percent release toxicity of GM's Moraine Assembly and more than equaled by the GM Corvette factory in Bowling Green, Kentucky, with 25.6 percent.

Last in this consideration are the eco-efficiency scores, in which operational scale plays a role. Japanese assemblers show slightly better performance using this indicator, with a mean eco-efficiency rating of 0.82 compared to 0.97 for non-Japanese facilities. As might be expected from their performance in regard to the other indicators, Toyota of Indiana and GM Moraine score best among the facilities, excluding the special situation of the Ford Lorain plant. Honda Marysville is the surprise, having removed virtually all toxicity from its releases.

Although there are variations among facilities, there appears to be little significant difference between Japanese and non-Japanese automakers in terms of environmental performance regardless of the indicator used. General Motors, like Ford, has embraced Japanese lean production methods, and this may help explain why the environmental differences between Japanese automobile assembly transplants and domestic automakers are slight. The NUMMI plant in California, a joint venture between GM and Toyota, was a learning experience for General Motors. GM subsequently set up the Saturn plant in Tennessee on the basis of the Japanese system, and has been reworking its approach to manufacturing to incorporate the core features of lean production. General Motors's Global Manufacturing System (GMS) has been described as "a holistic approach to vehicle manufacturing similar to the Toyota Production System."[11] The Moraine Assembly plant was gutted in 2000 and rebuilt completely in accordance to GM's new lean production system. Although TRI data since the reconstruction are not yet available,

[11] See "Moraine gets lean" 4 April 2002 in online journal Autofieldguide.com; and "GM's Global Manufacturing System: A system to build great cars and trucks," extract from speech by Guy Briggs, GM

it will interesting to see if full implementation of the Japanese system in this facility has a further effect upon pollution prevention.

9.7.2. Automotive supply firms

Those facilities whose production is entirely concerned with supplying the automotive industry are defined by the specific SIC classifications 3465 (automotive stampings), 3592 (carburetors, pistons, piston rings and valves), 3647 (vehicular lighting equipment), 3694 (electrical equipment for vehicle engines), and 3714 (motor vehicle parts and accessories). For the comparison in this section, firms classified as producing vehicles or vehicle bodies are excluded (SIC categories 3711, 3713, 3715, 3716, and 3751).[12] Because of the relatively limited number of firms in several of the classes, the comparison is made by combining statistics for in the five automotive categories. Fifty-one Japanese firms and 159 non-Japanese facilities are included among these five industrial classifications. Most of these firms were in the generalized SIC class 3714, about 80 percent for each ownership group. A little more than half of the Japanese facilities were regulated under both TRI and RCRA, compared to about 40 percent of non-Japanese. Japanese firms averaged 516 workers, with only four that employed over 1,000. A far greater proportion of the non-Japanese firms would be considered very large, since 27 facilities employed more than 1,000 workers, contributing to a larger mean firm size of 721 workers.

The information shown by Table 9.14 allows comparison of environmental indicators for Japanese and non-Japanese facilities. Japanese firms average less production waste

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Vice-President and General Manager, at manufacturing conference in Nashville, April 2001, accessible through http://www.media.gm.com.

[12] See Table 5.5 in chapter 5 for explanation of these codes.

Table 9.14. Environmental indicators for firms in automotive-specific components sectors, by nationality of owner

Source: RTK NET and author's database

Owner	No. of cases	Prod waste	Releases	Release ratio	Release toxicity ratio	Eco
Japanese	51	169,464	19,473	11.5	6.4	0.25
non-Japanese	159	281,905	11,983	4.3	3.2	0.64

but allow more of it to escape as releases than non-Japanese. Both types, however, have very low release rates, and even lower release toxicity ratios, particularly when compared to the percentages obtained by the assembly plants (see Table 9.13). Japanese facilities achieve a better eco-efficiency score than non-Japanese, although scores for both are better than all but a few of the assembly plants.

Firms whose SIC classification is not automotive-specific but manufacture auto components as a significant proportion of their production greatly outnumber those firms that are readily identifiable as automotive related. Seventy two Japanese firms and 640 non-Japanese firms conduct such manufacturing, which is primarily concentrated within the same three industrial classes – rubber and plastics, primary metals, and metal fabricating – for both owner classes. About 75 percent of both Japanese and non-Japanese automotive-related but not automotive-specific firms fall within these sectors. In each case, a little less than half of the firms are regulated under both the TRI and RCRA programs. The mean size for Japanese facilities was 322 workers, with only one firm over 1,000 employees, compared to a mean of 390 workers for non-Japanese facilities and more than 30 plants employing over 1,000.

Table 9.15. Environmental indicators for firms in automotive-related production of components or materials, by nationality of owner
Source: RTK NET and author's database

Owner	No. of cases	Prod waste	Releases	Release ratio	Release toxicity ratio	Eco
Japanese	72	404,821	31,524	7.79	6.28	0.61
non-Japanese	640	798,030	94,228	11.81	14.46	2.17

Environmental indicators for these two populations are shown in Table 9.15. Performance for Japanese firms was superior for all indicators used. Mean production waste and releases averaged about half that of non-Japanese firms; the release ratio for Japanese firms was 66 percent that of non-Japanese and the release toxicity ratio less than 50 percent. At 0.61, the eco-efficiency score for Japanese firms was less than one-fourth of the value for their domestic counterparts.

9.8. Summary of findings

The purpose of the analyses carried out within this chapter has been to investigate the proposition that Japanese industrial facilities, because of their more fully implemented lean production systems, should demonstrate superior environmental performance in terms of reduced production waste, waste releases, and toxicity of waste and releases than non-Japanese facilities. The investigation was complicated by a high variability of waste outputs even among firms within the same industrial sectors; in nearly every sector, the majority of waste and/or releases and associated toxicity was produced by one or a few firms rather than being generated by the collective action of firms.

Facility size, as initially suggested by the regression models, proved to be the most important single factor accounting for variations in waste outputs. The regression analysis had not attached significance to owner nationality. Subsequent analysis suggests that this may be because the importance of nationality is contextual. When controlling for size, industrial sector and regulatory program, environmental indicators pointed to better performance by Japanese facilities in a given set of circumstances, but sometimes inferior in other circumstances. For example, in some cases where Japanese firms exhibited better management of release quantities, non-Japanese firms did better in controlling the toxicity of those releases. In general, Japanese facilities in the middle size ranges appeared to perform better in comparison with non-Japanese facilities than did very large or very small Japanese facilities with their equivalent non-Japanese counterparts.

Program type appears to be both an indicator of the diversity of waste types and the magnitude of waste managed. Firms that were regulated under both RCRA and the TRI programs were managing a greater variety of wastes, since each program addresses different waste types. The RCRA program addresses solid waste which may be transported to ordinary landfills or to hazardous waste landfills; the TRI program is concerned with toxic wastes that are, at least in the released form, non-solid. A greater proportion of Japanese firms are regulated under TRI and/or RCRA programs than non-Japanese, which suggested that Japanese firms tend more to be located in waste-generating industries.

Firms that were regulated simultaneously under both RCRA and TRI accounted for more total waste than single-program firms because of the additive effect for two waste categories. The effect for dual program regulation increasing total waste magnitude appears, however, to hold even if only TRI wastes are considered. Dual program firms accounted for more TRI waste generation and releases in terms of both magnitude and toxicity than single-program firms. The analysis indicates that dual program firms tend to be larger in scale than single program firms, and that Japanese firms are larger in scale than non-Japanese firms in both cases.

Examination in detail of the data revealed that a very small proportion of facilities was responsible for producing most of the waste generated and waste released, both in terms of absolute magnitude and when adjusted for toxicity. For example, the top five percent of firms in each category of ownership are responsible for 75 percent of the toxicity for Japanese releases and 85 percent of the toxicity for non-Japanese releases. Accordingly the most accurate comparisons are made when these outliers are removed to prevent skewing the data. Following this adjustment, evaluations made based on number of firms that compared the total magnitude of generated waste and waste releases, and the toxicity for generated waste and waste releases, indicated that the Japanese share of magnitude and toxicity for both generated waste and waste releases was proportionately equivalent to their representation in firm numbers. This suggested that Japanese firms were no better or worse than non-Japanese firms in resource conservation and pollution prevention. For RCRA solid waste, however, Japanese firms showed slightly better waste management performance in terms of less waste shipped off-site, proportionate to the number of firms involved.

When analyzed according to industrial sector, the majority of generated waste is distributed among a relative few sectors for both Japanese and non-Japanese firms. In terms of generated waste toxicity, however, one sector alone, chemicals, was dominant, in extreme, for both ownership categories. The pattern displayed for waste releases was quite different, in that releases were generally concentrated in different industrial sectors according to owner nationality. Release magnitude and release toxicity for non-Japanese firms was concentrated in chemicals and primary metals, whereas the transportation equipment sector was most significant for Japanese firms. Throughout this analysis, the effect of a handful of firms that produced the most waste and waste toxicity was evident in both categories of owner nationality. Similarly, generation and shipment patterns for RCRA waste were signifiantly different for Japanese and non-Japanese firms, being concentrated in different sectors. Again, for Japanese firms, the transportation equipment sector was proportionately of greater importance than for non-Japanese.

The results reported above are based upon environmental variables considered singly – magnitude and toxicity for waste generation and releases – and hence have limited application for making performance comparisons. Comparisons using single variables are, at best, weakly suggestive of possible trends. Waste magnitude in particular is uninformative, since subsequent management determines not only the efficiency of the operation but also the potential environmental impact of materials not reclaimed. Environmental performance evaluation and comparisons concerning hazardous materials require the combination of variables in some manner to reflect management practice and/or the fate of the materials. Accordingly, the performance comparisons were based upon the use of three constructed performance indicators that were believed to best represent the effectiveness of management practices in reducing environmental hazard.

These constructed variables were based on proportionate releases and release toxicity, measuring releases and release toxicity as a percentage of waste generation and generation toxicity. In addition to these two, an eco-efficiency indicator was constructed measuring release toxicity per plant worker. Plant worker was chosen as a more representative and responsive economic indicator than plant size. The proportionate indicators were compared separately by owner nationality against program type and plant size, where plant size was limited to two categories either < or > 1,000 workers. By regulatory program type, dual or single, Japanese firm performance was only slightly better than non-Japanese firms for proportionate releases and release toxicity. By size, small and large Japanese firms performed better at minimizing the proportion of waste generation released to the environment, but did not do as well at minimizing the toxicity of releases as the non-Japanese firms.

The eco-efficiency indicator was compared by owner nationality against firm size and industrial sector. Firm size was broken into six classes, and Japanese firms exhibited slightly to significantly better performance in every class except for firms >1,000 workers and firms <50 workers, the largest and smallest classes. By industrial sector, Japanese firms performed better in every case, considerably so except for the chemicals sector.

These same performance comparisons were also applied to the automotive industry, in regard to three classes of firms: automobile assembly plants, automotive SIC codes (roughly equivalent to first-tier suppliers), and automotive-related production as defined in Chapter 5. For the most part in these comparisons, differences were minimal. Non-Japanese assembly plants slightly outperformed Japanese assembly plants, although both Toyota plants and GM's Moraine assembly plant were outstanding within their respective groups. Japanese assembly plants received slightly better ratings in eco-efficiency. For the first-tier supplier firms, non-Japanese firms performed better on two of three indicators, with the Japanese firms ahead in terms of eco-efficiency. For auto-related production, which includes a substantial proportion of the total number of firms in the database, the performance of Japanese firms was better on all three indicators.

The analysis of the trend over time for the select group of seventeen priority chemicals once targeted for reduction by the EPA in its 33/50 program provided results that were both unexpected and of considerable interest. This group of chemicals had been selected for no other reason than to allow a temporal comparison. Any other group of chemicals might have been equally as useful, but these were chosen because the EPA had specifically promoted minimization or elimination. The expectation had been that Japanese firms would show a reduction equal to or possible greater than non-Japanese firms; the exact opposite proved to be true. Both Japanese and non-Japanese companies made significant reductions in the use of these chemicals, but non-Japanese did better by far. A number of interpretations are possible. These chemicals, for example, may have been more significant to the industries in which Japanese firms are located. Another possibility is that Japanese firms were unable to reduce usage as quickly as non-Japanese firms because they had already minimized and further reductions were more difficult to achieve. One intriguing possibility is that increasing adoption of lean production methods by non-Japanese firms allowed dramatic improvements in pollution prevention. Further study involving temporal trends is called for, using a different set of chemicals or expanding the range of substances.

Chapter Ten

Promoting Lean and Clean through the Supplier Net: Toyota of Kentucky

10.1. Introduction to case studies

Statistical data, such as that derived from the federal TRI or RCRA programs, or even that from the mail survey conducted as part of the present research project, provide the means to assess WHAT is occurring in terms of environmental performance outcomes but shed very little light on HOW improvements are achieved. For most Japanese transplant firms in the United States, lean production methods constitute the operational framework and, increasingly, ISO-14001 establishes environmental goals. The actual application of these management tools is, however, contextual in nature, reflecting not only the broader corporate philosophy but also the commitment of management at individual facilities to seek innovation and pursue continuous improvements in environmental performance. To determine what lies behind the statistics, resort to qualitative methods is necessary. Accordingly, case studies of several individual firms are included to indicate some of the many ways by which Japanese companies seek to minimize the environmental impact of production operations.

The five case studies presented in three succeeding chapters focus on different aspects of lean production and environmental management. The first case study is about a major automaker – the Toyota plant in Kentucky - that is determined to achieve environmental performance superior to other automakers, domestic or foreign. The Toyota corporation originated and freely disseminated the principles of lean production in Japan and, through its assembly facilities in North America, actively propagates the concepts and methods of the Toyota production system downward through its supplier networks. Through initiatives and standards, Toyota both encourages and coerces its suppliers to improve their own environmental performance.

In Chapter 11, two case studies are presented from the opposite perspective, an upward look from the point of view of supplier firms who take their cues from another major automaker, their most important customer: Honda in Ohio. Honda has taken the basic lean production concepts and developed their own variant, “BP” or Best Practice, that they actively promote among their suppliers along with environmental standards. The two firms featured in this chapter have taken a proactive approach to managing for environmental quality, rather than simply reacting to their customer’s initiatives. Chapters 10 and 11 thus focus upon the interaction between automobile assembly plants and the smaller firms that supply components, providing us with a dual perspective on how lean production concepts and methods, with their environmental implications, are being diffused through firms in the United States.

In Chapter 12, two firms are profiled whose performance standards, in terms of quality, productivity, and pollution prevention, are not driven by any one external customer but rather by a self-imposed desire to excell. In one case, this is a result of having a great many customers rather than a dependency upon a single firm for most of their business, so the system under which they operate is not precisely that of Toyota or Honda or Nissan but is lean production all the same. The final case, presented in Chapter 12, concerns a firm that has nothing whatever to do with the automotive industry but instead produces heavy construction equipment, about one unit per day. Unlike the other firms in the case studies, all greenfield plants, this company was acquired and has gradually introduced lean production methods, literally sending American employees to school to learn how Toyota's system could be applied within their own firm.

Case studies, using qualitative methods, provide the means to illuminate the HOW and the WHY behind observed phenomena. Qualitative methods in themselves can neither prove nor disprove a hypothesis, but are intended to reveal patterns and to provide insights into behavior. Qualitative research can take many forms and employ many different methods, depending upon the research questions involved and the nature of the research subject. Ethnography is the use of qualitative methods to study cultures, including organizational cultures.

Ethnography is, however, a very difficult undertaking in business organizations, as Atsushi Sumi (1998) discovered in his efforts to conduct anthropological studies of Japanese industry in the Midwest and West Coast: "Business organizations constitute very closed social groups, and business organizations have more decision-making power over any outside researcher" than is true for most other study groups. Sumi spent considerable time and effort to gain access to industrial plants, to either be hired by any one plant, in any capacity, to informally conduct research by participant observation, or by means of a formal request to conduct research over an extended period. He met with a complete lack of success, both at American-owned firms and even at Japanese-owned firms, despite some close personal contacts at some of the latter facilities. In Kentucky, Sumi was told that many such requests to conduct research were received:

> The most that he [a plant manager] had ever done in the past, he said, was to take a few hours for interviews. His concern was basically time, cost, and safety. The company cannot afford to ignore the loss of work time caused by outside researchers, especially a researcher like me, who wanted to talk to production workers. In terms of cost, he told me that the company would have to pay its workers for the hours spent for the

> interviews, which was totally unrealistic from his point of view. For company safety, I needed to be accompanied by production supervisors because of the high powered equipment on the shop floor. The company obviously could not afford to assign someone to be with me all the time (pp. 46-47).

Management reluctance to allow studies in depth has sometimes been overcome through deception; either by misrepresenting the purpose of the study or by falsely obtaining employment at the company for the purpose of participant observation. Burawoy (1998,22) notes: "To penetrate the shields of the powerful the social scientist has to be lucky and/or devious." The technique of deceptive employment for research has been employed by a number of researchers to investigate corporate culture, including Burawoy and also Graham (1995).

The use of ethnographic techniques such as participant observation may be appropriate when the object of investigation is concerned with human relationships with or within Japanese facilities. An ethnographic approach may provide answers not obtainable by other means for investigations of community reaction to transplants, acculturation of workers, or the dynamics of labor/power within a particular facility. Ethnographic research furthermore requires a substantial time commitment to a single group. The present research is concerned more with discovering practices rather than relationships, and to appraise the possible variety and range of such practices using a sample of several facilities whose basic characteristics differ in terms of size and products manufactured. Accordingly, because the research questions are not ethnographic in nature, ethnographic methods were not undertaken as part of the case studies.

Instead, the case studies were derived from multiple investigative methods. The primary method entailed site visitation with non-participant observation and semistructured interviews with key informants. Key informants were those persons whose job responsibilities specifically included environmental management issues. These included personnel, both supervisory and non-supervisory, who were responsible for promoting improvements in environmental performance through implementing broad corporate environmental initiatives; assessing facility-specific environmental issues, setting goals and targets, and evaluating results; preparing for ISO-14001 certification and ensuring that the facility adheres to the procedures and standards; enhancing worker awareness of environmental issues; and evaluating the feasibility of worker suggestions for environmental improvement. In addition to informants whose duties were primarily concerned with environmental issues, interviews were also conducted with plant personnel from other areas, including production operations managers and personnel within human resources departments.

A site visit typically consisted of a period of one or two hours spent in a conference room during which environmental issues were discussed with informants, followed by a tour of the facility. The plant tour focused on areas associated with specific environmental problems, and entailed discussion of solutions, both successful and unsuccessful, that had been sought to address these issues. During the course of the tour, short interviews were often conducted with workers encountered, supervisory and non-supervisory, who could provide further input.

Following the site visit, numerous additional communications with key informants, by telephone and email, were undertaken to clarify points raised during the interview and tour. The case study was then written using notes taken during the interviews and tour, and supplemented by material obtained from company websites, company public brochures and internal reports, and data from RCRA and TRI. Other information sources reviewed, and material incorporated where relevant, included non-company Internet websites and articles from news media, trade magazines and scholarly journals. The draft of the case study was then returned to the key informants at the facility for comments and corrections of factual errors.

The response by management personnel at each facility to the research project was unanimously favorable, and even enthusiastic in some cases. As noted in Chapter 5, arranging access for the purpose of a case study had only been problematic where assembly plants of major automakers were concerned; although, after rejections by Honda and Nissan, Toyota's unhesitating response was both cordial and cooperative. Bearing in mind the concerns over the length of time involved expressed by a plant manager to Sumi (1998), care was taken when making contact to emphasize that no more than a half-day would be required for the site visit.

The interest shown by plant managers in the project can perhaps be gauged by the reception on the day of the site visit: rather than being hosted by a single functionary impatient to be finished with an unwelcome task, in every case several interested plant personnel from various departments participated in the initial meeting. During the initial meeting and in the course of the subsequent plant tours, upon occasion comments were made that were critical of specific company policies or practices, indicating that respondents were not simply parroting a "party line." At several of the facilities, managers expressed an interest in receiving a copy of the completed dissertation so that they might compare the environmental performance of their company against others; this is a reflection of the "benchmarking" practice described by Toyota personnel. Following the site visit, during the email and telephone correspondence used to clear up various points, one respondent asked for suggestions on recommended readings in lean production and environmental management. Another respondent expressed pleasure when receiving, for comment, the draft copy of the case study for his facility; noting that it provided him with a capsule description of company operations that would be useful to him in the future.

The facilities included in the case studies were selected on the following basis: (1) at least one vehicle assembly plant, representing both destination for numerous suppliers and among the region's largest firms; (2) the majority of the facilities to be derived from sectors involved in automotive supply chains, given the importance of the transportation industry in the study area; and (3) at least one facility not involved in an automobile-related industry. Facilities were selected from the list of Japanese companies in the study area on the basis of consent; once a facility had been contacted and assented to participate in the case study, other facilities of a similar nature (in terms of product manufactured) were eliminated. The five facilities chosen were: Toyota Motor Manufacturing Kentucky; Madison Precision Products (IN); Mitsubishi Electric Automotive America (OH); Yorozu Automotive America (TN); and Link-Belt Construction Equipment Company (KY). Figure 10.1 shows the location of these facilities, and Table 10.1 provides basic information on plant size and industrial classification for the five facilities included in the study.

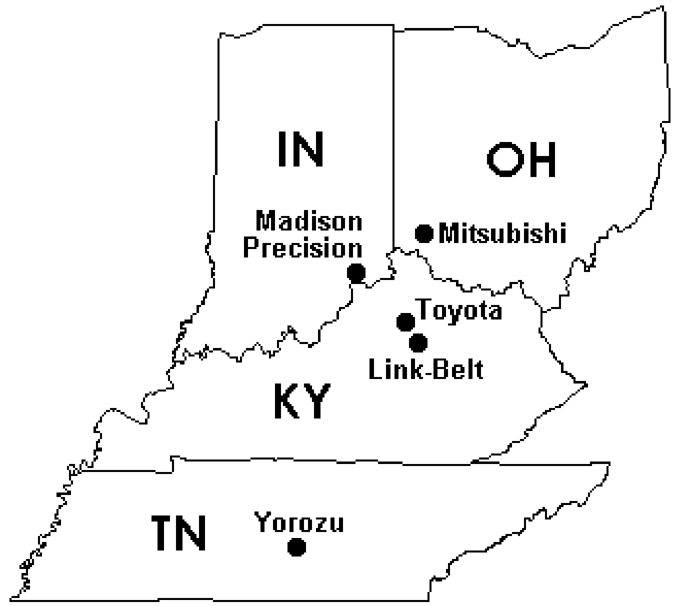

Figure 10.1. Location of facilities selected for case studies.

Table 10.1. Basic characteristics of facilities selected for case studies.

Firm	Location	SIC	Employees (2002)	Square Ft (2002)
Toyota Motor Manufacturing Kentucky	Georgetown, Kentucky	3711 Auto assembly	7,800	7,500,000
Yorozu Automotive Tennessee	Morrison, Tennessee	3465 Auto suspensions	850	675,000
Link-Belt Construction Equipment	Lexington, Kentucky	3531 Heavy cranes	600	500,000
Mitsubishi Electric Automotive America	Mason, Ohio	3694 Starters/alternators	433	450,000
Madison Precision Products	Madison, Indiana	3363 Auto engine parts	400	178,666

Case studies are divided into sections common to each: Industrial Context, Organization of Production, Production Management System, Environmental Management, and Environmental Impact. The section on Industrial Context provides a description of the location and scale of the facility, its products and customers, and its place in the overseas operations of the parent company. Organization of Production provides an overview of the types of manufacturing processes in which the facility is engaged. An understanding of the processes and their linkages is contextually important to an understanding of how and where wastes are generated and the potential for resource conservation and pollution prevention measures. Accordingly, these processes are described in some detail. The section on the company's Production Management System describes and evaluates the application of lean management methods at the facility. The Environmental Management section describes the environmental policies and practices on both the corporate and facility level, including the implementation of a formal environmental management system such as ISO 14001, if applicable. The Environmental Impact section evaluates environmental issues specific to the facility and examines trends in RCRA and TRI data. Although the organization of the information for the case studies is uniform, the individual case studies generally tend to emphasize one aspect more than others.

Thus, the Toyota case study emphasizes the flow of various processes involved in assembling a complete vehicle and upon how the company-wide environmental policies of the parent are interpreted and implemented at the local level. The Madison Precision Products case study is concerned with the influence of Honda, its major customer, upon production and environmental operations and issues, and provides more details concerning documentation within the facility's ISO-14001 environmental management system. The case study for the Mitsubishi plant in Ohio places extra emphasis upon production operations and in the relations between corporate and local environmental policies and practices. For Yorozu Automotive, the case study focuses upon the ISO-14001 implementation process. In the final study, that of Link-Belt Construction Equipment, the study examines in detail the transformation of a company, formerly American-owned and employing traditional fordist production methods, to a Japanese-owned company gradually phasing in lean production systems.

10.2. The assembly plant as agenda-setter

The Japanese automobile assembly plant occupies the central position of power in a hierarchy of many smaller firms who are more or less dependent upon the business provided by their major customer. This description may also be used to characterize the traditional relationship between U.S. automakers and their suppliers; the signal difference is in the nature of the relationship. Whereas domestic automakers engage suppliers on the basis of short-term, cost-based considerations, the Japanese manufacturers prefer to enter into long-term, performance-based relationships with suppliers. According to Florida (1996), the distinctive nature of the relationship between the Japanese automobile assembly plant and its supplier network is the key determinant of the adoption and diffusion of innovative manufacturing practices that improve environmental outcomes.

In Japan, the relationship between assemblers and their suppliers is characterized by a long history of association and interactive cooperation. For the overall benefit of the manufacturing complex, knowledge and technology are freely shared not only between automaker and supplier but among suppliers as well through the mechanism of supplier associations. To a large extent, the functioning of the network replicates externally the same sort of mutually supportive social and processual dynamics that are typical of lean production systems within facilities. Referring to supplier relations, Imai (1986) notes that product or service quality downstream is best assured by maintaining quality upstream. Within a production facility, this same philosophy is often expressed in terms of "your customer is the next process in line." For a successful just-in-time flow of parts and materials through the system, externally from suppliers and internally through manufacturing processes, close communication and joint commitment are necessary.

When Japanese automakers entered the new North American manufacturing environment, they found domestic suppliers embedded in fordist tradition were unaccustomed to strict performance standards for quality and delivery. The assembly plants were therefore at first heavily dependent upon imported parts and components, while at the same time expending considerable effort to develop the networks of lean supplier firms that had served them so well in Japan. The network began to form as Japan-based suppliers followed their primary customers overseas and then, increasingly, U.S. firms able to meet Japanese standards were incorporated into supplier networks. Through supplier support systems, the Japanese automakers worked assiduously to embed lean production philosophy and methodology within both types of suppliers, transplants and domestic firms. Ultimately, in North America the automotive transplants have succeeded in recreating a system of relationships very similar to that which supported their activities in Japan (Pil and McDuffie,1999).

The supplier network serves as one of the most important mechanisms for the cross-border diffusion of Japanese production systems. The assembly plant serves as an outpost for knowledge and technology transfer, which is transformed and hybridized in the new environment.[1] The economic power of the assembly plant forces organizational change upon firms who wish to become or remain suppliers to the plant. The ultimate beneficiary of improved performance and productivity by supplier firms is, of course, the assembly plant, which realizes lower costs, fewer defects, and improved just-in-time flow of parts and materials.

The case of Toyota Motor Manufacturing, Kentucky (TMMK), is of interest because this facility, the largest of the Japanese automotive transplants in North America, is representative of the way in which the auto assembly transplants use their vast economic leverage to transfer specific forms of knowledge, influencing the organizational structure and behavior of many lesser firms. Toyota, like the other major Japanese automakers in North America, has long operated a mentoring program intended to promote lean manufacturing among its suppliers. Toyota, along with Honda and Nissan, have recently undertaken initiatives specifically targeting the environmental performance of their suppliers, following Ford and GM's lead in requiring supplier firms either to obtain ISO-14001 certification or, at minimum, to become compliant with ISO-14001 standards. The diffusion of lean production philosophy and methodology, however, is likely, in the long run, to be of greater consequence to environmental quality than specific environmental programs. Richard Florida's (1996) national survey and analysis of manufacturers concluded that: "Environmental improvements flow from ongoing joint efforts to improve productivity, eliminate defects, and reduce costs, rather than from direct efforts to transfer pollution prevention technology or organizational strategies designed expressly to eliminate toxins or prevent pollution" (p. 100).

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[1] For a discussion of the hybridization process, see Chapter 4.

10.3. Toyota Motor Manufacturing Kentucky, Inc. Georgetown, Kentucky[2]

10.3.1. Industrial context

Although Toyota Motor Corporation was the last major Japanese automobile manufacturer to establish facilities in the United States, the Toyota plant north of Georgetown, Kentucky is the largest foreign-owned vehicle assembly plant in the four-state study area and represents an investment of more than 5.3 billion US dollars. Located on a 1,300-acre tract in the heart of the Bluegrass region, Toyota Motor Manufacturing Kentucky (TMMK) is an integrated facility for assembly of three vehicle models, the Camry four-door sedan (see Fig. 10.2), Avalon sedan, and Sienna minivan

Figure 10.2. The Toyota Camry, produced at the Georgetown plant, was the best-selling automobile in the U.S. during 1997, 1998, 1999, 2000 and 2002.
Photo courtesy TMMK.

[2] Plant visit and interviews conducted March 1999 and 11 November 2002. The primary informant in 1999 was Steve Green, then manager of the Environmental Section. Primary informants in 2002 were Rick Hesterberg, Corporate Communications, and Environmental Specialists Chris Holbrook and Garth McLane. A further key informant was Tim Gevedon, a former worker "on the line" at TMMK for eight years who was ultimately promoted to team leader; Tim recently left Toyota's employment to pursue a college education.

(TMMK 2002).[3] The original plant, which began production in 1988, promised to employ 3,000 people to assemble 200,000 cars annually (Haywood 2001,155). After two major expansions, most recently in 1994, the 7.5-million square foot facility now employs more than 7,000 workers who turn out nearly half a million automobiles each year. As of October 2002, the Georgetown plant had manufactured more than 4.7 million vehicles since beginning production in 1987, or nearly half of all vehicles that have been manufactured by Toyota in North America.[4]

Toyota Motor Corporation (Toyota Jidosha), headquartered in Toyota City in central Honshu, Japan, is one of the world's largest multinational corporations. The company is Japan's largest automaker and third largest globally. Toyota ranks twelfth (2002) on Forbes "Super 50" list of the world's most powerful companies[5], with nearly 250,000 employees worldwide and annual revenues of more than $120 billion U.S. dollars. Automotive business, including sales finance, accounts for more than 90 percent of total sales, with Toyota and Lexus brand vehicles marketed in more than 160 countries. In addition to twelve plants in Japan, in 2002 Toyota has 54 manufacturing facilities in 27 countries producing vehicles and components (TMC 2002a).

Manufacturing facilities presently operating in North America include four vehicle assembly plants and five facilities that produce vehicle components. Toyota's first automobile plant on the continent was established in 1984 in preexisting facilities in Fremont, California, a joint venture with General Motors known as New United Motor Manufacturing, Inc. (NUMMI). Subsequent investments in vehicle plants were made as

[3] Sienna production will be moved to the Indiana plant at the end of 2003, to be replaced at Georgetown by the Solara.
[4] Cumulative production statistics from TMMK website, http://www.toyotageorgetown.com/.
[5] Forbes website link: http://www.forbes.com/forbes/2002/0722/world50.html.

construction of greenfield facilities, with the Georgetown, Kentucky, operation beginning production in 1988; a plant opened in Cambridge, Ontario in 1988; and, most recently, a production facility in Princeton, Indiana, on line in 1998. Facilities for component manufacture include TABC, Inc., a 1974 acquisition that manufactures truck beds, catalytic converters; stamped parts and steering columns; aluminum wheel production in Delta, British Columbia (established 1983); Bodine Aluminum, Inc., two locations in St. Louis and Troy, Missouri, acquired in 1990, that produce cast aluminum auto parts; and a facility constructed in Buffalo, West Virginia, in 1998 that manufactures engines and automatic transmissions. Currently under construction are facilities in Huntsville, Alabama, scheduled to begin production in 2003 of truck engines for the Princeton plant; and a facility in Baja California, Mexico, scheduled to begin production of truck beds in 2004 (TMC 2002c). In the planning stage, expected to begin operations in 2006, is a facility in San Antonio, Texas, which will produce Tundra pickups.

Toyota's North American manufacturing administrative headquarters, located in northern Kentucky in the community of Erlanger, oversees purchasing, production control, finance and engineering for the company's North American plants. The headquarters facility, centrally located with respect to Toyota operations in Kentucky, Indiana, and West Virginia, was established in 1996 and represents an investment of $68 million. In 1998, a quality and production engineering laboratory was added to the facility, which currently employs about 700 persons (Karan 2001,6; Gaver 1998).

Toyota's decision to build a major vehicle production facility in Kentucky's Central Bluegrass region was influenced by many factors, but among these was the willingness of the Commonwealth to provide incentives toToyota. These incentives included securing an acceptable site and ensuring timely development of infrastructure, assisting with permits and licenses, and training a capable but inexperienced workforce. Competitive bidding wars among states to attract foreign investment had become the norm during the early 1980s, and the value of proposed incentives escalated rapidly. In 1985 the state of Kentucky offered Toyota the largest incentives package awarded to a foreign firm to date, valued at $147 million in direct state investment and $320 million including indirect benefits (Karan 2001,5).[6] Although the magnitude of the incentives offered was controversial at the time, the deal has been of considerable benefit to both Toyota and the Commonwealth of Kentucky.

Economist Charles F. Haywood (2001) has calculated that the state will receive more than $1.2 billion in tax revenues, beyond the original cost of the incentive package, from Toyota during the twenty-year period 1986-2005. In addition to this, there have been significant multiplier effects on the Kentucky economy from Toyota's presence, both direct and indirect, resulting from Toyota parts and materials purchases, its half-billion dollar annual payroll, and the creation of new jobs in many industries. Although Haywood has calculated Toyota's impact only upon the Kentucky economy, there is little doubt that its economic effects reach far beyond the state boundaries.

Toyota's Georgetown operation represents a significant component of the regional economy, not just for central Kentucky but, through an extensive supplier network, for a multi-state area. Domestic content of vehicles manufactured at TMMK has reached the 75 percent level, with parts and materials obtained from more than 350 U.S. suppliers, 70 of which are located in Kentucky (TMMK 2002). According to Karan (2001,6) Toyota's

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[6] See also Bosman (1999) and Potter (2001) for accounts of the process through which Toyota was induced to locate in Kentucky.

purchases for all of its North American plants handled through its Erlanger headquarters exceed $8 billion annually from more than 500 U.S. companies, of which about 150 are located in Kentucky, Indiana and Ohio. A significant number of Toyota domestic suppliers, however, are Japan-based transplants who followed their primary customer overseas.

The presence of Toyota and other Japanese vehicle assembly plants in the Midwest and South has contributed to the development of a regional economy that has become increasingly dependent upon the automotive industry. In Kentucky, the number of plants producing automobile parts increased from 55 in December 1985 to 175 in December 1997, representing an estimated capital investment of $2.7 billion (Haywood 2001, 162). These plants are links in a complex network that provides parts and materials to the many regional auto assemblers. Some plants supply parts or materials exclusively to TMMK; some are suppliers to other assemblers in addition to Toyota; the majority are providers to vehicle assemblers other than Toyota both within and outside Kentucky, both Japanese and domestic. Through its own supplier network, however, TMMK has contributed to the diffusion of lean production methods and the proliferation of ISO-14001 environmental management certification in the region. As Haywood notes (2001, 162-163): “The 1985 decision by the Commonwealth and Toyota Motor Corporation has been a significant part of the restructuring and relocation of the motor vehicle and parts manufacturing industry in the United States during the 1980s and 1990s.”

10.3.2. Organization of production

The Georgetown facility is Toyota’s largest global facility in terms of workers employed, and is only exceeded in areal size (square footage under roof) by a few Toyota plants in Japan (TMC 2002a). The facility was originally planned for vehicle assembly only, but prior to completion of the assembly plant the design was modified to include production of four-cylinder engines and axles in a separate facility on site. The first vehicles began to roll off the assembly line in summer 1988, even as construction of the power train plant began. In 1990 Toyota announced that the plant capacity would be doubled from 200,000 vehicles per year to more than 400,000 with the construction of a second assembly line. Construction of the second line, which added 3.2 million square feet to the plant, was completed early in 1994. During the same year, an expansion of the power train plant was completed which added V-6 engine production and increased total production capacity to more than five hundred thousand four- and six-cylinder engines annually (Haywood 2001, 156-157; Hill 1993). As a result of these expansions, the Toyota plant was enabled to produce many of its own components, which currently include steel body parts such as doors and hoods; injection molded plastic bumpers; axles and axle assemblies; steering components; and engine parts including machined cylinder blocks, cylinder heads, camshafts, crankshafts and pistons.

The plant is organized into distinct production areas: powertrain; die construction; stamping; body welding; painting; plastics; and final assembly. Figure 10.3 shows the layout of these facilities at the Georgetown plant, with the two assembly and paint lines peripheral to a central core of component manufacture. Each vehicle takes about twenty hours to move through the production process.

The powertrain plant manufactures four and six cylinder engines and axle assemblies for the vehicles produced in the Georgetown facility, and also engines and engine

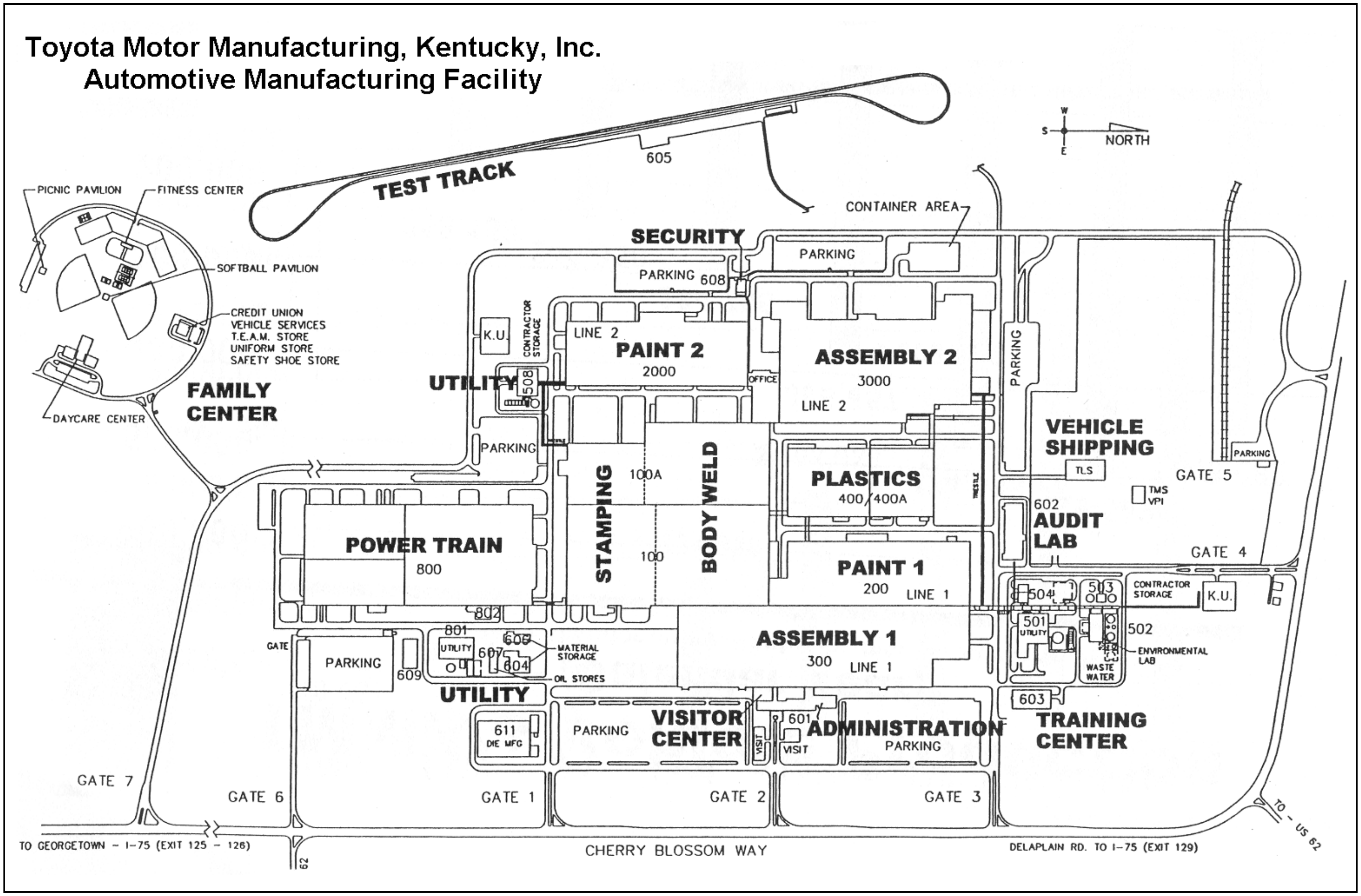

Figure 10.3. Physical layout of Toyota Motor Manufacturing Kentucky

Source: TMMK 2002

components for export.[7] Each engine type has a separate production line that completely assembles the engine from machined components, using electronically controlled nut runners and impact wrenches that drive nuts and bolts to a specified torque. Finished engines must pass quality tests and are then sent to a staging area, from which they are delivered to the assembly plant by dollies and tow trucks. Assembly of finished front and rear axles was transferred to the powertrain plant in 1991, with second and third lines added in 1994 and 1997.

The die manufacturing shop (Figure 10.3, nearest to Gate 1 and below the powertrain plant) manufactures dies used in stamping small interior parts and external panels for the Georgetown vehicle models and also makes dies for other Toyota plants in North America. The stamping plant, where more than 200 different body components and parts are manufactured from steel coils, is centrally located between the powertrain plant and the body weld facility. The stamping area consists of 24 production lines and 44 presses of various sizes, the largest press having a capacity of more than 5,000 tons. Steel coils, delivered to the stamping facility and loaded onto cradles by overhead cranes, are fed by robots through a series of rollers that clean and straighten the steel. From the rollers the flattened steel is moved to a large press and cut into “blanks” that are sized according to the part to be produced. The blanks are next transferred as needed to a press line where machine dies shape the metal, trim excess and pierce holes. Peak daily production can consume more than 800 tons of coil steel in the manufacture of 250,000 parts. Stamped parts are transferred to temporary storage and fed into the body weld facility as needed.

[7] The descriptions of facilities, equipment and manufacturing processes in this section are summarized from TMMK (2002).

The body weld plant manufactures the automobile body or shell from stamped parts, beginning with the vehicle frame. A combination of human welders and more than 700 robotic welders make more than 4,200 spot welds per vehicle, building body sides and roof structures as subassemblies which are moved to the framing area. Here robots weld the subassemblies together into a complete body shell and, after inspection, the doors, hood, trunk lid and fenders are installed. Following a final inspection and finishing of the metal, the completed body is moved by overhead conveyor to the one of the two separate paint facilities. The vehicle shell spends more than ten hours in the paint area, undergoing a complex series of preparation, priming, sanding, sealing and topcoating processes using both water-borne and solvent-based paints. After inspection, the painted body is sent by overhead conveyor to the assembly facility.

The plastics area, located between the two assembly facilities, produces plastic components for installation during final assembly. Seven basic procedures are involved. Many components are produced by injection molding, in which plastic pellets are melted and forced into molds. Bumpers are produced by a combination of molding and curing, and are then painted and assembled. Slush molding and vacuum forming is used to produce the skin of instrument panels, and then filled with a liquid chemical foam that hardens. A further production line is responsible for finishing the instrument panel safety pad components. All finished products are inspected before moving to vehicle assembly.

Camrys and Avalons are put together in Assembly One, and Camrys and Siennas in Assembly Two. Each assembly area is divided into three operations. In the trim division, the empty vehicle shell is equipped with parts that are not normally seen, such as the wiring harness, heating and air conditioning units, and sound insulating pads.

From trim, the vehicle moves to the chassis division, where underbody and engine components are installed, including brake and fuel lines, suspension, front and rear bumpers, axles and engines. In final assembly, customer appearance and safety items such as air bags, instrument panels, seats and windshields are installed, and fluids such as gasoline, power steering fluid, and radiator fluids are added. From assembly, completed vehicles are moved to an adjacent external shipping area.

10.3.3. Production management system[8]

Toyota is the originator of Japanese "lean production" and these methods are fully implemented at TMMK. Toyota's economic success, according to Besser (1996,1), has apparently led to an unwillingness to change "the essentials of its production and management systems in its overseas operations." Although some concessions have been made to the American work environment in terms of looser social controls, core features of Japanese management have been retained such as work teams, job rotation and the creation of organizational ideology and a sense of community. Besser's study of corporate culture at the Georgetown plant concludes that the "elements that Toyota has transferred, uncorrupted, to its U.S. facility from Japan are associated with work structure and plant layout and include standardized work, fast set up and retooling, just-in-time manufacturing system, jidoka, and kaizens" (p. 181).

Although TMMK adheres faithfully to the methodology that made Toyota one of the world's most efficient corporations, rededication to the company's guiding principles is necessary upon occasion. One of the first acts by newly appointed TMMK president Masamoto Amezawa in the summer of 1998 was to direct plant managers to spend more

[8] The Toyota Production System is described in detail in Chapter 3.

time on the floor in pursuit of kaizen and less time in meetings. Due to changes in senior personnel and major expansions in the facility, Amezawa felt that it was necessary for management to refamiliarize themselves with the fundamentals of the Toyota Production System (Chappell 1998a).

Despite a global commitment to maintain an operational and management system that has worked so well, the Toyota system has evolved over time in response to changing circumstances. According to Fujimoto (1999, 225),Toyota, unlike the common conceptualization of the rigid and monolithic corporation, possesses an evolutionary learning capability. Fujimoto's analysis (pp. 206-269) of recent changes in the Toyota system pertinent to TMMK is summarized below, focusing primarily upon the final assembly process.

The Toyota manufacturing process evolved gradually through a multi-path emergence process, which Toyota was able to implement more effectively than competing auto manufacturers and hence has been more competitive overall. The evolution of the Toyota system has led to plant design and layout modifications that differed significantly in the 1990s from facilities built in the 1980s. This process of evolutionary development can be observed in the process geography at TMMK's Georgetown plant, built originally in 1987 and expanded considerably in 1994 with the addition of a second production module that doubled plant capacity.

The original Georgetown plant design replicated that of the Tsutsumi plant in Japan, built in 1970 and like TMMK, a producer of Camrys. The traditional final assembly process implemented at TMMK Assembly #1 and in other Toyota plants constructed through the mid-1980s resembled a somewhat shorter version of the Fordist moving assembly lines. These conveyor lines tended to be separated into three functional line segments with different conveyor systems: trim, chassis, and final assembly. Lacking any buffer between the segments, the assembly process operated in effect as a single long, continuous line. Although the stamping and body weld areas tend to be highly automated with numerous robotic machines, few robots are used in traditional final assembly lines. Assembly-line workers were trained to be multiskilled, which raised productivity, but were often given mutually unrelated tasks to accomplish, which diminished worker interest. According to Fujimoto,

> The performance of Toyota's assembly lines has been traditionally evaluated internally in terms of efficiency and product quality, as well as safety. The quality of the work environment had not been equally emphasized, though. There was an evaluation system that identified tasks that are potentially harmful to workers' health, but evaluation criteria for measuring work fatigue had not been developed in the past (p. 227).

By the early to mid-1990s, the product and labor environments had changed significantly. The collapse of the bubble economy of the late 1980s saw an end to continuous growth and restrictions on capital availability. Japanese products in the bubble era suffered from what has been termed "fat product design"; high-cost designs that included excessive product varieties, fast model change cycles, too few common parts, overspecification (unnecessary functions and equipment), and overquality (excessively sophisticated structures and/or materials for a given function) (Fujimoto 1999). While these characteristics had helped bring about Japanese global competitiveness in an earlier era, by the early 1990s "fat products" were a distinct disadvantage in a changed market environment. The Japanese response has been to develop "lean products" to accompany their lean production.

A further difficulty faced by Toyota and other automakers, primarily in Japan, was a tighter labor market, brought about by an aging population and an increasing reluctance by younger workers to seek employment in certain manufacturing industries regarded as “dirty, demanding and dangerous.” Toyota considers the lack of job attraction in the automotive industry a long-term problem that requires a solution.

In response to these problems, Japanese automakers have attempted various solutions to improve working conditions, but, according to Fujimoto, only Toyota has successfully articulated and implemented a new concept of final assembly which is “explicitly aimed at improving not only customer satisfaction but also employee satisfaction” (p. 225). The new concept addresses all plant areas but focuses primarily on the final assembly process, with modifications to improve morale and motivation and eliminate physically demanding jobs. In summary, “the new system attempted to preserve the strength of the conventional Toyota (or lean) system in quality, cost and delivery, while improving the attractiveness of its assembly work, both physically and psychologically” (p. 229). The 1994 TMMK expansion was designed with this goal in mind, and hence differed significantly in organization from the earlier 1987 installation.

Toyota’s new Kyushu Island facility, built in 1992, was the first factory to embody the new process design, which diffused to subsequent plant construction and renovation. The primary features of the new system are (1) a functionally autonomous and complete process; (2) in-line mechanical assembly automation; (3) an ergonomics evaluation system; (4) low-cost equipment to promote a better work environment and work posture; and (5) supporting human resource management (HRM) policies.

A functionally autonomous and complete assembly process is achieved through decoupling the main assembly line into semi-independent segments which each function physically and organizationally separate from the others. Each segment is assigned a group of functionally related assembly tasks, within which the functions and responsibilities of group leaders are enhanced. Performance results for this layout redesign indicate increased quality and productivity, and improved worker morale. In-line mechanical assembly automation was intended to alleviate the negative effects produced by large automation equipment that requires line stoppage for automatic assembly and disrupts manual operations and teamwork. The in-line technologies coexist in the same assembly line zones as manual assembly, and are controlled by the assembly workers rather than by maintenance technicians. Furthermore, the technologies used tend to be the simplest, least expensive, and easiest to monitor and repair, rather than highly sophisticated and highly expensive equipment. In-line mechanical automation reduces manufacturing cost, promotes kaizen by workers, and improves employee satisfaction through a sense of ownership and control over the process.

Additional modifications to improve the work environment and employee satisfaction included implementation of an ergonomics evaluation system that measures the workload of each assembly line job quantitatively. Using this tool, process planners could identify which tasks were the most physically demanding and target these for improvements. Relatively inexpensive tools and equipment were introduced in many areas to assist in manual assembly and make the jobs less physically demanding and dangerous. Such improvements included better lighting, air conditioning, power-assist equipment, motorized carts for parts transport, comfortable seats to replace crouching work positions, and height-adjustable conveyors or platforms to give the best work positions. These were intended to improve working conditions, rather than to increase productivity.

When constructed, the #2 assembly area at TMMK embodied these changes to the assembly process and working environment. Whereas the original 1987 assembly area contained seven lines that operated without a buffer between processes, the new facility contains eleven independent lines. Through its process modifications, TMMK seeks prevention of worker injuries, improvement of the physical environment, and a plant where product changes are easier and faster to implement.

The new production philosophy is apparent in changes recently made to the body weld plant, an approach termed “Blue Sky.” Many of the large automation processes were removed from the shop and replaced with smaller, lighter tool stations. The modifications are intended to allow more light and open space into the environment, hence the name “Blue Sky,” but also to increase flexibility. The new body weld system, currently undergoing testing, will allow different vehicles to move through the process rather than maintaining fixed tooling for specific vehicle models (Chappell 2002).

Production methods at the plant serve as a model to many corporations interested in Japanese methods, and instruction in lean production is offered free of charge to suppliers and other North American companies, through seminars at the Erlanger headquarters and on-site consultation at participating facilities. This service operated out of the Toyota plant until 1997, when it was transferred to Erlanger (Couretas 1997; Chappell 2000).

10.3.4. Environmental management

Environmental policies and practices at TMMK, as with most large multinational corporations, operate through several different levels, from international to local. One of the most powerful corporations in the world, Toyota has had a significant role in shaping environmental policy for companies operating in Japan and abroad. As an advisory member of the Central Environmental Council (established 1993) of the Japanese environmental ministry, Toyota Motor Corporation has helped to develop recommendations for the implementation of the environmental laws and regulations in the home country.[9]

One of the original members of the Japanese Federation of Economic Organizations, or Keidanren (an association of Japanese businesses), Toyota played a major role in the development of voluntary environmental standards for corporations to follow in domestic and overseas operations. Shoichiro Toyoda, chair of Toyota Motor Corporation from 1992 to 1999, served as vice-chair of the Keidanren and was elected chair in May 1994.[10] During Toyoda's terms, the Keidanren's Global Environmental Charter, which included guidelines for Japanese corporations operating abroad, was issued in 1991 and followed in 1996 by the Appeal to the Environment and formulation of the Voluntary Action Plan,

[9] Center for Environmental Science webpage: http://ces.iisc.ernet.in/hpg/cesmg/sd/japan.html.
[10] Toyota corporate website: http://www.toyota.com/about/operations/manufacturing/alabama/stoyoda.html

which established specific environmental targets and goals for many industries.[11] When, in 2002, Keidanren merged with the Japan Federation of Employer's Associations (Nikkeiren) to form Nippon Keidanren, Japan's largest business lobby, Hiroshi Okuda, the current chair of TMC, was named to head the organization.[12]

Toyota Motor Corporation's continued involvement with environmental issues associated with multinational corporations is also represented by participation in the World Business Council for Sustainable Development, an international organization headquartered in Geneva. Dr. Shoichiro Toyoda, currently honorary chair and board member at TMC, serves as a vice-chair on the WBCSD executive committee, along with representatives from corporations such as DOW Chemical (USA), Royal Dutch/Shell Oil (Netherlands), Grupo IMSA (Mexico) and Aventis (France).[13] The World Business Council for Sustainable Development promotes the concepts of sustainability and ecological efficiency in manufacturing operations.

Toyota Motor Corporation has set company-wide environmental improvement as its "top-priority management issue" (TMC 2002c), and has pursued many environmental initiatives during the last decade. The Toyota Earth Charter was developed in 1992, revised in 1996, and in its most recent iteration, formalized in 2000, the Charter sets forth ambitious goals that are directed to all Toyota companies and subsidiaries, both domestic and overseas. Through the Earth Charter and its associated Environmental Action Plan (described below), the company has been striving to institutionalize environmental

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[11] "Nippon Keidanren inaugurated," *Journal of Japanese Trade and Industry*, September/October 2002. Japan Economic Foundation. Electronic journal.

[12] Keidanren website, http://www.keidanren.or.jp/index.html. For more information on Keidanren policies, see Chapter 2.

[13] World Business Council for Sustainable Development webpage: http://www.wbcsd.ch/aboutus/exco.htm.

consciousness throughout the organization. Environmental education for employees is a vital component of this strategy.

In 1992, Toyota established a corporate Environmental Committee, chaired by the president, to promote company-wide environmental initiatives. Committee responsibilities are divided among three subcommittees, Environmental Product Assessment, Production Environment, and Recycling. The Environmental Affairs corporate Division (established 1998) manages the action policy and goals, drafts the environmental action plan and annual company-wide policy (TMC 2002c, 8-9). In North America, the Manufacturing Environment Committee is comprised of presidents of the various facilities who coordinate implementation of environmental policy at the plants. Each facility has an environmental steering committee, which encourages employee involvement (TMNA 2002,11).

The 2002 revision of the Toyota Earth Charter consists of basic policy statements and a set of action guidelines:

I. Basic Policy

- Contribute towards a prosperous 21st century society.
  Aim for growth that is in harmony with the environment and set a challenge to achieve zero emissions through all areas of business activities.
- Pursue environmental technologies.
  Pursue all possible environmental technologies, developing and establishing new technologies to enable the environment and economy to coexist.
- Take action voluntarily.
  Develop a voluntary improvement plan, based on thorough preventative measures and compliance with laws, that addresses environmental issues on global, national, and regional scales while promoting continuous implementation.
- Work in cooperation with society.
  Build close and cooperative relationships with a wide spectrum of individuals and organizations involved in environmental preservation, including governments, local municipalities, and related companies and industries.

II. Action guidelines

- Always be concerned about the environment.
  - Work toward achieving zero emissions at all stages, i.e., production, utilization, and disposal.
    - Develop and provide producers with top-level environmental performance.
    - Pursue production activities that do not generate waste
    - Implement thorough preventative measures
    - Promote businesses that contribute towards environmental improvement
- Business partners are partners in creating a better society.
  - Cooperate with associated companies
- As a member of society – actively participate in social actions
  - Participate in creation of a recycling based society
  - Support environmental government policies
  - Contribute to non-profit activities
- Toward better understanding
  - Actively disclose information and promote environmental awareness

(TMNA 2002,10)

In association with the revised Earth Charter, the Third Environmental Action Plan is aggressive in setting tough and specific targets for reduction of the environmental impact of manufacturing operations. Toyota North America intends to be proactive by setting clear goals and improving continuously in performance, not simply meeting regulatory requirements but exceeding them wherever possible. The new Action Plan sets the following ambitious targets to be achieved by 2005:

- Reduce electric and natural gas usage by 15 percent per unit;
- Reduce VOCs (volatile organic compounds) by 30 percent per unit;[14]
- Reduce hazardous waste disposal at landfills by 95 percent per unit; and
- Reduce water usage by 15 percent per unit (TMNA 2002,19)

Staff responsible for primary policy decisions are located at the headquarters in Erlanger, Kentucky, and coordinate among plants in North America. At Georgetown, the Environmental Section is contained within the Production Control department and reports to a senior vice-president during meetings scheduled twice each month. The manager of

[14] Volatile organic compounds are generally those solvents that volatize, or evaporate, during paint operations as the paint dries.

the Environmental Section supervises a team of five environmental specialists who are solely concerned with the local operation. Each specialist has primary responsibility for a certain geographic area of the plant, such as the paint shops or vehicle assembly areas, and a specialty focus in a particular media such as water, air, or waste. The specialist in "air" coordinates on matters of that nature with all the geographic area specialists, so that there is a central point of responsibility and a consistency of implementation. The specialists are assisted by four support associates and assistant staff, who perform such functions as data entry, and, currently, co-op students from the University of Louisville.

The present ten-person team represents a reduction in force from the fourteen-member environmental staff existing at the time of the 1999 visit and interviews. As Toyota's first greenfield facility here, the Kentucky plant served to identify environmental issues, to develop and refine procedures to address those issues, and to train environmental staff prior to centralizing North American environmental efforts to the Erlanger headquarters.

All production workers and contractors are required, upon hiring, to undergo environmental education. The initial training includes MSDS[15] information, emergency response, and waste management, and is reinforced by annual RCRA training. On the production floor, each work team has a team leader, who serves to bring ideas and suggestions from the workers. Both quality circles and suggestion boxes are extensively used, and generate many thousands of submissions each year. Employees receive

[15] Material Safety Data Sheets (MSDS's), required by the Occupational Safety and Health Administration (OSHA), are designed to provide both workers and emergency personnel with the proper procedures for handling or working with a particular substance. MSDS's include information such as physical data (melting point, boiling point, flash point etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill or leak procedures.

financial bonuses for ideas that result in savings.[16] Many of the suggestions that come by these routes are concerned with improving the plant's environmental performance.

The annual planning process usually consists of a refocus of emphasis according to the progress that has been made on the overall company goals. TMC corporate environmental goals are conveyed to the North American manufacturing headquarters and forwarded to individual plants, where plans are devised to meet or exceed those goals. Toyota is determined to have the most proactive environmental record of any automobile manufacturer in the United States. Evaluating environmental benchmark data shared among assemblers, TMMK deliberately establishes goals as part of their ISO 14001 EMS process that are more stringent than those of other automobile manufacturers.

Environmental planning at the Georgetown plant involves many people at all levels of the plant, from upper management to the workers on the production lines. Each year the environmental team at TMMK develops a set of goals which are sent to the individual shops for feedback. Following discussions and refinements, the goals are forwarded to the plant president for evaluation and approval, and then sent back down to the shops, who then develop specific plans to meet the environmental goals and targets. A similar pathway is followed for assessment and implementation of worker suggestions that are not directly derived from the annual planning process.

Each proposed process modification is evaluated for potential environmental impact. The environmental team writes a process description and calculates the materials balance, raw materials in versus waste out. During the 1999 interview, section leader Steve Green

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[16] Tim Gevedon, former line worker at Toyota, observed that employees made extensive and enthusiastic use of the suggestion system; some who frequently contributed useful suggestions were able to make their monthly car payments entirely using cash awards from the company.

noted, "If material doesn't end up on the car, then it is wasted, a wasted resource." The evaluations are sent back to the shops for further input from the workers. This insures that more people become involved, that perspectives and ideas derive from more than just the environmental team. To provide incentive, a scoring system was developed to calculate points gained in waste reduction in every aspect of the suggestion, by which means financial rewards to the innovator could be fairly determined. Initially this feedback system was primarily concerned with reducing usage of raw materials, but now is also concerned with pollution prevention.

Green made an important point in 1999 when he noted that it is always easier to promote the environmental benefits of changes if a financial benefit can be demonstrated, yet "Environmental protection almost always is the result of an efficiency gain. The less materials used, the less waste produced."

All of Toyota's manufacturing plants in North America have achieved ISO 14001 certification; TMMK, which was certified in November 1998, was one of the first Toyota facilities here to become so certified. Unlike most of the other facilities profiled in these case studies, who had achieved certification in QS-9000 or ISO-9001 prior to seeking ISO-14001 certification, TMMK did not have this experience to draw upon when undergoing the ISO-14001 planning and implementation process. According to Chris Holbrook (2002 interview), TMMK did not feel that the standards of the QS-9000 and ISO-9001 programs were as stringent as the Georgetown plant's own standards.[17] Nevertheless, according to the TMMK website, "The ISO 14001 standard mirrors the Toyota Production System in following the Plan — Do — Check — Action cycle. It also

[17] Holbrook indicated that TMMK may, however, seek these certifications in the future due to the requirements of European governments.

fosters continuous improvement. Given these similarities, ISO 14001 is a natural tool for Toyota to use as a benchmark."[18]

The ISO-14001 implementation and certification process is similar at most facilities, although the goals and targets differ from one company to another. Key personnel receive training in ISO-14001, and in turn train others within their facility. Although all employees typically receive some education in ISO-14001 concepts, goals and methods, the extent of such training usually depends upon each worker's job function and "need-to-know." In most cases, a committee consisting of representatives from various departments is established to evaluate the environmental issues associated with plant processes and to establish the ISO-14001 framework and goals. Once an environmental management system (EMS) in accord with ISO-14001 has been developed, including employee education and rigorous documentation, certification may be attained through an external audit which demonstrates compliance to the EMS.[19]

Three members of the TMMK Environmental Section, the manager, assistant manager, and an Environmental Specialist, received initial training in ISO-14001 offsite from a consulting firm. Environmental goals, particularly waste reduction, had been part of the planning process for the Georgetown plant since the early 1990s; these older goals were incorporated into the ISO-14001 program. The goals addressed in the new EMS were associated with reductions in the following areas:

- Overall waste generation;
- TRI waste emissions;
- VOC emissions;

[18] TMMK website: http://www.toyotageorgetown.com/envcomply.asp
[19] For a detailed examination of the ISO-14001 implementation and certification process, and examples of documents associated with this environmental management system, see the case study for Madison Precision Products in Chapter 11. See also Chapter 2 for more information on ISO-14001 and environmental management systems.

- Non-hazardous landfill waste;
- Water usage;
- Energy usage.

In addition to waste reduction and pollution prevention goals that were part of the EMS, TMMK's initial goal focused, naturally enough, upon achieving the status of ISO certification through documentation and training.

Although the EMS would be applied throughout the plant, different areas had different characteristics and this was recognized during the planning process. For example, the paint and vehicle assembly areas added by the 1996 expansion (paint and assembly) had more modern and effective pollution control technologies installed than the equivalent older sections; realistic goals had to take such differences into account. Planning was thus based on evaluation of separate areas within the larger facility.

Once the initial goals and targets had been formulated, representatives were appointed for each individual shop in the plant to implement ISO-14001 activities. Most shops had multiple representatives, the number based upon the potential environmental impact of production activities within the shop area. For example, in the stamping area, which has a minimal generation of potentially hazardous wastes, a total of three representatives were appointed, one each from production, maintenance, and engineering. In contrast, in each of the two paint shops, which are responsible for nearly all of TMMK's airborne emissions, had seven or eight representatives. Once the representatives were selected, consultants were brought into TMMK to train the environmental staff, the shop representatives, and key management people who would be involved in the process. Environmental staff at the Kentucky plant have been certified as ISO-14001 internal auditors and receive annual updated training.

The ISO-14001 EMS is now a way of life at the TMMK plant, and the facility has achieved notable successes in waste reduction. Waste reduction targets set to be accomplished by 2006 have, in many cases, been achieved by 2002. The case of VOCs (volatile organic compounds) in Paint I and Paint II illustrates the difference between old and new pollution control technologies and how TMMK has often been able to achieve environmental goals years ahead of schedule. The VOC target to be achieved by 2006 for Paint I, constructed in 1987, was a reduction of emissions to no more than 30 grams/meter^2; by 2002 emissions had been reduced to 30.8 g/m^2. Built in 1996, Paint II's target was 20 g/m^2, a goal reached in 2001 and reduced to 16.9 g/m^2 in 2002.

A recent corporate initiative from TMC has been its long-term goal of Zero Landfill Waste, a goal about which some of the current environmental team members have mixed feelings. All acknowledge its desirability as a general principle, but are concerned that a focus to eliminate one environmental problem may simply alter the form of the waste without any real gain in environmental quality. Zero solid waste, according to TMMK Environmental Specialist Garth McLane (2002 interview), can certainly be achieved: "We could burn everything, which would result in zero landfill waste, but is that the best environmental solution? It simply moves the waste from one media to another." TMMK has, in fact, reduced landfill disposal of hazardous waste to zero for 2002 through offsite incineration.

Although this issue remains controversial in the view of TMMK environmental staff, other means have been implemented to reduce solid waste, both hazardous and non-hazardous. Throughout the plant are highly visible "Earth Care" stations intended to remove recyclable materials from the waste stream. This involves presorting of waste at the source of generation – individual work stations. McLane noted that there was, initially, a low level of resentment among some few workers, who expressed their discontent by taping "Janitorial Staff" signs to the back of their uniforms. This initiative has generally been well received by employees; it is a cultural change, and time will be needed to achieve total success. Team members sort waste by type into containers at the point of generation; according to the volume of waste, these may be small or large containers or drums for liquid wastes. At the end of the shift, or several times during the shift if necessary, these may be taken directly to a collection area or transferred to a larger container near the work station. Large containers are picked up and transported to the shipping area, or may be picked up at the work station by contract haulers. Waste handling methods vary according to the type of waste and the quantities generated. The waste reduction policy applies in all areas of TMMK; Earth Care stations are located not only in production areas but also in the plant offices and the many cafeterias in the facility.

A high rate of recycling, Chris Holbrook observed (2002 interview) can be misleading; while recycling is an important management method to reduce waste, better still is source reduction. Holbrook gave the example of two companies, one who reported a large quantity of recycled cardboard and one who reported very little cardboard as recycled. The first company's record was not necessarily one of which it should be proud, because it obviously was not using returnable containers for shipping; hence the large quantity of cardboard recycled. TMMK requires their suppliers to use returnables, and more than 98 percent of all parts and materials received at the plant are sent in returnable containers which are used over and over until worn out completely.

TMC, as noted, has undertaken the deliberate diffusion of lean production management through the supplier chain to help assure that components obtained by will be of the highest quality. Implicit in lean production is a philosophy based on waste reduction and clean production. Explicitly, Toyota's commitment to improving environmental quality is demonstrated by its Green Supplier Guidelines, which require approximately 500 suppliers who provide parts, materials or components directly or indirectly to Toyota to meet certain environmental goals. Suppliers are required to complete one or more of the following initiatives:

1. ISO 14001 certification. All suppliers must develop and implement, by December 31, 2003, an environmental management system that conforms to the ISO 14001 standard and is certified by a third-party auditor.
2. Comply with chemical ban list. Toyota has developed a chemical ban list based on evaluation of toxic chemicals regulated globally. This initial list contains 450 chemicals and will be updated regularly. Suppliers must phase out these chemicals from new and/or reformulated materials beginning August 1, 2000.
3. Hazardous materials transportation management system. All North American suppliers must develop appropriate policies and procedures to assure compliance with all applicable state, federal and international hazardous materials transportation requirements.

Through its policies and initiatives, corporate Toyota and its North American subsidiaries, including TMMK, are improving not only the ecological efficiency of its own operations but those of a host of other facilities associated with the automotive industry.

10.3.5. Environmental impact

The painting operations are TMMK's greatest area of environmental concern. The paint shops are responsible for nearly all of the plant's airborne emissions, nearly all of the RCRA hazardous waste, and half of all water used. Body shells are painted in downdraft spray booths, where air, entering through filters in the top of the booth, flows over the top of the vehicle and around the sides and is pulled down through floor grating into a water-filled pit where overspray is trapped. Paint sludge is skimmed from the water in the pit on a continuous basis, and the floor grates and the jigs that hold the parts must be cleaned on a routine basis. Paint guns must also be cleaned frequently, and whenever there is a color change. Temperature and humidity are carefully controlled in the spray booths, using steam generated in boilers. VOC emissions result from solvent evaporation both within the spray booths and in the succeeding step, the curing ovens.

Although the best pollution control technology available for paint booths was installed when the plant was built in 1986, TMMK is a major source for VOCs. During the 1994 expansion, when the second painting shop was constructed, newer technology did a far better job of handling VOCs and a materials change replaced some solvent-borne paint with water-based coating. Paint I still mainly uses solvent-based paints, although some conversions to water-base paint have been made. As is often the case with solutions to environmental issues, the use of water-borne paints represents a trade-off. Water-based paints produce less VOCs but require longer curing and hence use more energy; Paint II consumes five times more energy than Paint I, where solvent-based paints are dominant.

Table 10.2. Most significant RCRA wastes generated by TMMK, 1999
Source: RTK NET

Waste Category	Generating Process	Tons
PURGE THINNER (IGNITABLE)	Cleaning solvent base paint guns	1,332.50
SOLVENT AND WASTEWATER (IGNITABLE)	Cleaner water base paint guns	430.80
PAINT SLUDGE (IGNITABLE)	Paint booth wastewater	350.22
RAGS/PAPER/PAINT WASTE (IGNITABLE)		230.24
GAS TANK ANTI-CHIP SLUDGE (SOLID)	Gas tank anti-corrosive coating	212.11
CAUSTIC STRIP/PAINT SLUDGE (CORROSIVE)	Cleaning paint booth jigs & grates	171.22
TOTAL		2,727.09

Paint sludges and materials used to clean paint from surfaces and equipment represent most of the plant's hazardous waste. Paint sludge from the booths is processed into "filter cake" at the facility and sent offsite for energy recovery through incineration. An inventory of TMMK's RCRA wastes reveals the significance of paint wastes to the plant's total waste generation. The Toyota plant is classed as a Large Quantity Generator of RCRA hazardous waste. Prior to the 1994 expansion which doubled production capacity, hazardous waste generation averaged about 2,500 tons annually from 1991 through 1994. After the expansion, waste production appears stabilized in the vicinity of 3,500 tons. The impact of next-generation pollution control technology is apparent here, in that a doubling of capacity resulted in an increase of only fifty percent in RCRA waste.

The most recent data available is for 1999, during which TMMK reported generation of 3,334 tons of RCRA waste, all of which was shipped offsite for treatment or disposal. Although the RCRA waste generated at Toyota was comprised of several dozen waste categories, six categories only comprised more than 80 percent of the total hazardous waste (Table 10.2). As can be observed from the descriptions of these wastes, all are associated with coating and painting operations; areas where Toyota has focused its efforts to find substitutes and improve process efficiency.

TMMK has endeavored to implement an innovative and environmentally friendly solution for the ultimate fate of paint sludge recovered from wastewater. Beginning in 1998, the plant shipped the sludge to a company in Ohio that processed it into a pulverized building material used by manufacturers to make decorative garden border bricks, roofing material, low-strength concrete and road-building material (Chappell 1998b). “It was a good program while it lasted,” noted Chris Holbrook (2002 interview), but the sludge processor’s parent company succumbed to economic difficulties and went into bankruptcy, ending the relationship between its subsidiary and Toyota of Georgetown. Since then, the paint wastes have been burned for energy recovery, but TMMK has been negotiating financial arrangements with a brick manufacturer to turn waste water sludge into bricks. The necessary permits have been obtained and a pilot program operated for three months, but the project was sidelined by the brickmaker due to recently increased demand by the building industry for conventional bricks. It costs far less to simply incinerate these wastes, since Toyota must pay for long-distance transportation to the brick manufacturer, but TMMK is committed to seeking the best solutions to environmental problems wherever feasible. If implemented, this waste-to-bricks process represents an ecologically ideal solution in that it closes the loop, taking another small but significant step towards creation of a larger industrial ecology.

As a large water consumer, TMMK is also a large generator of wastewater. After pretreatment, about 1.2 to 1.3 million gallons of wastewater per day is discharged to an adjacent city treatment plant, dedicated solely to serving Toyota, that the company helped build. In 1989, Toyota's wastewater failed an environmental monitoring test and low levels of toxicity - nickel and zinc - were found at Georgetown's #2 treatment plant, to which TMMK is the only discharger (Prather 1989). Several modifications were made in Toyota's pretreatment system to reduce the metals content of wastewater sent along to the city treatment plant. Success in this endeavor is confirmed by TRI data, which show a trend of decreasing nickel releases. The water transferred from TMMK's pretreatment plant meets drinking water standards for nearly all constituents even before entering the city treatment plant.

TMMK reported TRI production waste generation of 1,597 tons for the year 2000, of which 502 tons – slightly less than one third - were released into the environment. An additional 23 tons required landfill disposal and 34 tons were discharged to the local water treatment plant. Approximately equal proportions of generated waste were managed through off-site recycling (29.8 percent) and through burning for energy recovery both on- and off-site (30.05 percent).

Evaluation of waste management effectiveness over time, using TRI data, requires that a consistent set of chemical substances be used as the basis for analysis in each year. Not only have there been additions and deletions to the TRI list made by the USEPA, the Georgetown facility has itself both added and discontinued use of certain chemicals. Sixteen TRI listed chemicals have been consistently generated as waste at TMMK during the period 1991 through 2000: barium compounds, benzene, certain glycol ethers, copper, ethylbenzene, ethylene glycol, lead compounds, manganese compounds, methanol, methyl ethyl ketone, methyl isobutyl ketone, N-butyl alcohol, nickel compounds, toluene, xylene (mixed isomers). The emissions of these specific substances

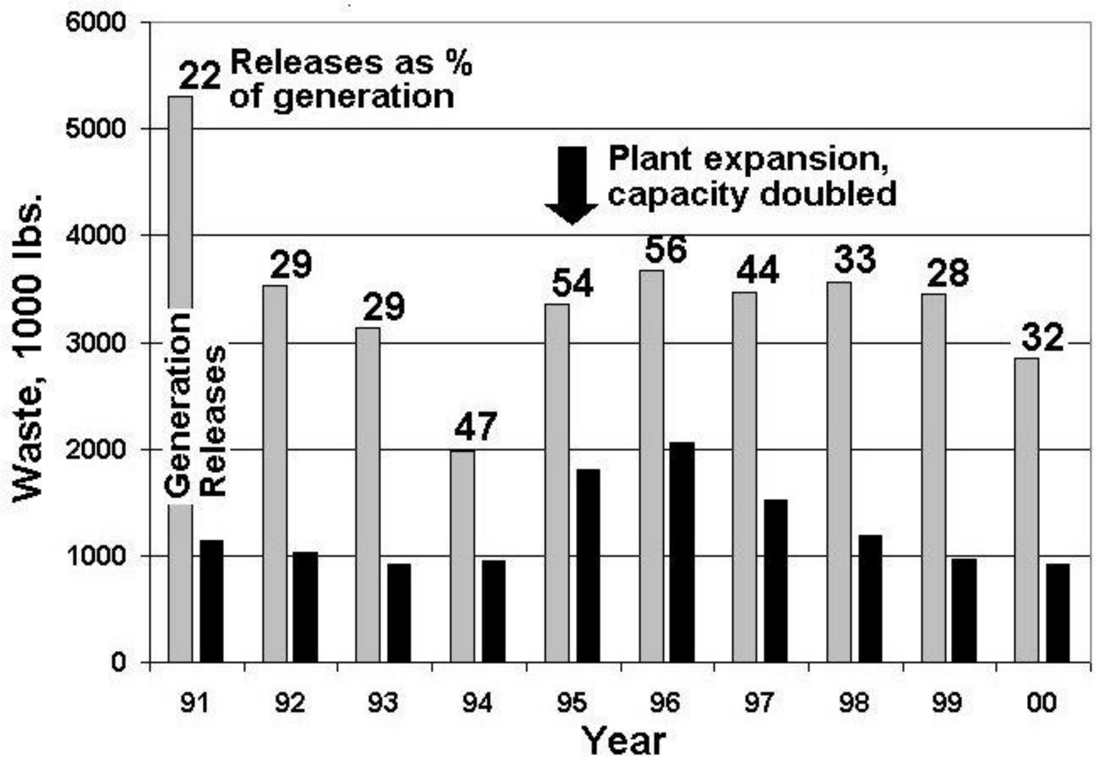

Figure 10.4. Waste generation compared to waste releases at TMMK, 1991-2000
Source: RTK NET

represents more than 90 percent of total annual waste releases during each of the years 1991-2000 (92% of total releases for 2000), so the trend expressed by these substances may be considered representative of the whole period.

Figure 10.4 shows total generation and emissions for these sixteen chemicals during the ten-year period 1991-2000. During the time 1991-1994 prior to the 3.2-million square-foot expansion, the data show a steep downward trend for waste generation and a more gradual decrease in waste releases. Emissions as a proportion of total waste, however, increased during this period, indicating that waste management efficiency was not improving even though less waste was being generated. From 1995 through 2000, following a major expansion that included the addition of Paint #2 and Assembly #2 areas and effectively doubled the areal size of the plant, there was an immediate jump in both total waste generation and releases. Over the next five years, although total waste generation experiences only a slight downward trend, the proportion of waste that escapes from management and is released into the environment declines sharply. By 2000, the total quantity of waste generated and the quantity of chemical emissions has declined to a level approximating that which existed prior to the plant expansion. This is a clear reflection of both the next-generation pollution control equipment installed during the 1994 expansion and of a greatly improved waste management efficiency.

An even clearer depiction of the trend in waste management efficiency is gained when we examine waste releases at TMMK on a per-unit-of-production basis. Although production units cannot be used to compare different facilities, this is a valid technique

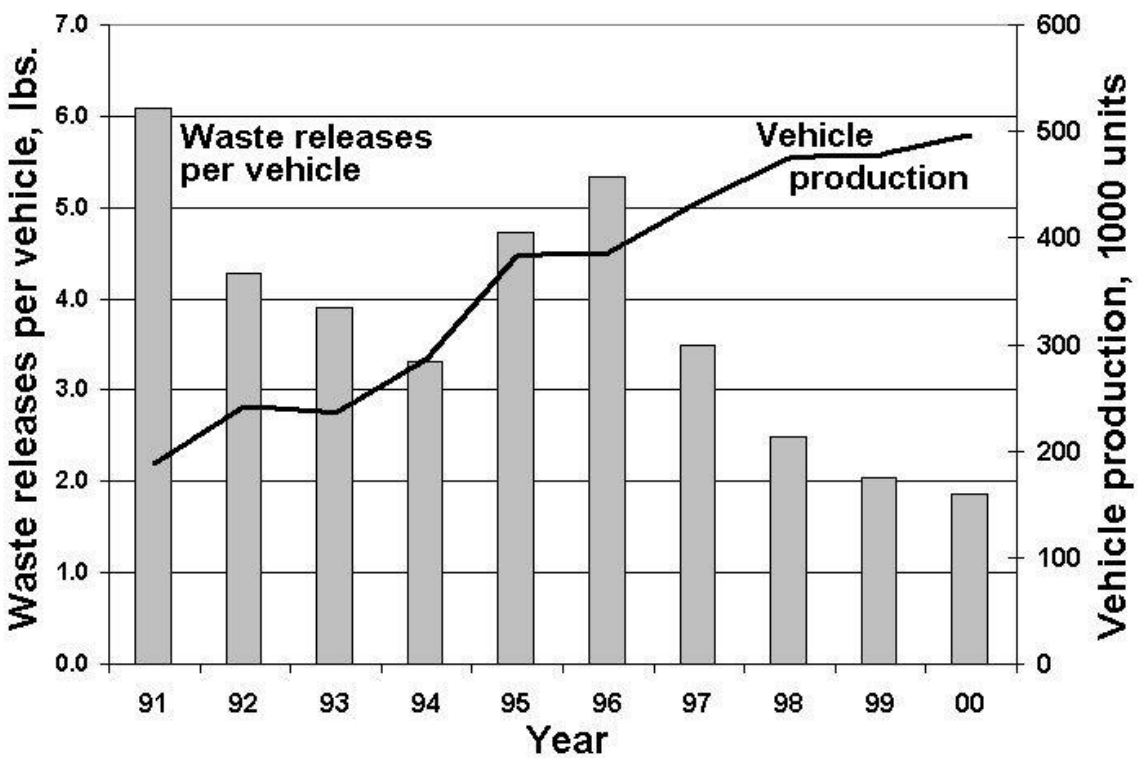

Figure 10.5. Waste releases per vehicle unit of production at TMMK, 1991-2000
Sources: RTK NET, TMMK (2002)

Table 10.3. Waste generation and release means for TMMK, other Japanese and non-Japanese automobile assembly facilities (1999 data)
Source: RTK NET and author's database

	Total releases	Total release toxicity	Release ratio	Release toxicity ratio	Eco efficiency
TMMK	1,060,888	4,239	27.5	32.2	0.54
Other Japanese (N = 6)	792,925	3,015	48.2	47.6	0.86
Non-Japanese (N = 8)	860,551	3,862	38.9	41.0	0.97

applied to a single facility that has maintained the same type of production over time. Figure 10.5 depicts waste releases per vehicle produced, compared to vehicle production totals. The waste data resembles the trend shown in Figure 10.4, declining across time after the original installation and again after the expansion. In a way, this may well represent a "learning curve" as management and workers become familiar with equipment and procedures and the production system is fine-tuned. More significantly, a threefold decline in waste releases occurs even as unit production climbs by 250 percent, suggesting a significant gain in waste management efficiency.

A conclusive evaluation of waste management efficiency requires comparison of TMMK's waste statistics against those of other vehicle assembly plants. Table 10.3 compares TMMK to other Japanese assembly plants and to non-Japanese assembly plants,[20] using computed means for (1) TRI waste releases; and (2) toxicity-weighted TRI waste releases; (3) the release ratio, or releases as a percentage of generated waste; (4) release toxicity ratio, or the toxicity of releases as a percentage of generated wste

[20] The anomalous Ford Lorain, Ohio, facility is not included in these calculations. See Chapter 9 for explanation.

toxicity; and (5) the eco-efficiency score, derived as the toxicity-weighted releases per facility worker.

Toyota's Kentucky plant generates more production waste than any of the other assembly plants, but also has a higher rate of vehicle production. What is noteworthy about TMMK is how that production waste is managed. From the table it is apparent that TMMK is significantly superior in all performance measures (release ratio, release toxicity ratio, and eco-efficiency score) than the the mean for other Japanese-owned assembly plants or the non-Japanese plants, although some individual plants may equal or exceed TMMK. This is particularly significant considering that the TMMK facility outsources less production than most Japanese assembly plants, manufacturing a large number of its own components including engines. Worthy of note is the fact that the Toyota plant in Princeton, Indiana (TMMI) demonstrates environmental performance superior even to TMMK (see Chapter 9). This most likely represents a more advanced pollution control technology at the newer (1998) TMMI facility.

In 1999 the Environmental Defense Fund (EDF) released a comparison of "pollution prevention performance" for vehicle assembly plants in the United States, ranking Toyota of Georgetown among the worst performers.[21] This ranking was based absolute quantities with single-year data, using 1996 TRI records and 1994 VOC data from the EPA's AIRS (Aerometric Information Retrieval System) database. A detailed analysis of Toyota's environmental record, such as the foregoing, underlines the weaknesses in the EDF's methodology. The EDF ranking does not take into account TMMK's rapidly diminishing rates of waste generation and emissions over time, nor does it take into

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[21] Environmental Defence Fund website: http://www.environmentaldefense.org/documents/990_GC_VAfacilityranking.htm.

account that TMMK manufacturers more automotive components, such as engines, within its own facility, than is customary for many automakers. A more equitable assessment of relative performance among assemblers would compare Toyota's record against the total waste emissions of other automakers plus their engine plants.

Perhaps the most succinct assessment of TMMK's overall environmental performance is the 1998 statement by Oscar Geralds of the local chapter of the Sierra Club: "We don't have any major problems with Toyota" (Butters 1998).

Chapter Eleven

Driven by Honda: Madison Precision Products and Mitsubishi Electric Automotive

11.1. The suppliers perspective

In 1996, Susan Helper and her associates (1997) interviewed thirty automotive supplier firms located in northeast Ohio (Cleveland area), combining the results with those from a 1993 mail survey of automotive firms throughout the United States and Canada. This research project investigated many aspects of the relationships between assembly plants and supplier firms and among supplier firms. Helper found that, in general, relations between customers and their suppliers in northeast Ohio were weaker than those outside the area; adversarial in some cases. Compared to other regions, in northeast Ohio: (1) regional suppliers exchanged far less information about products and processes with their customers, so that many opportunities for mutual benefit were not taken; (2) suppliers felt customers were less likely to help them in ways not required by contractual obligations, to provide assistance to reduce price or improve quality; (3) fewer suppliers believed that they had a long-term committed relationship with their customer, contractual or implicit. Helper attributed the relatively low levels of commitment and interfirm information flow to one primary factor: only one of the northeastern Ohio supplier firms had any substantial business with a Japanese assembly plant: “In both the survey and the interviews, firms with Japanese customers reported substantially more frequent visits, discussions about the design of the product and process, and expressions of long-term commitment if performance goals were met” (p. 52). Significantly, supplier firms in northeastern Ohio used older machinery, had less automation, carried larger inventories, used less defect prevention as part of their quality assurance programs, paid lower wages, and trained workers less.

Information sharing is a key component of the Japanese production system, which tends to improve the performance of all firms in the hierarchy while building firm-specific knowledge and capabilities. Multidirectional interfirm flow of information and technology as a primary characteristic of lean production is believed to derive primarily from Toyota's origination of the "black box" system of joint product development during the 1950s.[1] According to Fujimoto (1999), transactions between automakers and their suppliers can be divided into three broad categories: supplier proprietary parts, detail-controlled parts, and black-box parts. These categories are essentially the same as those identified by Asanuma (1989) as marketed goods, drawings supplied, and drawings approved. Supplier proprietary parts are highly standardized parts used by a variety of vehicles, such as tires, batteries or alternators, which are developed entirely by the supplier as its standard product from concept through manufacturing. For detail-controlled parts, most of the basic engineering and also the detailed engineering is performed in-house by the assembly plant; the supplier takes responsibility for process engineering and production on the basis of provided blueprints. For black-box parts, the

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[1] The precise origin of the black box system is difficult to determine. There is some evidence that the practice may have been transferred to the automotive industry from the more advanced locomotive and aircraft industries in Japan. There is also strong reason to believe that this derives from the 1949 spinoff of the Nippondenso (Denso) company from Toyota. In post-war Japan Toyota was forced to design and produce electrical parts in-house due to a lack of quality parts suppliers. In 1949 Nippondenso was created as an independent entity to resolve a financial crisis; subsequently Toyota found itself dependent upon the capabilities of Nippondenso because virtually of of its electrical engineering staff had moved to the new company. Although Nippondenso today still provides components primarily to Toyota, contracts made with other automakers led to a diffusion of the black box concept in the 1960s. Because U.S. automakers did not use the black box system prior to the establishment of Japanese automakers in North America, this concept was not adopted from western Fordism. If the practice in fact originated with the Nippondenso spinoff, the practice thus emerged as a result of historical imperative rather than rational calculation (Fujimoto 1999).

work of product development is shared between the assembler and the supplier, where the former provides a basic design for a component or subassembly and the supplier performs the detailed engineering.

Detail-controlled parts is the dominant form of supplier transactions in the United States, but black box parts manufacture is still an important mechanism here for the diffusion of knowledge through associated firms. According to Fujimoto, this concept is one of the primary factors responsible for the Japanese competitive advantage in the 1980s, and one particular element of the Japanese supplier system that U.S. firms have attempted to adopt.[2] Suppliers play a crucial role in the process of adoption of innovations, providing feedback from their trials about operational problems and successes; the learning experience influences the likelihood for adoption of additional innovations (van Dijken, *et. al.* 1999). Joint development also spreads the costs and risks of product or process development through two or more firms, rather than remaining focused within a single company.

Information sharing through joint product development is one important component of interfirm knowledge transfer in Japanese supplier systems; the other important aspect is the diffusion of the concepts and processes involved in lean production. A supplier firm that is lean is more likely to deliver high-quality, low-cost components within the exacting standards of just-in-time delivery. The major Japanese automakers in the United States all have supplier development programs to teach lean production to willing supplier firms. One measure of the assembly plants' intense desire to recreate a lean production network in the U.S. is that such services are offered for free in this country,

[2] This has led to increased outsourcing by U.S. automakers.

whereas suppliers in Japan are charged substantial fees for such training (Pil and McDuffie 1999). Mentoring of this sort may even involve the exchange of employees between firms for weeks or even months in order to assess problems and learn new methods.

One reason that assembly plants are able to work so closely and intensely with supplier firms is that Japanese automakers generally deal with far fewer suppliers than U.S. automakers. A survey by Pil and MacDuffie (1999) found that U.S. automakers averaged more than 500 individual supply firms, whereas Japanese automakers averaged only 164 suppliers. Furthermore, the long-term relationships typical between suppliers and assemblers lead to the development of a level of trust not often found between firms in the United States, such that there may often be virtually no inspection of incoming parts from a firm that has proven itself in the past. Supplier firms are usually graded and sent regular scorecards assessing their performance in the number of defective parts, percentage of on-time deliveries, and in cost reduction. Should a supplier firm fail in performance, the assembler generally will not dismiss the company but instead will impose a penalty by shifting a portion of business away for a time to another source. (Womack, Jones and Roos 1990).

Although close interfirm ties are of mutual benefit to both assemblers and their suppliers, there are some negative aspects as well. As noted in Chapter 10, assembly firms are able to use their economic leverage to coerce supplier firms to innovate, cut prices, and share proprietary information and technology. Furthermore, for firms that are strongly committed to a single assembler, the nearly constant presence of consulting personnel from the customer within the supplier's facility can lead to an erosion of the dependent firms identity.

The overall significance of the supplier network in the simultaneous transfer and harnessing of group knowledge has been aptly summarized by Kenny and Florida (1993,306):

> These networks are not simply new mechanisms for efficient parts supply and procurement. They function as yet another organizational mechanism for mobilizing knowledge and intellectual labor on a collective, social basis. The networks provide a powerful dynamic of innovation. Each firm in the network feels economic and social pressure to improve; thus the network is constantly stressed. Suppliers respond by improving technology and speeding up work. As suppliers' knowledge advances, it becomes expertise laden and is able to innovate on its own. These improvements are in the interest of the assembler, so they encourage the process through the extension of technical and other assistance.

The effectiveness of the supply chain as a mechanism for diffusing knowledge and innovation has led to a number of studies as well as initiatives directed toward assessing its potential for improving firm environmental performance. Supply Chain Environmental Management refers to "a variety of approaches through which companies work with their suppliers to improve the environmental performance of the products or manufacturing processes of the supplier, customer, or both" (NEETF 2001). In this regard, among survey findings reported by the Business for Social Responsibility Education Fund (2001), involving several industries in which supply chains operate, were the following: (1) Nearly all supplier companies (in several industries) had received requests from corporate customers to address environmental issues and these requests had motivated changes in supplier's environmental performance; (2) Companies in the automotive and electronics sectors received the most such requests. These requests generally focused on elimination of toxic substances from products and ensuring that suppliers are implementing environmental management systems; and (3) Environmental requests are flowing both ways along the supply chain. Several suppliers described initiatives to involve their customers in meeting their own environmental goals, such as changing product specifications to allow pollution prevention activities, or to incorporate environmental considerations into purchasing decisions. Activities of the sort described in these findings were apparent in the previous chapter, particularly concerning Toyota's "Green Supplier Guidelines," and are equally evident in the actions of the supplier firms featured in this chapter.

The two facilities profiled in this chapter exemplify the sort of close and interactive relationships that develop when supplier firms are heavily dependent upon a single customer, to the point where processes and procedures within the supplier firm are adopted directly from the customer's preferences. The firms, one located in southern Indiana, and one in southern Ohio, are both first-tier supplier to Honda of America, also located in Ohio. Of all the major Japanese automakers, Honda's supplier development program, known as "BP", is probably the most dedicated and successful in imparting Honda's value system and performance standards to its supplier firms.

" BP" is an acronym which stands for many things, which together might be summarized as "Best Practice." BP represents opportunities for supplier performance improvement that support Honda's manufacturing philosophy, in terms of productivity, quality, cost-reduction, and partnering to gain the "synergy factor of knowledge transfer activity" and developing long-term relationships (Nelson, Mayo and Moody 1998). The BP supplier improvement process is essentially indoctrination in lean production; identifying and solving problems, continuously improving, and striving for excellence.

When a supplier is chosen for BP, staff members from the supplier development group, operating out of Honda's Marysville plant, form a team with employees of the supplier representing both management and floor workers. This team spends several weeks at the supplier firm focusing, initially, on projects in a few specific work areas that do not require large capital expenditures to implement. These projects are narrowly defined in order to give quick results and provide motivation. The supplier does is not required to pay Honda for its time[3] but must provide tools and materials as needed; the supplier must also agree not to lay off any employees as a consequence of BP activities. Honda requires full cooperation of management, including any and all needed information about the supplier's cost structure and technology, and the ability for Honda consultants to move freely throughout the facility. BP activities have been shown in some firms to increase productivity as much as 50 percent over prior levels (MacDuffie and Helper 1999).

Personnel at the two firms in this case study were universally enthusiastic about the BP program, and evidence of its influence were manifest in attitudes expressed about waste, quality and productivity, in the organization and cleanliness of the workplaces, and in the many large posters and exhortations prominently displayed. The sense gained through the interviews was not that of firms subservient to Honda, but rather of firms with a sure sense of their own identity, with pride in their capabilities and performance and proud to be in partnership with the automaker.

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[3] In contrast, suppliers in Japan are required to pay Honda 2 percent of sales for this service (MacDuffie and Helper 1999).

11.2. Madison Precision Products, Inc.
Madison, Indiana[4]

11.2.1. Industrial context

Madison Precision Products, Inc., occupies a 54-acre tract at the top of a long incline up from the Ohio River, just off U.S. Highway 421. The plant lies just outside Madison, Indiana, a riverside community of 13,000 persons that has achieved national distinction for its successful preservation of the largest tract of historic buildings in the state. Madison Precision supplies the automotive industry with a variety of aluminum die-cast parts, mainly engine components. The bulk of the facility's output is destined for Honda, for which it is a first tier supplier, and as second-tier supplier to AFCO also counts all major automobile manufacturers among its customers. Established as a greenfield plant in 1988, the company employs more than 400 workers in a constantly expanding facility that currently stands at 181,650 square feet. Madison Precision is a wholly-owned subsidiary of the METTS Corporation, Japan.

METTS Corporation is headquartered in the city of Saitama and operates six manufacturing facilities in Japan as well as single plants in Brazil, the Philippines, Portugal, and the United States. METTS specializes in production of die cast aluminum and magnesium components serving a number of industries, primarily automotive.

[4] Plant visit and interviews conducted February 6, 2002. Primary informants were Dennis Welch, ISO coordinator, and Louis Alexander, facilities maintenance engineer. Follow-up interviews for additional clarification were subsequently conducted by phone and email.

11.2.2. Organization of production

The manufacture of die-cast aluminum parts at Madison Precision Products is highly automated, involving the injection of molten aluminum into die molds and subsequent deburring and, for certain parts, machining. The Madison plant has 24 different aluminum die casting machines and nine melting furnaces with a melting capacity of approximately 65,500 lbs. per day. The casting process consists of a four step cycle: (1) lubrication of the open mold with a mixture of water (95%) and oil (primarily vegetable oil); (2) closing of the mold; (3) the injection; (4) breaking open the mold and ejection of the cast part. None of the parts are coated but are shipped and assembled as bare metal.

Because different parts often require specific grades of aluminum, production at the facility is divided into distinct work areas, each focused upon a furnace that produces a melt of that particular grade. These work areas may be very large or small, depending upon the variety and production quantities of parts that require a certain grade of aluminum. In a major production line, the melt is conducted in a large furnace and conveyed in relatively small ladles along an overhead trolley to individual holding furnaces attached to casting machines. This operation is completely automated. The holding furnace automatically signals the large furnace (Figure 11.1) when the need for a resupply is imminent; the ladle of molten aluminum proceeds to the holding furnace while flashing a number indicating its destination, thus warning any personnel in the vicinity to step away from the impending pour area. Smaller production lines may consist of a single casting machine with an attached furnace that both performs the melt and supplies metal to the machine (Figure 11.2). These small lines are self-contained, in that clean scrap is recycled back into the melt.

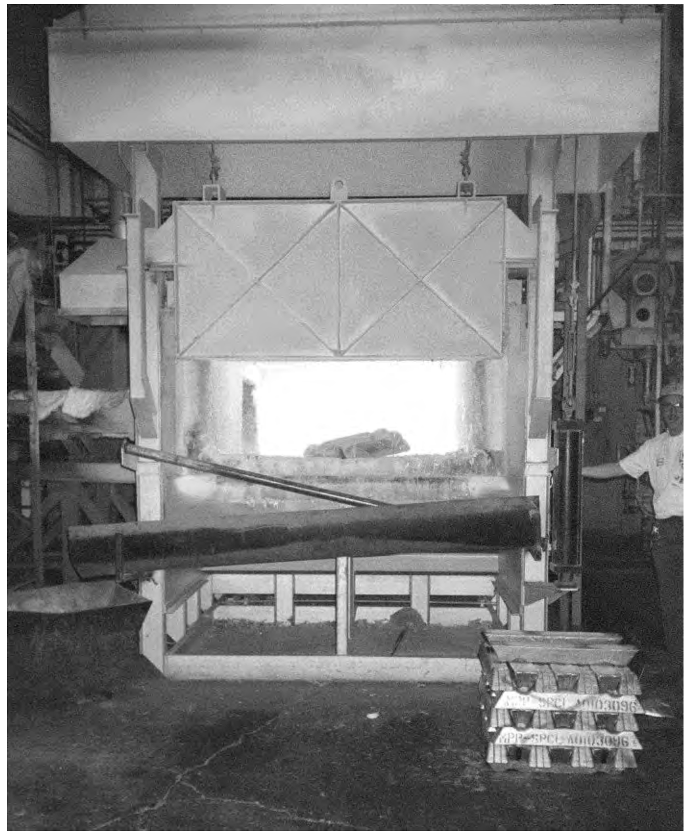

Figure 11.1. Large melt furnace opened briefly to show ingots heating inside.
Gary A. O'Dell.

Figure 11.2. Smaller, self-recycling furnace on the production line.
Gary A. O'Dell.

11.2.3. Production management system

As a new greenfield facility in 1989, Japanese production methods were implemented from the very first. Because Honda of America Manufacturing, with assembly plants located in Marysville and East Liberty, Ohio, is Madison Precision Products' primary customer, the Madison facility adopted the Honda version of lean manufacturing through the automaker's BP supplier development program. Like the Toyota system, the Honda derivative emphasizes product quality and operational efficiency, based on the twin pillars of modern Japanese manufacturing, just-in-time and continuous improvement. Through JIT, Madison strives to hold no more than 3-6 days inventory on the premises at any given time.

Madison's kaizen is evident through its dedication to improvement through Total Quality Management. Meetings involving management staff are held at the beginning of each day to address various issues that may include safety, quality, production operations, or cost efficiency. Visual management is a key component of kaizen at Madison, with prominently posted graphs and charts to identify goals and monitor progress. Floor workers are engaged through daily shift meetings and additional input from associates is solicited through strategically located suggestion boxes placed throughout the facility. "Improvement teams" address general production issues and are also formed to investigate specific issues that may arise.

Close ties are maintained with Honda as part of the auto assembler's supplier improvement process. Madison Precision's improvement teams set targets and measure progress, reporting to Honda and consulting on a regular basis with Honda personnel in regard to issues, problems and achievements. Representatives from various departments within Honda visit Madison nearly every week. Honda also offers intercorporate training seminars intended to enhance supplier efficiency and product quality, and supplier representatives are expected to attend.

Madison Precision Products, which achieved ISO 9001 registration in 1999, has received several awards for excellence from Honda and other major customers, and in 2000 received the US Senate Productivity Award. The latter award, established in 1983, is given by U.S. Senators to the company in their state that has shown the greatest increase in productivity each year, companies that have shown their commitment to innovation, quality, and customer service.

11.2.4. Environmental management

Madison Precision Products believes strongly in proactive pollution prevention. The company's environmental policy goals are summarized by the acronym MPP, likewise corresponding to the initials of the company:

> Madison Precision Products is dedicated to preserve our environment and will strive to:
>
> **M**eet and exceed relevant laws and regulations
> **P**revent pollution
> **P**romote continual improvement.
>
> By setting and meeting objectives and targets, Madison Precision Products is committed to continual improvement of our environmental management system (EMS) for our associates and our community through ongoing education, EMS audits, and utilizing new technology.[5]

A commitment to environmental quality is affirmed by the unequivocal phrasing of this statement, an explicit policy to "meet and exceed" environmental regulations. Many company environmental policy statements commit no farther than to "meet" regulatory

[5] MPP website: http://www.madisonprecision.com/environ.html

requirements, let alone attempt to exceed them. The Japanese corporate dedication to kaizen is also directly apparent in the Madison policy, where "promote continual improvement" is kaizen by definition and comprises one of the three stated goals.

Madison Precision Products does not maintain a separate environmental staff but instead combines these functions within health and safety and coordinates with facility maintenance. Dennis Welch, with an occupational background in quality management, has been a Madison Precision associate for four years as the ISO coordinator and investigator in safety issues. Louis Alexander, facilities maintenance engineer, was formerly maintenance supervisor for Dayton-Walther Corporation[6] and since joining the Madison staff has become more involved in environmental issues, now handling all environmental compliance matters for the facility.

Honda requires that all suppliers be compliant with ISO 14001 but does not mandate certification. Madison Precision Products chose to take the more demanding path, and achieved ISO 14001 registration on 15 December 2000. For Madison, the process was perhaps less arduous than for many companies because they already had trained internal auditors on staff in consequence of accomplishing ISO 9002 certification in June 1999. Madison chose to have its own personnel certified internally as ISO 14001 auditors, rather than depend upon outside consultants for this service. This approach, wherein the environmental management system is directly developed by persons most familiar with plant operations, assures a deeper commitment and more sophisticated understanding of the goals and procedures of the EMS. Dennis Welch, ISO coordinator for Madison,

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[6] Today known as Meritor Corporation.

noted “Every facility needs someone who is well trained in the standards because the consultant will no longer be there.”

Welch was sent to an intensive five-day, 36-hour ISO-14001 auditor course approved by the Registrar Accreditation Board (RAB).[7] Individual accreditation required each participant to take and pass an exam given at the end of the seminar. Having received this training, Welch could apply, through RAB, for status as a provisional auditor and perform ISO 14001 audits at other companies under the authority of a certified lead auditor. Such was not the purpose of the training, however. With an ISO-14001 certified auditor in-house, Madison could craft a far better EMS and provide better training for workers than could be obtained through external consultants and packaged courses. Upon his return from the ISO 14001 course, Welch passed along what he had learned to the other company auditors in a course that lasted several days, culminating with participation in a real ISO 14001 audit at another facility. Madison Precision’s auditors are thus well qualified to perform internal audits, though only at the Madison plant.

A steering committee was formed, comprised of representatives from all levels of the company from managers to floor workers, to develop an ISO 14001 environmental management system specific to the perceived needs of Madison Precision Products. The entire process of development and implementation of the ISO 14001 EMS required about seven months. All employees received awareness training in regard to the new EMS, with designated associates receiving more thorough training on a need-to-know basis according to his or her responsibilities.

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[7] The 36-hour lead auditor course typically includes a general review of the ISO 14000 series of standards with specific emphasis on ISO 14001; a review of environmental laws and regulations; hands-on, interactive case studies; and workshops that demonstrate auditing techniques and skills, including audit planning, execution, reporting, and follow-up activities.

Detailed and thorough documentation is the core of any ISO 14001 EMS, providing procedural guidance and feedback toward accomplishment of goals. Component documentation associated with Madison Precision Products' environmental management system include the items listed below, which are tied to the requirements of the ISO 14001 auditing process:[8]

1. MPP Quality and Environmental Policy Manual

This manual addresses issues related to both product quality, according to the requirements of ISO 9001:2000, and environmental aspects of production related to ISO 14001:1996. Sections of the manual address: (a) the scope of the quality management system (QMS) and EMS, including details of and justification of any exclusions; (b) reference to the documented procedures established for the QMS and EMS; (c) a description of the interaction between the processes of the QMS; and (d) a description of the core elements of the EMS and their interaction.

2. EMS Aspects Identification Work Instruction

The purpose of this document is to identify aspects of Madison's activities, products and services which may have a significant impact upon the environment, where an impact is defined as being "any change to the environment, whether adverse or beneficial" that is wholly or partially a result of Madison's activities, products or services. Environmental objectives and targets are derived from a consideration of significant environmental aspects identified through this process. Significant aspects and related objectives and targets are to be reevaluated on a routine basis, annually or as-needed.

[8] Referenced documents provided courtesy of Madison Precision Products.

3. EMS Regulatory Compliance Evaluation Work Instruction

Procedures outlined in this document are intended to ensure that the company identifies, evaluates and complies with all applicable laws, regulations, and other requirements (federal, state and local) that apply to the identified environmental aspects of Madison's production operations.

4. EMS Objectives and Targets Work Instruction

In order to implement the environmental policy the company is to establish and document environmental objectives and targets, consistent with a commitment to pollution prevention, which provide the means to gauge effectiveness of measures taken and to improve performance. Objectives are site goals, to be quantified wherever possible, that are "consistent with the environmental policy and which considers significant environmental impacts and applicable laws and regulations." In addition to the regulatory considerations, objectives must also take into account technological, financial, operational and other business requirements and the views of customers, associates, and other interested parties. Targets are detailed performance requirements, also to be quantified where possible, based on environmental objectives; targets must be met for the objective to be achieved. According to the instruction, "targets are established for different functions within the company and for different areas within the plant. Individual departments may set targets based from company-wide objectives or a company-wide objective may translate into individual projects in different plan areas."

5. EMS Monitoring and Measurement Work Instruction

This document outlines procedures for monitoring and measurement of the key characteristics of operations and activities that may have a significant environmental impact. This includes “recording of information to track performance, relevant operational controls and conformance with our environmental objectives and targets.” Monitored aspects include monthly wastewater treatment, machine leaks, waste disposal and recycling, furnace particulate matter emissions, and energy usage (gas and electric).

6. EMS Operational Control Work Instruction

Operations and activities associated with identified significant environmental aspects are to be conducted according to specified conditions. Documented procedures are to be established for operations and activities where the absence of instructions may lead to deviations from the EMS policy and associated objectives and targets. All employees are expected to follow established guidelines and reporting requirements. In addition, where applicable, procedures and requirements are to be communicated to suppliers and contractors.

7. EMS Nonconformance Handling and Investigation Work Instruction

This section of the EMS is to establish means to handle and investigate nonconformances “to mitigate any impacts caused and for initiating and completing corrective and preventative action.” All employees are responsible for reporting actual or potential situations that may have an adverse effect upon the environment. Emergency situations require additional documentation (see below).

8. EMS Emergency Preparedness and Response Work Instruction

This document refers to the facility’s emergency preparedness and response in relation to identified significant environmental aspects and potential impacts. The intent of this work instruction is environmental protection, which differs from the separate *Emergency Action Plan Work Instruction* intended to protect employees from major disasters including fire, tornado, earthquake, bomb threat or hazardous spill. Environmental emergencies may concern flux smoke, wastewater and waste liquids, and hazardous spills, among other situations.

9. EMS Internal and External Communication Work Instruction

This document describes processes for internal communications regarding the company's EMS, and procedures to be followed in receiving, documenting and responding to communications from external parties, including "proactive steps that MPP takes to maintain a meaningful dialog with external interested parties on environmental matters."

11.2.5. Environmental impact

The ISO 14001 steering committee examined all aspects of the plant's operation that had the potential for environmental impacts and derived a list of four priority areas to be addressed: (1) recycling, (2) wastewater and waste liquids, (3) furnace exhaust waste products, and (4) energy use.

Essentially every pound of aluminum that comes into the plant as ingots goes out as manufactured product; all metal scrap produced at Madison has always been recycled as a routine part of processing operations. Received ingots that are soiled or defective are returned to the supplier for reprocessing and sent back to Madison at a discounted rate. similarly, ingots that become soiled during processing operations, process scrap, and aluminum scraps cleaned out of the furnaces are also returned to the supplier.

As part of ISO 14001 implementation, the company embarked upon a program to significantly reduce the amount of solid waste tonnage and to reduce or eliminate the hazardous waste component from their solid waste disposal (see Figure 11.3). Formerly, much of the waste generated included hazardous waste and was classed as "special waste" under state and federal regulations, with special requirements for handling and disposal. Today the only RCRA hazardous waste generated at Madison is paint scrap. Filter cake reclaimed by the wastewater treatment process, consisting mostly of zinc and ferric iron, is considered nonhazardous waste and does not require special handling or disposal. In April 2001 a strict program was instituted to capture recyclables such as cardboard, paper, aluminum cans, printer cartridges, and plastics.

One example of proactive waste recovery is represented by the elimination of the use of "Floor-Dry" absorbent material to soak up machine oil spills and leaks. This method

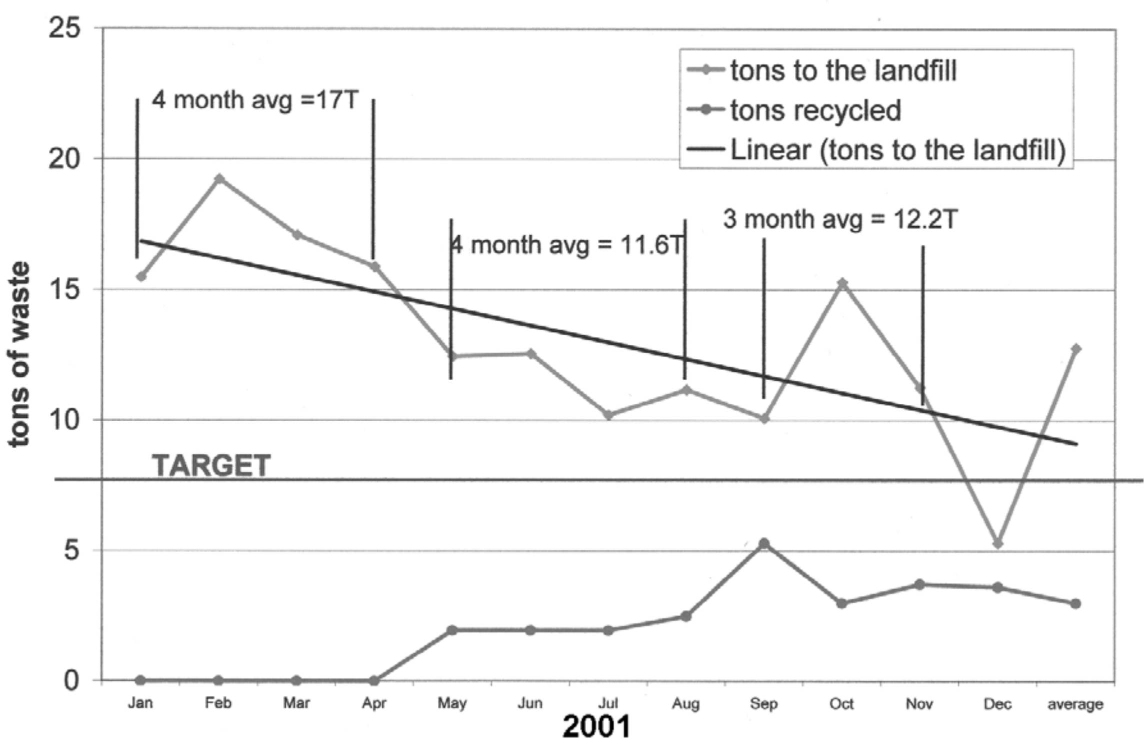

Figure 11.3. Solid waste management at Madison Precision Products, 2001.
Chart courtesy Madision Precision Products, Inc.

was replaced by simply mopping up the oil, allowing recovery of the waste oil and eliminating the need to purchase and subsequently dispose of the contaminated absorbent. Madison Precision has greatly exceeded its initial goal of a fifty-percent reduction in solid waste disposal.

Wastewater generated through manufacturing operations at Madison Precision Products is contaminated with heavy metals such as copper, nickel and manganese and with oil and grease. All such wastewater was sent to the city of Madison POTW (Publicly Owned Treatment Works) for treatment. The contaminant content of the wastewater was highly variable, and at times failed to meet stringent Federal Categorical Standards for the die-casting industry. Recognizing this problem, in 1996 Madison Precision began working with the city and with state regulators to design and install a wastewater treatment system at the facility that would release to the city only wastewater that had been treated so that contaminant levels fell with ranges meeting federal standards. The facility collection and treatment system was installed in 1999 and has since operated in compliance with the standards. The results were dramatic; according to TRI data, heavy metals released to the POTW had averaged more than 500 pounds annually through 1998 but were reduced to only 15 pounds in 1999.

Along with the facility treatment system, Madison embarked upon a overall reduction of water usage in its operations: less water used, less wastewater produced. The goal set was to produce more than nine pounds of aluminum castings for every gallon of resulting wastewater. Water usage at the plant is primarily associated with lubrication of the molds, each mold being sprayed with a mixture of water and vegetable oil as part of the machine cycle for each casting. Reduction in water consumption has been achieved

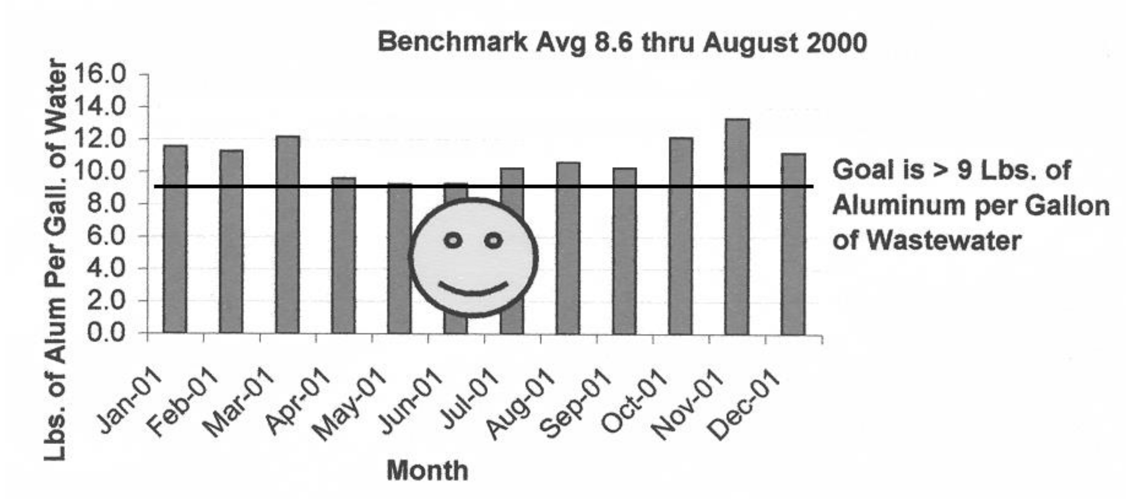

Figure 11.4. Aluminum castings produced, in pounds, per gallon of water used. Note the "happy face" indicating an environmental goal successfully achieved. Progress charts such as this are prominently displayed in the employee smoking room and cafeteria. Compare this with Fig. 8.6, "Kilowatt-hours of electricity vs. pounds of aluminum melted", below.
Courtesy Madison Precision Products.

primarily through improvements in the efficiency of the water delivery system, with installation of automatic shutoffs and prompt attention to leaks. Wastewater generation averaged one gallon for every 8.6 pounds of castings in 2000, but improved significantly during 2001 with an average 10.9 pounds of aluminum product for each gallon of resulting wastewater (see Figure 11.4). This represents approximately 1.5 million gallons wastewater produced in the manufacture of more than 16 million pounds of castings.

In past years, periodic cleaning of the melt furnaces with a fluxing agent resulted in a smoke plume which, although non-toxic and not in violation of state or federal regulations, was highly visible in the neighborhood and represented a potential public relations problem. Fluxing is necessary to remove solid aluminum oxide which accumulates on interior surfaces of the furnaces; if not removed on a regular basis, small particles can go into the melt and cause inclusions in the casting. This results in reduced product quality and may damage tools during machining or casting. The problem was solved by installation of air filtration systems on each furnace to capture particulates

Figure 11.5. The furnace air filtration system.
Each of the five melts is vented to this system. The rack containing disposable filter cartridges is directly behind the two people shown. *Gary A. O'Dell.*

resulting from the fluxing process. These filter systems were installed on five melt furnaces at a cost of approximately $160,000 to $180,000 each (See Figure 11.5). Particulates which once contributed to air pollution are now trapped by filters which are replaced annually and disposed of as ordinary, non-hazardous trash.

Despite many successes, not every effort by Madison to reduce the environmental impact of operations has achieved its goals. Of the four priority areas selected by the steering committee, the facility has, as yet, been unable to make more than slight improvements in consumption of gas and electricity (See Figure 11.6). Recently, the company installed energy-efficient pour spouts in the holding furnaces which reduces the opening by 90% and thus reduces heat loss. Madison Precision Products is also working

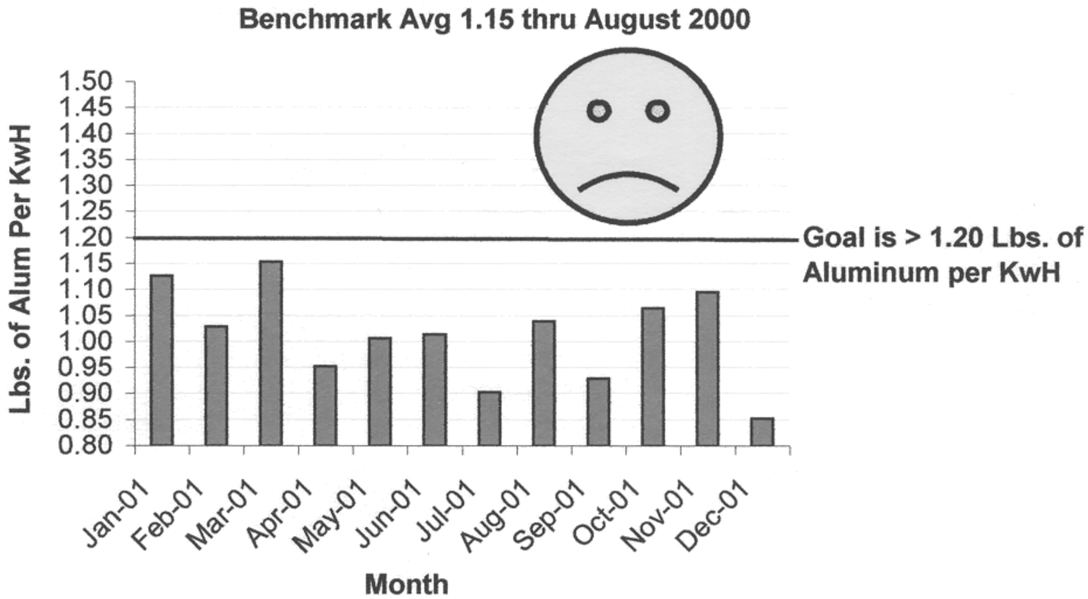

Figure 11.6. Kilowatt-hours electricity consumed versus pounds of aluminum melted. Energy efficiency remains a problem at Madison Precision Products, as indicated by the chart above, despite efforts to improve performance. *Courtesy Madison Precision Products.*

diligently to reduce the use of compressed air, which factor is the single largest consumer of electric power in the plant. Recognizing this as a priority, management has committed to expediting modifications to increase the efficiency of compressed air usage.

Madison Precision Products generates only minimal quantities of waste regulated under RCRA and is classified as "conditionally exempt," meaning that, on average, less than 10 kilograms of RCRA waste are produced per month. Madison's only RCRA waste is paint scrap.

Prior to the 1995 reporting year, toxic wastes generated by Madison Precision were insufficient to fall with the regulatory threshold for the Toxic Release Inventory. TRI reports from 1995-1999 indicate only three regulated substances constituted production wastes in this program: copper, manganese, and nickel. These waste metals derived from trace elements present in the aluminum ingots melted for casting. Of a total of nearly 160,000 pounds production waste, only 260 pounds (0.16 percent), primarily copper, escaped the facility as a release. The majority, 157,500 pounds, was captured and recycled; 106,000 pounds recycled on-site at Madison and 51,500 pounds transferred off-site for recycling. The remainder, slightly less than 2,500 pounds, was disposed in landfills (2,465 pounds) and released to the city wastewater treatment plant (15 pounds). The dramatic impact of the installation of a facility wastewater treatment system at Madison Precision is evident, given that releases of metals to the city POTW in 1998 was reported as 750 pounds.

Figure 11.7 depicts total production waste from 1995-1999 compared to the facility size in square feet. Facility size is shown by the shaded gray background. The original plant erected in 1988 was 59,000 square feet, expanded to 89,000 in 1991. Further expansions increased the facility size to 134,000 ft^2 in 1996, 164,000 in 1999, and to

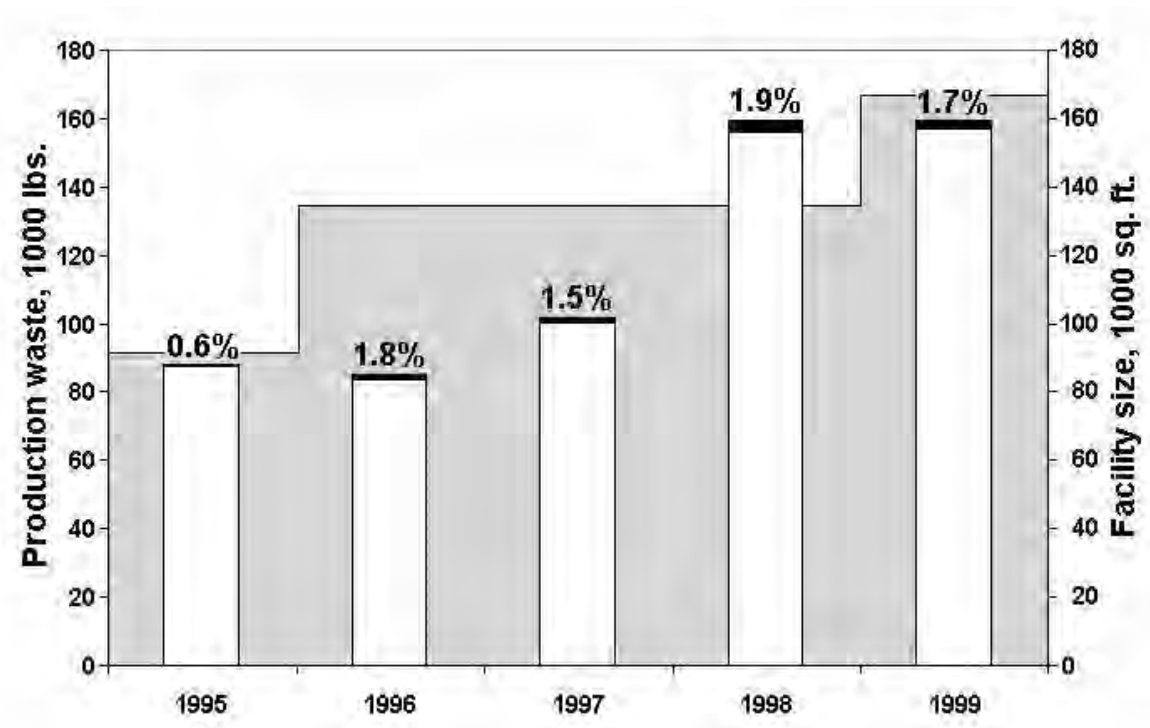

Figure 11.7. TRI waste generation compared to facility size for Madison Precision Products.
Sources: RTK NET, Madison Precision Products

181,650 in 2002 (not shown on graph). Production waste is indicated by the vertical columns; for each column, the small section shaded with black at the top represents the total amount of waste that could not be recycled but was released, landfilled, or sent to the city POTW. The proportion of non-recycled waste has remained stable at slightly less than two percent since 1996, despite a substantial plant expansion in 1999.

According to Dennis Welch, waste is the "bottom line" for the company; anything that reduces the amount of waste ultimately saves money for Madison Precision Products.

11.3 Mitsubishi Electric Automotive America, Inc. Mason, Ohio[9]

11.3.1 Industrial context

The Mitsubishi Electric Automotive facility is located off Highway 42 in Mason, Ohio, a community of 22,000 persons about twenty miles north from Cincinnati and conveniently accessible from both Interstate 75 and 71. The 450,000 square-foot plant employs 433 workers engaged in the manufacture of automotive starters and alternators. More than 1.5 million starters and 1.5 million alternators are manufactured annually.

Mitsubishi is a first tier supplier and all production at the Mason facility is destined for OEM (Original Equipment Manufacturers), used to assemble new automobiles. The plant's largest customers are DaimlerChrysler and Honda of America. More than 400,000 alternators are shipped annually to Honda's engine plant at Anna, Ohio, where they are assembled onto engines which are next transported to the automaker's East

[9] Plant visit and on-site interviews conducted 18 June 2002. Primary informants were Shelby J. Jones, Assistant Manager of Human Resources; Bill Mondillo, Plant Operations Manager; Scott Stephenson, Quality Assurance Manager; Julie Zelner, Environmental Specialist; and Mary Anne Phillips, Safety and Environmental Engineer. Brief interviews were also conducted with several floor workers. Follow-up interviews for additional clarification were subsequently conducted by phone and email.

Liberty plant in Ohio for installation in the Honda Civic. Mitsubishi also manufactures starters for the Honda Accord assembled at Honda's Marysville, Ohio, auto plant. Other major customers include Mitsubishi Motors Corporation; SIA (joint venture between Subaru and Isuzu); CAMI (joint venture between the Suzuki Motor Corporation and General Motors of Canada Ltd.); AAI (Auto Alliance International, joint venture between Ford and Mazda); Ford; and Nissan. The Mason plant supplies all Japanese automakers in North America with the exception of Toyota. The company also manufactures armatures under contract to Delco-Remy, shipping to their plants in the United States and Mexico.

The Mitsubishi facility in Mason has received several awards for excellence, including Honda's supplier quality and delivery awards in both 2000 and 2001. Out of more than 450 Honda suppliers, this facility is one of only seven companies recognized with a double award for both quality and delivery. During 2001, the Mason Mitsubishi plant shipped more than 812,000 parts to Honda with zero defects, while meeting delivery requirements for correct time, quantity and labeling.[10] The plant also received honors from CAMI as its most outstanding supplier, and significant quality and performance awards from Mitsubishi Motors, Nissan, Mazda and Ford.

Mitsubishi Electric Automotive America (MEAA), a relatively tiny segment of one of the world's largest multinational corporations, as might be expected has a complicated corporate genealogy. The MEAA division consists of four locations in the United States. A facility for rebuilding exchanged parts is located in Garden Grove, California, and the

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[10] Mitsubishi Electric Automotive America news release, 20 May 2002: "Employees At Mitsubishi Electric Automotive America Accept 2001 Honda Supplier Award for Quality and Delivery." http://www.meaa-mea.com/news

division sales, marketing, and engineering operations and rebuild distribution center is located near Detroit in Northville, Michigan. Two plants involved in manufacture of new automotive parts are located respectively in Mason, Ohio (starters, alternators) and Maysville, Kentucky (ignition coils, engine control units – ECU or fuel injection computers, and car stereo/CD players). The Mason facility is corporate headquarters for the U.S. automotive division.

MEAA was established in 1979 with the opening of the Detroit area sales office, then located in Plymouth, Michigan, and soon gained AMC/Jeep and Chrysler as early customers. A Cypress, California rebuild operation (later relocated to Garden Grove) and the Mason, Ohio plant both began operations in 1988, and Maysville Kentucky began production of radios in 1995, ECUs in 1996, and ignition coils in 1998.[11] Combined sales for the MEAA group were in excess of $700 million in fiscal year 2001.

MEAA is in turn a division of the Mitsubishi Electric America (MEA) corporate group, headquartered in Cypress, California. MEA comprises more than 6,000 employees in 30 locations throughout North America, with $2.6 billion in sales for fiscal year 2000.[12] Manufactured products include high-definition projection televisions, DVD players, VCRs, projectors, printers, factory automation equipment, automotive equipment, medical devices, escalators, elevators, telecommunications and satellite systems, heating and air conditioning units, semiconductor devices, large scale video displays for stadiums and arenas, and electric utility products.[13]

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[11] "Mitsubishi Electric Automotive America, Inc." company brochure.
[12] Mitsubishi Electric America website: http://www.mitsubishielectric-usa.com
[13] Mitsubishi Electric America website: http://www.mitsubishielectric-usa.com/

The parent company, Mitsubishi Electric Corporation of Japan (MELCO),[14] is one of the world's largest corporations, with operations in 34 countries serving the following industries: automotive, semiconductor devices, industrial technology, heating and air conditioning, consumer electronics, heavy machinery, telecommunications, power, transportation, and information technology. Ranked at number 98 on Fortune's Global 500 list,[15] MELCO has more than 116,000 employees and total revenues exceeding $27.4 billion for the year ending March 31, 2002.[16] Mitsubishi Electric is in the midst of a major restructuring brought on by the Japanese recession; the company intends to spin off, sell, or shut down unprofitable businesses, such as semiconductors and audio-visual products.[17] Global corporate sales were down 12 percent for fiscal year 2002 compared to the previous year, and in North America down by more than 17 percent.[18] This global economic downturn for MELCO has had little effect on MEAA; the Mason plant has experienced a progressive increase in orders and continues to expand production. In consequence of the continuing profitability of the U.S. automotive division, the company is in the process of establishing a starter/alternator division in China.

11.3.2 Organization of production

Only two basic products are manufactured at Mitsubishi's Mason plant – automotive starters and alternators in different models according to customer specifications. Most of

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[14] Mitsubishi Electric Corporation is independently owned and operated; the original Mitsubishi company was broken up after World War Two into a number of separate entities. Mitsubishi Electric America website: http://www.mitsubishielectric-usa.com/about/history.htm

[15] Fortune website: http://www.fortune.com/lists/G500/index.html, list as of July 23, 2001.

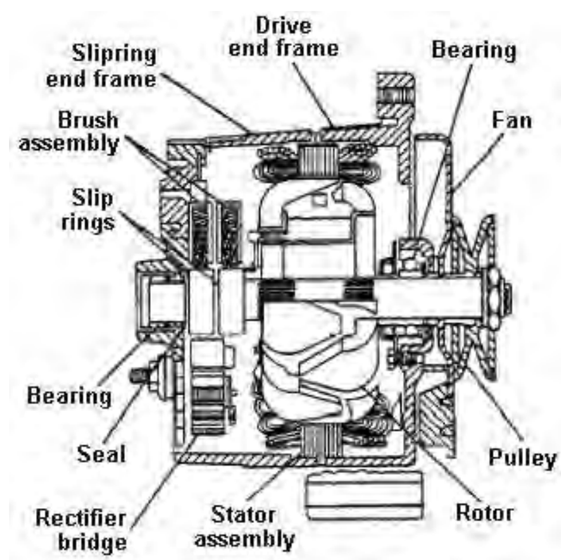
[16] Mitsubishi Electric Automotive America news release, 20 May 2002: "Employees At Mitsubishi Electric Automotive America Accept 2001 Honda Supplier Award for Quality and Delivery." http://www.meaa-mea.com/news

[17] Hoover's Online, company capsule report: http://www.hoovers.com.

[18] Mitsubishi Electric Corporation news release, 26 April, 2002, "Mitsubishi Electric Announces Financial Results": http://www.mitsubishielectric.com/news

the components required for assembly are manufactured at the plant. For the alternators, nearly all parts are made on-site; for the starters, about 50 percent by part count, with 25% outsourced from American suppliers and about 25% imported from Japan, primarily from the parent corporation.

Some basic knowledge of the components of a typical alternator and starter is necessary in order to understand the flows in the production process. An alternator generates electricity which is used to operate the electrical components of a vehicle and to charge the battery. An AC electrical current is induced when a magnetized field, called a rotor, revolves within a set of stationary coils called a stator. The stator and rotor assemblies are contained within a two-piece die-cast aluminum housing (See Figures 11.8 and 11.9). Aluminum is used for the housing because it is non-magnetic, lightweight, and has good heat dissipation.



Left: Figure 11.8. One of the alternator models built at the Mason facility.
Courtesy MEAA.

Right: Figure 11.9. Cutaway diagram of typical alternator, showing major components. *Integrated Publishing: http://www.tpub.com/basae*

The stator assembly is nonrotating and is clamped between the front and rear housing, It consists of a steel frame around which three windings are arranged in layers in each of the slots in the frame. The rotor assembly (see Figure 11.10) consists of a rotor shaft, a winding around an iron core, two pole pieces, and slip rings. The rotor shaft is pressed onto the core. Six-fingered malleable iron pole pieces are pressed onto the shaft against each end of the winding core so that the fingers mesh without touching. The rotor assembly is supported by bearings mounted in the front and rear housing.

The rectifier assembly consists of six diodes mounted in the rear housing; three of the diodes are connected to the ground, three are mounted in an insulator. The alternating current (AC) produced by the alternator is converted by the diodes and rectifier assembly to the direct current (DC) required by automotive electrical components. A fan and pulley assembly is pressed onto the rotor shaft or held on by a nut. The pulley drives the rotor through an engine accessory drive belt; a fan behind the pulley pulls air in through vents in the rear housing to cool the diodes.

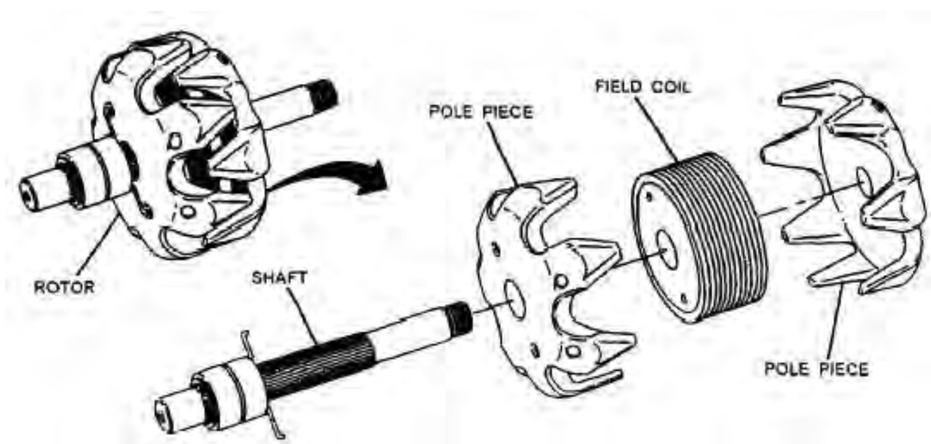
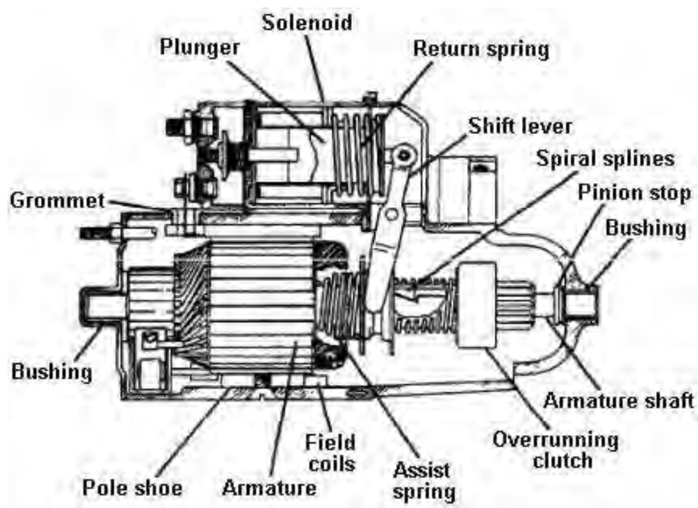


Figure 8.10. Alternator rotor assembly. *Integrated Publishing: http://www.tpub.com/basae*

Figure 11.11. One of the starter models built at the Mason facility.
Courtesy MEAA.

Figure 8.12. Cutaway diagram of a typical starter, showing major components.
Integrated Publishing: http://www.tpub.com/basae



The automotive starter (Figures 11.11 and 11.12) is a small but powerful electric motor whose function is to engage and spin the engine flywheel until the motor starts and operates under its own power, and then disengage. Attached to the starter is an electromagnetic plunger – the solenoid – that kicks the pinion gear of the starter forward to mesh with the flywheel teeth, and then pulls it back out of the way so that the starter will not be damaged by the flywheel rotation. The starter motor, like the alternator, is comprised of both rotating and non-rotating assemblies.

The starter housing, or frame, encloses the internal components and protects them from damage, dirt and moisture. A typical starter motor consists of five main assemblies: armature assembly, field coil assembly, commutator-end housing, drive-end housing, and drive mechanism. The armature assembly consists of a laminated iron core mounted on the armature shaft, windings and a commutator assembly that spin inside a stationary field. The commutator is attached to and surrounds the armature, made up of heavy copper segments separated from each other and the armature shaft by insulation. The commutator segments connect to the ends of the armature windings. The central field and frame is non-rotating, and holds the field coils and pole shoes. The commutator-end frame houses the brush holders, brushes and shaft bushing. The drive-end housing contains the pinion drive assembly, with a bushing for the armature shaft. The pinion drive assembly consists of the pinion gear and pinion drive mechanism and is connected to the solenoid by a shift fork and linkage.

MEAA does not, at present, have the most efficient operational configuration. This is a consequence of the rapid multiple expansions of the facility that have taken place since the original 65,500 square-foot building was constructed in 1988. Major expansions occurred in 1989 (96,600 ft^2), 1990 (39,000 ft^2), 1991 (8,000 ft^2), 1994 (90,800 ft^2), 1996 (56,400 ft^2), 1998 (8,350 ft^2), and 2000 (85,300 ft^2). As a result of this accelerated growth, production areas for starter and alternator components are grouped in different locations through the facility rather than forming a cohesive production line for each product. This situation will be addressed during the coming year, when the operations associated with each product will be aligned together in separate regions of the facility.

Figure 11.13 shows the flow of production operations within the Mitsubishi plant. The flow arrows are intended more to be schematic rather than depicting actual travel

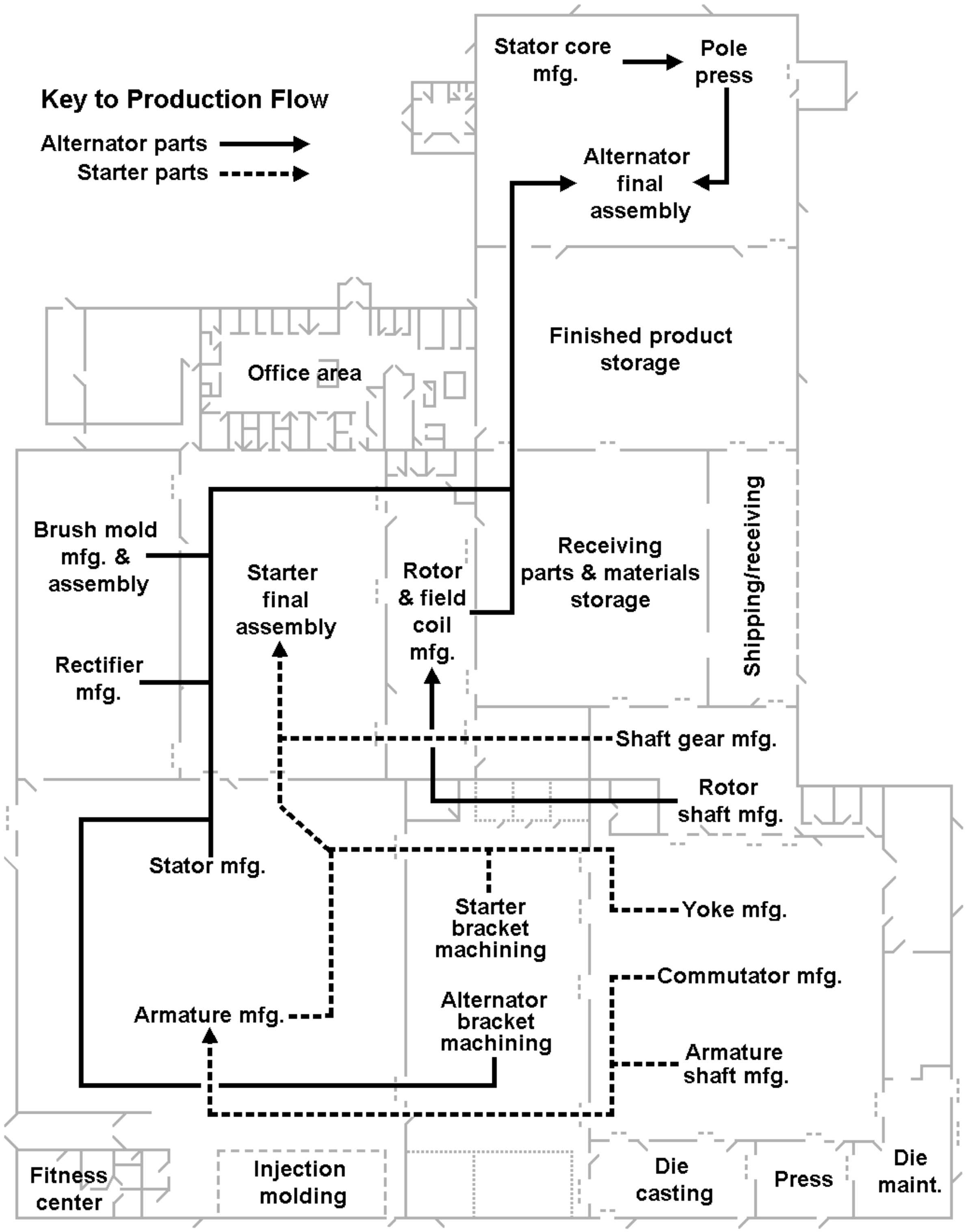


Figure 8.13. Operational flow at Mitsubishi Electric Automotive America, Mason, Ohio, 2002

Floor plan courtesy MEAA, adapted by author. Flow diagram based on plant visit and additional information provided by Bill Mondillo, Mason Plant Operations Manager.

pathways. Two feeder groups manufacture or machine parts which are then fed into either the alternator or starter production lines for the manufacturing and assembly of subunits, which then move to final assembly in different areas of the facility. Feeder Group One consists of the press, injection molding, die casting, and machining operations, all located in one end of the plant. In the press area, steel parts are stamped from continuous rolled steel. Injection molding produces the few plastic parts needed. The die casting operation manufactures aluminum housing brackets for alternators; starter brackets are purchased. Brackets move from either die-casting (alternator) or parts storage to the bracket machining area for boring, tapping and shaping operations. Feeder Group Two is concerned solely with shafts, machining rotor shafts for alternators and armature shafts and shaft gears for the starters.

The facility is highly automated, with large numbers of robotic machines conducting operations all along the production lines. Even the plant operations manager was unsure as to the exact number of robotic units employed, able only to estimate that there were between 500 and 1,000 individual robots in the plant. The robots are engaged in many different operations including parts handling ("pick and place", transfer of parts to and from bins and between operations); materials deposition (gluing and sealing); machining (cutting, drilling, tapping, deburring, finishing, etc); parts inspection (part or feature identification, detection of presence or absence of features, feature gauging), and assembly (parts joining and mating, component insertion). The use of robotics in the Mason plant is most intensive in the component and subassembly areas and least in the final assembly area, which is more dependent upon human skill.

Except for two plastics injection molding units purchased from Milacron Inc. of Cincinnati, nearly all equipment, robots and controllers, used in the plant was custom built in Japan by the parent company, Mitsubishi Electric. MELCO was also responsible for design of the process and the layout of production operations. Each robotic subunit of the manufacturing process is encased in clear plexiglas cabinets, so that a production line resembles a continuous series of boxes from beginning to end of the particular component process (see Figure 8.14, a section of one of the Mason plant's robotic lines).

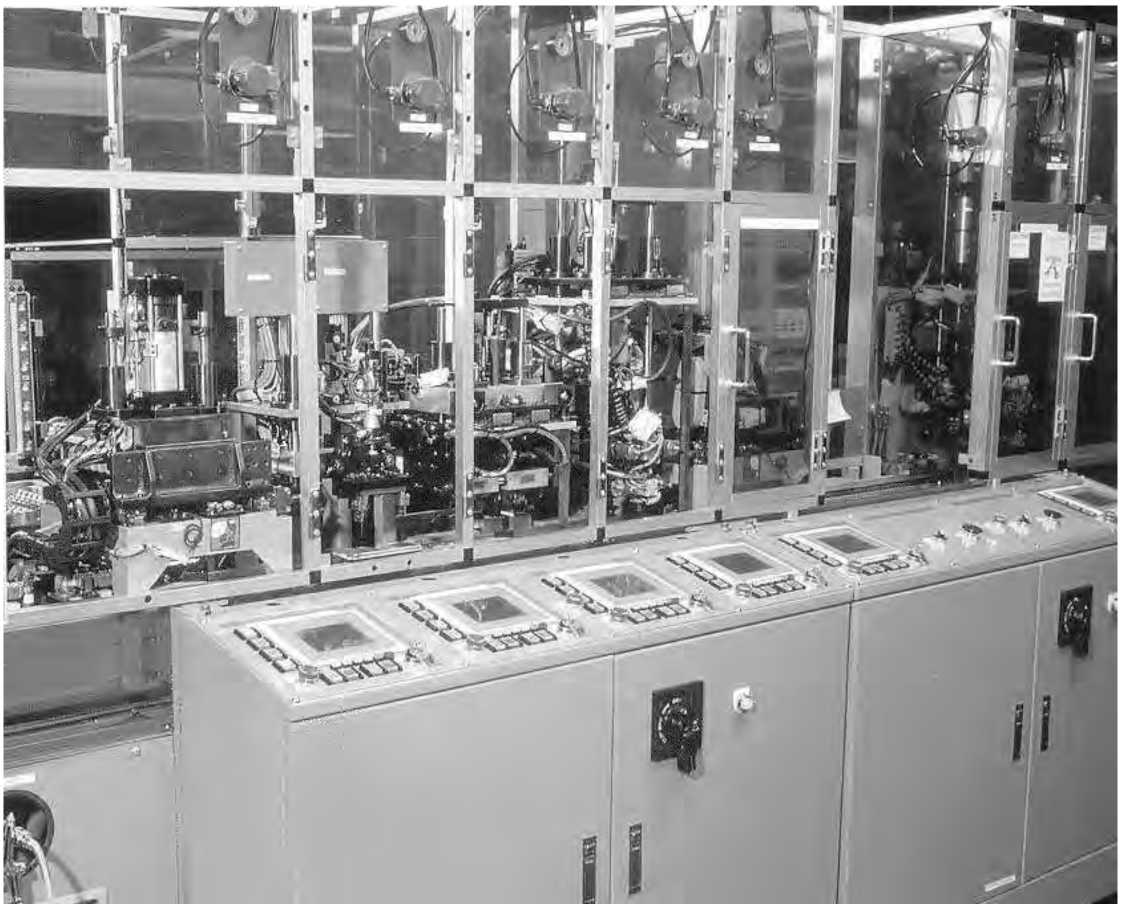


Figure 11.14. Enclosed robotic manufacturing line at the Mason plant.
Courtesy MEAA.

11.3.3 Production management system

The Japanese lean production philosophy and management methods are fully implemented at the Mitsubishi Mason facility. The parent corporation maintains a significant influence at the subsidiary. MEAA's president is a Japanese expatriate, as are several members of the management staff, including the engineering vice-president. Virtually all production technology is of Japanese manufacture, and the basic building and process designs were determined by MELCO. During expansion phases when major equipment installations are scheduled or process restructuring is required, Japanese nationals are flown in to assist. Decisions concerning process flow organization are determined by a cross-functional team that includes significant input from local representatives but is led by experts from the parent company. Management personnel from MEAA have been routinely sent to Japan to observe production methods in MELCO facilities in the home country, but, as one MEAA supervisor observed, "We have also taught them a few things."

As is common practice for most large Japanese corporations, kaizen is embedded company-wide. Pokayoke, devices or procedures intended to prevent mistakes or render errors immediately obvious, are an integral part of production methodology at MEAA. For example, the robotic machines are equipped with signal towers where lights shine red as long as everything is operating smoothly, but begin flashing yellow when the parts supply becomes low. Workers are authorized to stop the production line at anytime when, in their judgement, an error has occurred that may result in defective products. Quality circle meetings are held at the beginning of shifts, and each morning the line is stopped so that associates can be briefed on any problems that have been previously discovered by management or associates. A well-used suggestion system is in place; the suggestions are evaluated by a committee and employees receive points, convertible to cash, for any valid kaizen recommendations. A supervisor noted, "Our philosophy is to take care of the internal customers so the external are satisfied. We have a very small QC [quality control] staff, because everybody on the floor does QC."

According to a company representative, one of the most significant impacts on product quality has been the adoption of the QS-9000 standards, for which the company received certification in 1996. A measure of the strict quality standards to which the Mason plant holds itself is its self-imposed goal of no more than eight defective alternators and five defective starters annually, out of more than three million complete starters and alternators manufactured by MEAA each year. The results are reflected in the numerous awards for quality from its customers.

Like Madison Precision Products in Indiana, for whom Honda of America is also a major customer, the specifics of the production system are largely driven by the requirements of Honda. Although all customers visit the plant from time to time, Honda representatives are frequently on site, maintaining close contact with MEAA personnel in regard to new model launches, product quality, and lean production management techniques. Just-in-time scheduling is partly implemented; MEAA has been able to reduce WIP (work-in-progress) delays so that products can move through the system faster. The Mason plant's production is driven by customer orders and must maintain some stock on hand, but has been reducing inventories as JIT practices become steadily more effective. A company representative observed that at MEAA, "One of the biggest mistakes is if [an associate or manager] did something to cause us to miss a shipment or offend a customer. Customer satisfaction is number one." Several customer awards for excellence in just-in-time delivery testify to success in this endeavor.

The Japanese production systems have often been criticized (as have Fordist methods) as increasing labor effort and worker stress, leading to an increase in repetitive motion injuries, often referred to as cumulative trauma disorders (CTDs) (see, for example, Graham 1995; Wokutch 1992). Just as Toyota has taken various measures to address this issue, including the recent "Blue Sky" initiative at TMMK (see case study this chapter), MEAA Mason has taken steps to improve the quality of the work environment. Assembly and most manufacturing operations work a four-day ten-hour shift, with overtime on Friday if needed, allowing workers to have weekends off. The casting operation is an exception, run 24-7 because the melt furnaces cannot be allowed to cool. Along the production lines, workers are considered machine controllers, not laborers, and are able to move around quite a bit rather than remaining fixed to a particular machine. In contrast, associates engaged in assembly, which is more labor-intensive, do not have the same freedom of motion. Recently, the human resources coordinator was able to implement a policy change that allowed workers in assembly to rotate stations every two hours. The results of this experiment have been encouraging in terms of a greatly improved health and safety record, including a reduced incidence in carpal tunnel syndrome. Recognizing that the rapid growth of the MEAA's business, requiring frequent overtime from employees, could lead to worker burnout, special attention has been given to employee morale. Exceptional team efforts are rewarded by parties, barbecues and gifts distributed at company expense. MEAA's president, Takeo Sasaki, spends a significant amount of time on the plant floor interacting with associates, passing out candy bars, handshakes, and commendations.

11.3.4 Environmental management

MEAA's parent, Mitsubishi Electric Corporation (MELCO), bases its environmental policies and practices upon the concepts of sustainability and ecological efficiency, derived directly from the principles set forth by Schmidheiny (1992) and the World Business Council for Sustainable Development. These terms appear repeatedly throughout the environmental sections of the company website and in its published environmental reports. The company seeks "innovative measures that contribute to global environmental management," to "help achieve the promise of a sustainable society" (MELCO 2002). While bland phrases such as these often have the appearance of insincerity, Mitsubishi reinvests meaning by developing specific objectives and performance standards to apply to its operations and products.

MELCO's corporate environmental guidelines are intended to apply company-wide to both domestic and overseas operations, including MEAA. The focus of MELCO's environmental policies and initiatives are represented by the acronym MET, which stands for Materials, Energy, and Toxicity. Improvement in these general areas is directed to the entire life cycle of company products, including not only production processes but also procurement measures and post-consumer waste. To address these issues, the company applies the Deming "Plan – Do – Check – Act" (PDCA) cycle of activities within the framework of a corporate environmental plan.

MELCO's environmental plan is a systematic, problem-solving approach consisting of three parts: (1) a core policy and code of practices; (2) a set of environmental action objectives; and (3) an environmental management system (ISO 14001). The core policy emphasizes Mitsubishi's commitment to a technology-driven approach to achieving sustainable development, “protecting and improving the global environment through all business activities and employee actions utilizing knowledge accumulated in the past as well as technologies yet to be developed” (MELCO 2002). The associated five-point code of practices commits the corporation to:

- Reduce negative environmental impacts from products and activities; develop processes and technologies that are compatible with maintaining environmental quality; use a life-cycle approach in product development; and promote resource efficiency, conservation and recycling at manufacturing facilities.
- Develop an understanding of environmental problems; and contributing to a “universal awareness” that businesses need to integrate their activities with “the natural cycles of nature.”
- Establish environmental management systems at all manufacturing facilities; and will continually improve environmental controls.
- Through educational activities, to work toward establishing an environmental ethic in employees and provide support when employees “engage in activities that promote environmental protection.”
- Foster “active communication and cooperation” for global environmental protection.

Most corporate environmental policy statements are notable for their lack of specificity, and much that is contained within Mitsubishi’s declaration is ambiguous on the surface. MELCO’s five points are, however, developed in considerable detail through the remainder of their environmental report; when evaluated in this context, MELCO has undertaken a program that is both progressive and specific. The program is progressive in terms of its ambitious goals, and specific in terms of actions to be taken and in development of standards for self-evaluation.

At the corporate level, the Environmental Management Planning Department, led by the Environmental Director, is responsible for upholding basic environmental policies and directives. Each company group and individual facility has an Environmental Manager, who meet twice each year to discuss company environmental issues. The Environmental Technologies Committee advises the Environmental Director and is concerned with developing the technological means to meet objectives and methods to evaluate results. The Environmental Planning Department devises the basic policies and measures incorporated in the Environmental Plan, which is conveyed to the Environmental Managers and further developed within the Environmental Committee of each business group. Each facility, under the guidance of its business group, develops and implements a new environmental action plan each year, with goals and targets specific to that facility. Progress at each facility is periodically assessed by environmental audits (separate from ISO 14001 audits) conducted by the Environmental Management Planning Department, and each business group must also submit an environmental progress report to the Environmental Director each year.

Among recent environmental initiatives promoted by Mitsubishi at the corporate level have been the banning of 27 specific toxic chemical substances from all operations (1997); achievement of ISO 14001 certification for all manufacturing facilities (1999); introduction of “design for environment” guidelines and product life-cycle impact assessment (1999); publication of “Green Procurement Standards” and working closely with suppliers to improve environmental performance (2000); and development of an integrated environmental information system (2001), which will be accessible to all employees through the company Intranet when fully implemented. The Third Environmental Plan is operational from fiscal year 2000 through fiscal year 2002, expanding the objectives of the second plan (initiated 1996) and incorporates new objectives based on the MET concept. The company is engaged in promoting "environmentally conscious manufacturing processes" using the tripartite MET concept: effective use of resources ("M" or materials) through the "3-R" program of "Reduce, Reuse, Recycle"[19]; efficient use of energy ("E") and shifting to energy sources that have a reduced environmental impact; and reduction of substances potentially harmful to the environment ("T" or toxicity). A major theme that appears throughout Mitusbishi's environmental planning is to reduce the company's contribution to global warming ; for example, among the company-wide action objectives in the Third Environmental Plan is to reduce CO^2 emissions at each facility by a minimum 1.5 percent each year, targeting a 25% percent reduction by 2010 of 1990 emissions levels. In general, the various Action Objectives represent "tangible numerical targets" in each category, whether a product or a manufacturing process (MELCO 2002).

The environmental policy for the Mitsubishi plant in Mason, Ohio, states:

> MEAA is a Company committed to the preservation of the Global Environment. This will be achieved through:
> Continuous improvement of applicable environmental aspects;
> Conformance to all applicable environmental legislation and regulations;
> Commitment to recycling and the prevention of pollution;
> Cooperation with the community.

[19] The "3-R's" derive from the EPA "Waste Wise" Program initiated in 1994 and have been widely promoted through the present day. The 3-R slogan advocating "Reduce, Reuse, Recycle" has become something of a mantra for businesses, communities, and schools.

> To ensure that these objectives are achieved, MEAA will regularly set environmental targets, make action plans, and review progress.[20]

MEAA's action plan for 2001 included the following targeted areas: reduction of nonregulated (nonhazardous) waste; reduction of regulated (hazardous) waste; reduction of energy consumption by one percent; and raising environmental awareness of associates. According to a company representative, these areas have always been part of their environmental program and the standards have been continually raised.

The MEAA Mason plant full-time environmental staff consists of two persons, a Safety and Environmental Engineer and an Environmental Specialist, who operate from within the jurisdiction of the facility's Environment and Safety Department. Both staffers are relatively new, having gained their positions since the plant achieved ISO 14001 certification in June 1999.[21] Scott Stephenson, quality assurance manager, was involved in the certification process. According to Stephenson, seeking certification was driven more by customer requirements (specifically, Honda and Ford) than corporate mandate; although urged by the corporate office to become certified, the timing was forced by the customers. The transition, however, was not difficult, since MEAA had previously attained certification in QS-9000 a few years before. Stephenson noted that that, in consequence, implementing ISO-14001 was relatively easy, accomplished over a period of about nine months and very compatible with their management methods: "ISO-14001 is just an extension of [QS-9000]."

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[20] This environmental policy statement does not appear on the local company website, but was provided courtesy MEAA.

[21] Mitsubishi news release, "Mitsubishi Electric Automotive America, Inc. reinforces commitment to global environmental preservation by receiving ISO 14001 certification": http://www.mitsubishielectricus.com/news/1999/060999b.htm

To implement ISO-14001, a multidisciplinary team was formed. Headed by Stephenson as quality manager, the team also included the environmental engineer, training coordinator, production manager, engineering manager and controller. A consulting firm was employed to provide training, and Stephenson and the controller received Lead Auditor training. All employees received awareness training in regard to the new EMS, with designated associates receiving more thorough training on a need-to-know basis according to his or her responsibilities. According to Stephenson, the plant has received definite financial and environmental benefits from ISO-14001 implementation, particularly in regard to energy use and solid waste reduction. He would definitely recommend certification to other firms.

11.3.5 Environmental impact

Throughout its operational existence, MEAA has undertaken numerous initiatives to reduce its environmental footprint. In 1994 the company constructed an on-site wastewater treatment plant capable of processing 3,000 gallons per batch to meet all federal, state and local standards. Like nearly all companies involving in metal processing, MEAA has always recycled metal scrap. During the casting process, scrap is automatically fed back into the melt, and metallic waste resulting when the melt furnaces are cleaned is sent to a recycler. The company's solid waste reduction program currently focuses on the "3-R's." In addition to metal scrap, materials routinely recycled at MEAA include paper, cardboard and aluminum cans. Wooden pallets, on which parts and materials are often received, are reused within the plant; surplus pallets are sent to a third party for reuse or are chipped into mulch. Shipping containers are returnable rather than disposable. Also reused internally are packing materials (such as foam "peanuts"), with excess quantities sent to a mailing company. Waste reduction was achieved in the wastewater pretreatment process by changing the type of chemicals used, resulting in a lesser amount of filter cake requiring disposal.

Energy consumption has been reduced by replacing lighting fixtures with more energy-efficient models, and by reducing lighting in areas where it would not interfere with production. Motion sensors have been installed in conference and certain other rooms to automatically turn off lighting when no one is present. The sequencing of air compressors, which operate much of the production equipment, has been adjusted to eliminate frequent power usage in startups. Power usage has been further reduced through employee education, whereby lights and equipment are switched off when not actually needed.

The Mason facility is classed as a small-quantity generator (SQG) of hazardous waste, producing less than 100 kilograms of such waste per month, and so is less strictly regulated than facilities with greater waste production. According to a company representative, MEAA's hazardous wastes consist mainly of flammable liquids such as isopropyl alcohol and lacer thinners. Because these chemicals are used throughout the plant, the flammable liquids are taken to a central collection room for temporary storage, and subsequently shipped to a Transfer, Storage, and Disposal Facility (TDSF)[22] to be used in fuels blending.

During reporting year 2000, MEAA generated about 965,000 pounds of toxic waste regulated under the TRI program. The majority of this waste was copper and aluminum, virtually all of which was recovered and recycled. The 16,400 pounds of TRI waste

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[22] "TDSF" is an EPA classification for contract hazardous waste handlers.

emissions represents 1.7 percent of total waste generation and is comprised mostly of a single substance, styrene.[23] Stator, rotor and armature windings are dip-coated with a protective polyester resin varnish which contains a thermoplastic monomer, styrene, to promote fast curing. When MEAA undertook the Delco contract, setting up three additional lines to manufacture starter armatures, styrene emissions increased greatly (see Figure 11.15).

The company recognized control of styrene emissions as a significant problem requiring resolution and, in 2000, acquired equipment to destroy the styrene contained in its waste emissions. To achieve this, MEAA installed a catalytic oxidizer in line with its

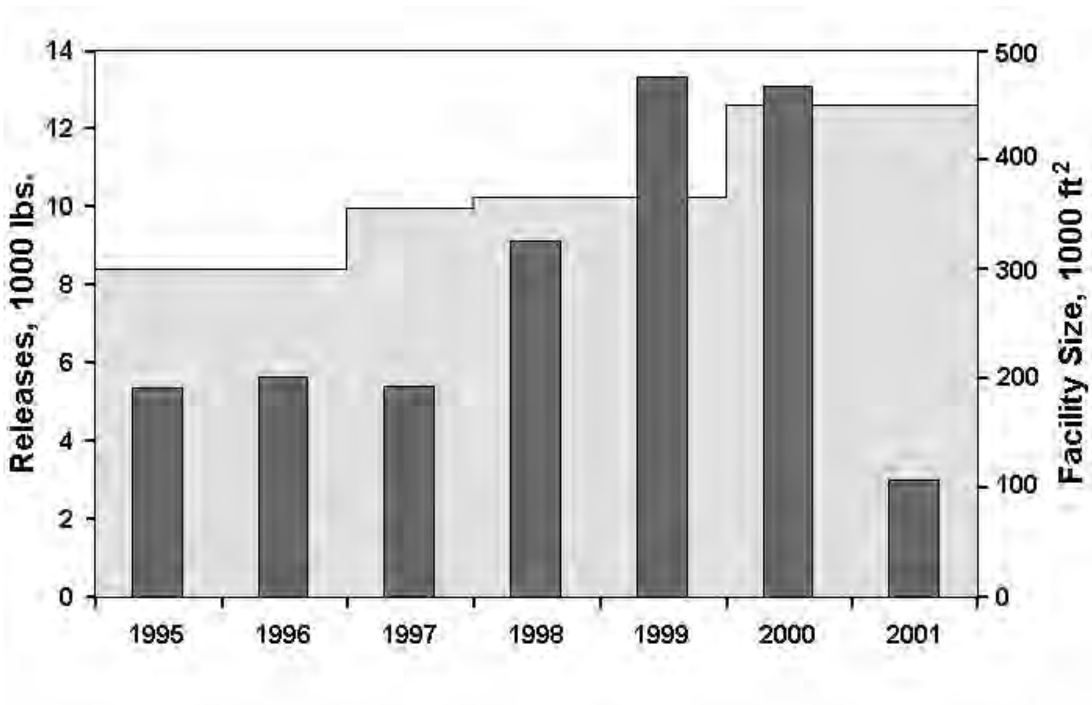

Figure 11.15. Styrene emissions at MEAA, 1995-2001.
Data for 2001 has been reported to EPA but is not yet publicly available through TRI; information supplied courtesy MEAA.

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[23] Styrene is widely used in manufacturing a broad range of products. Health effects from airborne exposure may include irritation of eyes, nose, throat and skin. Exposure to high levels may cause dizziness. Evaluation of styrene as a carcinogen has not yet been conclusive. See "Hazardous substance fact sheet: Styrene monomer," New Jersey Department of Health and Senior Services, 1998.

process exhaust system. Thermal oxidation technology is commonly used to control volatiles, smoke and odors by heating the incoming contaminated air to combustion levels, recovering much of the energy by transferring heat from the hot clean gas stream exiting the oxidizer into the incoming polluted gas stream.[24] A catalyst is a chemical compound that promotes a reaction without being consumed in the reaction; when a catalyst is used to enhance the operation of a thermal oxidizer such systems typically achieve greater than 99 percent destruction of styrene with relatively low temperature requirements.[25] The results from installation of the catalytic oxidizer at the Mason plant were dramatic (see Figure 11.15). Styrene emissions were reduced to less than a quarter of the level prior to installation of pollution control equipment, from 13,100 pounds in 2000 to 3,020 pounds in 2001. The styrene emissions for 2001, in fact, were 45 percent less than the emissions reported for this substance in 1997, prior to addition of the additional armature manufacturing lines.

According to Julie Zelner, Safety and Environmental Engineer at MEAA Mason, "Being ISO-14001 certified for four years now, we are continuously looking for ways to accomplish [environmental goals]. As times change, more resources become available or current ones improve. We are always evaluating our programs through employee involvement teams to continuously improve our environmental contributions."

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[24] Description of operation of thermal and catalytic oxidizers summarized from Durr Environmental website: http://www.durrenvironmental.com/AirPur.asp.

[25] "Controlling VOC and styrene emissions from a button manufacturer," case study reported by Institute of Clean Air Companies: http://www.icac.com/.

Chapter Twelve

Lean by Design: Yorozu Automotive and Link-Belt

12.1. Lean production as competitive advantage

The firms represented by the case studies in this chapter differ significantly from those previously profiled in the factors driving their adoption of lean production and environmental management systems. In the previous two chapters, case studies were presented in which the adoption of advanced manufacturing techniques was a result of the interactive relationships existing between an automobile manufacturing facility and its dependent suppliers, where the automobile assembly plant is the primary agenda-setter. In Chapter 10, the relational behavior of Toyota, originator of lean production, is representative of Japanese automakers as a class, perceiving a competitive advantage to be gained not only by adherence to these production and management techniques but also by shaping its suppliers into conformance. Thus Chapter 11, which concerns two first-tier firms that supply components to Honda of America, is nearly as much about Honda as it is about the specific firms profiled. The supplier firms perceived their competitive advantages to be best pursued by following the lead of their primary customer, the automaker, through adoption of a particular style of lean production and also through adoption of an environmental management system.

For the two facilities profiled in the present chapter, Yorozu Automotive and Link-Belt construction Equipment, the presence of dependency relationships based on economic leverage is greatly diminished or absent altogether. Supplier networks in the automotive industry are not always strictly pyramidal; in many cases suppliers provide components to more than one automaker and the influence of any single assembler is accordingly reduced. This is the situation of Yorozu Automotive, which supplies suspension components to every automaker in the United States except Dodge and Toyota. Lean production methods are firmly embedded in Yorozu's operations, however, and an ISO-14001 environmental management system has recently been developed and implemented at the firm.

Link-Belt differs from all of the other firms in the case studies in that it alone was not established as a solely Japanese greenfield plant but was a 1986 joint venture between a U.S. firm and a Japanese firm. Link-Belt, a non-automotive assembly plant for heavy construction equipment with its own supplier hierarchy, has not established a learning agenda for its suppliers but has itself undertaken to learn lean production methods; ironically, through an American university. During the course of the joint venture, which lasted for three years, Link-Belt operated by Fordist production principles rather than a lean production system. After the facility became a wholly-owned subsidiary of Sumitomo Heavy Industries in 1989, lean production methods were selectively phased into the operational structure so that today the company represents a hybridization of Fordist and Japanese methods. Although Link-Belt has not as yet adopted ISO-14001 as a formal EMS, the company is investigating the advantages that might be derived from so doing.

Absent the influence of a dominant partner in knowledge transfer, the question arises as to why and how firms such as Yorozu and Link-Belt choose to adopt lean production and possibly environmental management systems? What are the driving factors? The patent answer is, of course, that their parent firms in Japan have adopted lean production and so, naturally, overseas subsidiaries follow suit. The review of the literature, responses from the mail survey and anecdotal evidence acquired during this investigation indicate, however, that not all Japanese overseas transplants have adopted lean production methods, particularly in the case of acquisitions where Fordist systems are preexisting. Furthermore, one must logically follow this query backwards another step: Why did so many Japanese companies in Japan adopt and adapt the lean production system from Toyota before ever a Japanese transplant was located in the United States? For insight into this query, we must turn to theories of organizational behavior as applied to institutional change.

Michael V. Russo's (2001) study on the adoption of ISO-14001 by firms in the electronics industry is relevant not only to its stated purpose but also provides a useful framework for examining the diffusion of lean production methods. Russo has identified two theoretical perspectives related to institutional change: institution theory and resource-based theory. Institution theory suggests that the behavior of an organization is conditioned by the social environment in which it is situated. In an industrial milieu, firms tend to undertake selective imitation of certain characteristics of other firms that they perceive as having the ability to enhance their legitimacy or competitive success.

Haunschild and Minor (1997) distinguish three distinct modes of interorganizational imitation: frequency-based, trait-based, and outcome-based. Frequency-based imitation is the adoption of practices and structures that are common to a great many firms in their environment on the premise that use of a widespread practice conveys legitimacy to or proves the value of that practice. Trait-based imitation occurs when firms imitate the practices of other firms that are perceived as having traits such as larger size, higher status or greater success in their industry. Outcome-based imitation is not concerned with the number or characteristics of other firms, but upon the "perceived consequences" of the practices: "Practices or structures that produce positive outcomes for others will be imitated; those that produce negative outcomes will be avoided" (p. 476) Thus, the authors note, outcome-based imitation is linked more closely to technical processes than social processes.

Resource-based theory focuses upon "the acquisition, development and deployment of tangible, intangible and human assets, as well as the organizational ability to acquire, integrate and manage such bundles of assets. Organizations can produce sustainable competitive advantages if they develop and use assets that are valuable and difficult to imitate" (Russo 2001,11). The concept of limited imitability (and limited substitutability) of key organizational resources has been identified as a critical factor contributing to competitive advantage (Hoffman 2000; Peteraf 1993; Barney 1991; Direckx and Cool 1989). Institutional theory generally holds imitative actions to be primarily symbolic rather than substantive, increasing the legitimacy of the firm regardless of performance: "A valuable advantage that is distinct from efficiency and profitability can be captured by conforming to societal norms that might include having trendy organizational structures, professionally trained managements, and manufacturing quality programs" (Russo 2001,8). As Russo notes, organizational actions that can be easily imitated cannot lead to organizational improvement. Accordingly, the resource-based model for adoption of innovative practices by firms appears to have greater validity than the imitative model.

There is little doubt that the innovative work organization and process management methods characteristic of Japanese lean production systems have conferred a distinct competitive advantage upon firms that are wholly committed to these methods (Jenkins and Florida 1999; Pil and MacDuffie 1999; Kenney and Florida 1993; Jürgens, Malsch, and Dohse 1993; Womack, Jones and Roos 1990). Yet, as noted by Fujimoto (1999), the production system developed by Toyota is not only difficult for others to imitate but also difficult to identify, inasmuch as much of the system is premised upon intangibles: "Outside observers have tended to focus on the functionality of individual practices and subsystems, or tangible factors in general, but they may be overlooking these broader and intangible flows of value-carrying information, which have to be constantly managed throughout the manufacturing process" (p. 16). Many U.S. firms have made the error of attempting to adopt the Japanese system piecemeal, assuming just-in-time inventory reductions to be the critical element. When such imitation without commitment invariably fails, U.S. firms have attributed their inability to implement lean production to "cultural factors" that cannot be transferred to the American workplace.

Herein lies the explanation for the implementation of lean production within firms that are not driven to do so by a primary customer such as Toyota or Honda. Yorozu Automotive and Link-Belt Construction Equipment are lean organizations because they are wholly committed to this philosophy and methodology as a key to their competitive advantage over other firms. Yorozu is a tier one supplier of suspension components to most automakers in North American because they have demonstrated their ability to meet quality and delivery standards, performance made possible by their lean production system. Link-Belt has chosen to introduce lean production methods within its previously Fordist environment one step at a time, not randomly or piecemeal, but in a systematic fashion that integrates Japanese and Fordist methods into a new hybrid that reduces costs and increases productivity. Evidence from studies such as Pil and MacDuffie (1999), Nakamura et. al. (1999) and the JMNESG project (Kamiyama 1994) demonstrate that selective integration is the norm, rather than the exception among transplants. The incorporation of many U.S firms into the supplier networks of Japanese automakers demonstrates that lean production is transferable across cultures. Hybridization is inevitable, although the final form is not yet known:

> Japanese transplants abroad during the 1980s provide a striking example of adapting general principles to a local context, to the point that the final configuration has no precedent since it is a hybrid between the foreign model and the indigenous configuration (which may or may not have been transformed). It is difficult to arrive at general laws governing this trial and error process, yet it seems capable of being extremely adaptable (Boyer and Durand 1997,60)

12.2. Yorozu Automotive Tennessee Morrison, Tennessee[1]

12.2.1. Industrial context

Morrison is a small community of about 600 persons located in Warren County, Tennessee, near McMinnville and about 60 miles east of Nashville, the state capitol. Just north of the town, off of Highway 55, is the Mountain View Industrial Park which contains the Yorozu Automotive facility. The Yorozu plant occupies 675,000 square feet under roof, including office spaces, and employs more than 850 workers in the production of automotive chassis and suspension systems. The Morrison facility is a supplier to every auto assembler in the United States except Dodge and Toyota. At the time of the plant visit and interviews, the Yorozu Automotive plant in Tennessee was known as Calsonic Yorozu Corporation (CYC), a joint venture between the Yorozu

[1] Plant visit and interviews conducted on 8 January 2002. The primary informant was Keith Rogers, Environmental Engineer.

Corporation, headquartered in Yokohama, Japan, and Calsonic Kansei of Tokyo. Subsequently, during summer 2002, Yorozu Corporation acquired Calsonic's interest in the facility.

Calsonic Kansei was formed by the merger of Calsonic Corporation (Tokyo) and Corporation Kansei (Saitama) in April 2000.[2] This company manufactures a variety of automotive components, focusing upon heater and air conditioning systems, engine cooling systems, exhaust systems, instrument clusters, sensors and switches. The corporation conducts overseas operations at 38 facilities located in 15 foreign countries, including 13 in the United States. In addition to its former interest in the Yorozu plant in Morrison, the company produces automotive parts in six other Tennessee locations.[3]

Yorozu Corporation is a supplier of suspension modules and structural parts to the automotive markets in Japan, Thailand, Mexico and the United States. Until 2000 the major shareholder was Nissan Motor Company Ltd., but in September of that year Nissan sold a 17 percent interest in Yorozu to Tower Automotive, Inc, a U.S. automotive parts manufacturer based in Grand Rapids, Michigan. During the following January, Tower acquired an additional 13.76 percent holding from Nissan, bringing its total interest in Yorozu to 30.76 percent.[4] Yorozu Corporation's overseas operations are limited to a plant in Thailand and two in North America.[5] In addition to the Morrison plant, Yorozu Corporation has one manufacturing facility in Mexico and is constructing plants in

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[2] "Calsonic Kansei was born April 2000," http://www.calsonickansei.co.jp/english/calkanew.html.
[3] "Foreign sites," http://www.calsonickansei.co.jp/english/forei.html.
[4] "Tower Automotive announces fourth-quarter and year-end results," press release 31 January 2001, http://www.towerautomotive.com/releases/2001html/010131.htm
"Nissan Announces Sale of Holdings in Yorozu to Tower Automotive," press release 21 September 2000, http://www.nissan-global.com/GCC/Japan/NEWS/20000921_2e.html.
"Tower Automotive acquires equity interest in Yorozu Corporation," press release 21 September 2000, http://www.towerautomotive.com/releases/2000html/000921.htm.
[5] http://www.yorozu-corp.co.jp/index06.html

Mississippi and Michigan. Following Yorozu Corporation's acquisition of Calsonic's share of the Tennessee facility, the plant was renamed Yorozu Automotive Tennessee.

12.2.2. Organization of production

The production of automotive suspension parts at the Morrison facility is divided into two segments, in terms of both process and physical layout. Approximately one-half of the plant is dedicated to stamping and metal-forming operations, and one-half to assembly of finished components. The stamping operation uses conventional presses of up to 3,000 tons capacity to fabricate metal, but the forming operation employs a cutting-edge technology known as hydroforming to shape both steel and aluminum tubing. In the hydroforming process, unheated pre-bent tubing is clamped into presses and a high-pressure water based fluid inside the tube cases the tube to expand and take on the shape of the female die halves. Hydroforming allows the manufacture of a complex part with significant cross-sectional variation along its length (Pinkham 2001). This technology, which is beginning to replace stamping and welding in the production of automotive structural parts, results in lower production costs and lighter-weight components.[6]

In the assembly area of the plant, small parts are put together in numerous subcomponent lines and then flow to the main line for final assembly and finish coating. All processes throughout the facility are highly automated, with a large number of robots used for parts handling and welding operations. According to a company representative, the CYC plant in Tennessee has more robots under one roof (approximately 600) and more robots per square foot than any other manufacturing facility in the United States.

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[6] "Japanese Companies in the U.S.: Transportation Equipment." *Japan – U.S. Business Report* 362, November 1999, http://www.jei.org/Archive/BRArchive99.html.

12.2.3. Production management system

Lean manufacturing based upon Japanese management systems is integral to the Yorozu operation in Tennessee. Just-in-time, kaizen and pokayoke are fully implemented throughout all operations, and TQM, quality circles and kanban systems are applied to specific aspects of production. Because of the broad customer base, Yorozu's management system is not driven by a relationship with a major customer, as is the case with Madison Precision Products in Indiana, for whose "BP" operating system Honda serves as mentor.

12.2.4. Environmental management

The company environmental policy for Yorozu's Morrison facility implies that the company seeks a level of environmental performance that exceeds regulatory requirements. According to the policy statement,[7] Yorozu Corporation "is committed to continual improvement of the Environmental Management System and to the prevention of pollution." The company "strives for excellence in compliance with applicable environmental regulations and other requirements." The concept of "continual improvement" explicit in this statement is reflective of kaizen, an integral part of Japanese management systems. The policy further sets out how these goals are to be met: (1) through regular meetings in which environmental aspects of production processes are examined, and environmental objectives and targets are set and reviewed; (2) through communication of environmental policy to all company personnel, and made available to suppliers, patrons, authorities and the general public; (3) through examination of future business decisions with regard to environmental considerations. The company's

[7] "Environmental Policy. Calsonic Yorozu Corporation." Company brochure.

commitment to an integration of environmental concerns throughout the production system is demonstrated by having sought and achieved ISO 14001 certification in September 2001.

Prior to implementation of ISO 14001, the environmental management system at the Morrison plant was not well defined, consisting of a set of generic procedures that dealt primarily with emergency response. Waste minimization was sought as a corollary to the efficiencies inherent through the just-in-time production process, but was not a specific target beyond what was necessary for environmental compliance. In February 2000, a directive was received from corporate headquarters to research and put together an environmental management system that could be certified under ISO 14001. At that time there was only one person at the facility – Keith Rogers – whose responsibilities were entirely allocated to the environmental aspects of production. The task of planning Calsonic Yorozu's environmental management system was assigned to Rogers.

Nearly a year was required to develop an EMS that would fulfill the requirements of ISO 14001. Rogers attended courses on the subject offered by the University of Tennessee Center for Industrial Services and went to various related conferences and workshops. Every aspect of the operations at the CYC facility was analyzed in depth for its environmental impact. Objectives and targets for pollution prevention were identified based on this analysis, and the means and time frame for accomplishing these objectives and targets determined. The result was a detailed environmental policy and procedures manual that served as the basis for achieving and maintaining ISO 14001 certification. Documentation is central to the company's EMS, as spelled out in the policy manual:

> CYC establishes and maintains a documented procedure to identify the environmental aspects of its activities, products, and services and

> determines which of those have or can have significant impacts on the environment. CYC ensures that the aspects related to these significant aspects are considered in setting its environmental targets and objectives and that the information regarding these aspects is kept up-to-date.[8]

The policy manual also sets out the considerations involved in setting realistic goals:

> When establishing and reviewing its objectives, CYC considers its legal and other requirements, significant environmental aspects, technological options, financial, operational, and business requirements, and the views of interested parties. CYC establishes environmental objectives and targets consistent with the environmental policy, including the commitment to prevention of pollution.

Figure 12.1 is an extract from the Procedures section of the CYC environmental manual that shows an example of the step-by-step procedural detail for all of the involved parties.

Once the EMS had been devised, only a few months were required for its implementation. Most of the plant's employees have been trained in the ISO 14001 procedures, training priorities assigned according to job function. One outcome of the EMS implementation has been an expansion of personnel whose responsibilities are dedicated full-time to environmental aspects of production. Rogers is the environmental manager whose responsibility covers the full range of the EMS and is responsible for reporting to management. Assisting him are two environmental technicians, one who collects data for internal audits of the EMS and another technician who monitors waste handling in the plant. The environmental section is contained within the facility's Engineering department.

[8] Calsonic Yorozu Corporation Environmental Policy/Procedures Manual. 2001. By permission.

Calsonic Yorozu Corporation
Morrison, Tennessee

Disposal of Empty
Chemical Containers

I Purpose: To ensure that empty chemical containers are disposed of in a manner consistent with government regulations.

II Application: This procedure applies to personnel at Calsonic Yorozu Corporation.

III Associated Documents:
- ISO 14001 : 1996
- CYC, Environmental Policy Manual (Level 1)
- CYC, Procedures Manual (Level 2)

IV Responsibility: CYC Environmental Engineer

V Work Instructions:

Definition:
Tote – Any chemical container of greater than 55-gallon capacity.
Drum – Any chemical container of between 20 and 55 gallon capacity.
Pail – Any chemical container of less than 20-gallon capacity.
Empty Container – One in which there are less than 1" of residue and no free flowing liquid inside.
Returnable – A container that can be sent back with a vendor for re-use.
Disposable – A container that is not returnable.

Title or Function Responsible	Action to be Taken
Env. Tech Paint Shop Tech	1 Drains liquid and/or removes solid residue from container
	2 Rinses containers all containers containing water-soluble materials (three times) and drains all free liquids. (Does not rinse oil or grease drums.)
	3 Uses drained liquid in process whenever possible. If not possible, places the liquid and/or solid into the proper waste container.
	4 Wipes down outside of container to remove any residue.
	5 Replaces bungs and/or lids on drums and totes to seal containers. Leaves tops off pails.
	6 Disposes or transports as follows: (a) Disposes of pails in regular trash (b) Transports drum to the empty drum storage area behind paint shop #2 and places it into the appropriate rack. (c) Transports tote to a waste accumulation area.
Paint Shop Supervisor	7 Inspects empty drum storage area once per week.
	8 Notifies Environmental Engineer of any of the following: (a) Any drums not properly prepared for shipment (not empty, sealed and wiped down). (b) Leaks or spills.
	9 Arranges for & supervises shipment of drums. Signs paperwork as needed.
	10 Delivers paperwork to Environmental Engineer.
Env. Tech.	11 Ensures that totes are returned to original vendors.
	12 Inspects empty drum storage area, scrap sheds and waste handling facility as part of the RPCC plan.
Env. Eng.	13 Notifies manufacturing manager of violations of this procedure and issues correction action.

Figure 12.1. Extract from CYC environmental manual concerning empty chemical container handling. *Courtesy Yorozu Automotive.*

12.2.5. Environmental impact

Because the production operations within the plant are divided into two distinctively different segments of metal parts production and parts assembly, the types of waste generated and environmental issues involved also differ. Wastes produced as part of the metal stamping and forming operations consist primarily of steel and aluminum scrap and oil. A system of floor drains collects oil from the production machinery, which is sent to a wastewater pretreatment area. Metal scrap is loaded by conveyor systems from the plant floor into trailers which are parked under cover in drainage bays where oil drippings from the scrap are collected in wastewater pits. These measures are taken to prevent mingling and contamination of storm runoff waters with the process water. As required by law, the oily water collected from within the plant and from the drainage from the trailer bay receive pretreatment processing in which suspended metals are flocculated and, with other solids in the wastewater, are filtered and pressed into a solid mass. The "filter cake" is classified as "special waste" and is sent to special waste landfills. The remaining water, containing oil but classified as non-hazardous by the US Environmental Protection Agency, is then sent to a public wastewater treatment plant. The metal scrap loaded into the trailers is considered a valuable commodity and is entirely recycled back to the source foundries.

Paints and solvents are the primary wastes resulting from assembly operations. Parts once assembled move automatically by conveyor through a multi-step painting system. typically, the process consists of the following steps: (1) degrease and rinse (2) application of sealant coat (3) rinse (4) additional application of sealant (5) rinse (6) immersion in paint bath (7) heat curing. The painting process results in wastes consisting of exhaust vent filters, waste paint (some containing lead), and solvents, all of which are classed as hazardous wastes.

Other wastes and scrap of various kinds is brought to waste collection areas location strategically through the plant. As Rogers notes, providing such waste collection areas gives workers a place to discard things, and allows the discards to be disposed of in a proper, environmentally sound manner.

Generated wastes at the Yorozu plant regulated under the TRI program have, since 1992, included certain glycol ethers, phosphoric acid, polychlorinated alkanes, sulfuric acid and zinc compounds. Waste generation for the two acids, sulfuric and phosphoric, dropped beneath the reporting threshold in 1994 so that only the glycol ethers, polychlorinated alkanes and zinc have since been included. The glycol ethers, used in painting operations at Yorozu, constitute the most significant component of the facility's total production waste and releases to the environment. Ethylene glycol ethers are a very large family of industrial cleaners and formulation solvents in paints used for parts coating. A number of the glycol ethers, formerly used in the semiconductor industry and since phased out, have been associated with adverse developmental and reproductive effects in humans. According to the American Chemistry Council, an industry association, "Those particular ethylene glycol ethers have not been used in consumer products in the United States for the past 20 years. Other glycol ethers have been tested similarly, have been found not to cause such effects, and are used in a wide variety of products."[9]

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[9] Ethylene Glycol Ethers Panel of the American Chemistry Council, http://www.egep.org/index.shtml.

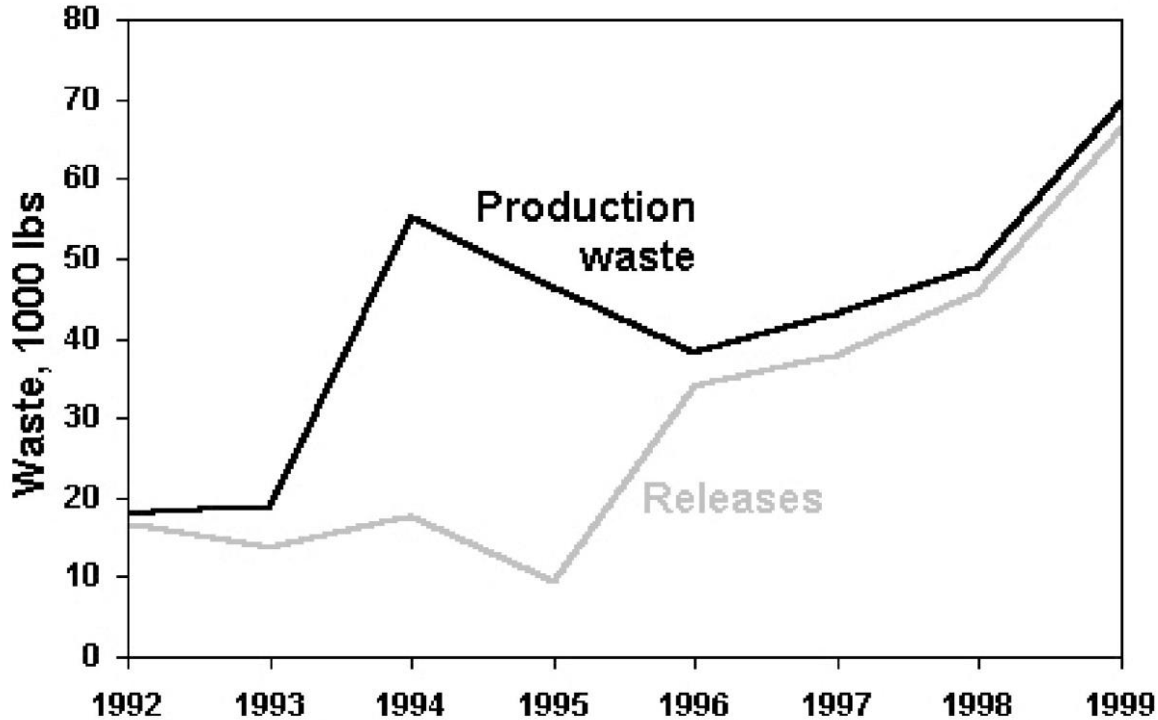

Figure 12.2. Waste generation and emissions for glycol ethers at Yorozu Automotive
Source: RTK NET

Figure 12.2 depicts the total production waste and releases to the environment, as reported under the TRI program, of "certain glycol ethers" for the Morrison plant for the years 1992-1999. As production at Yorozu Automotive increased, so did waste generation and associated emissions for the glycol ethers. Recognizing that this constituted a serious environmental problem, Yorozu switched in 2002 to a paint formulation that produced no hazardous air pollutants, thus reducing its TRI emissions nearly to zero.

According to Rogers, "The process of implementing ISO 14001 caused all of us take a closer look at what we were doing about energy consumption, solid waste disposal, used oil, airborne emissions, and waste water. Great improvements have been made in the last two years and more improvements are planned."[10]

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[10] Written response to mail survey.

12.3. Link-Belt Construction Equipment Company Lexington, Kentucky[11]

12.3.1. Industrial context

The Link-Belt facility is located in a heavily developed commercial and light industrial district in the eastern part of Lexington, Kentucky. Lexington and Fayette County, merged in 1974, is the state's second-largest metropolitan area with a 2000 population of more than 260,000. Rather than high-speed output of small parts typical of many manufacturers, the more than 600 workers in Link-Belt's 500,000 square-foot plant assemble huge telescopic and lattice-boom cranes at a rate of about 30 to 40 units per month. The Lexington facility, originally a 1986 joint venture between FMC Corporation (Philadelphia, USA) and Sumitomo Heavy Industries (Tokyo, Japan), became a wholly-owned subsidiary of Sumitomo in 1989.

"Link-Belt" is a brand name that is today applied to several types of heavy equipment built by different manufacturers. The original Link-Belt Machinery Company was founded in Belle Plaine, Iowa, in 1880 based upon a patent obtained by William Dana Ewart for a chain belt with detachable links for use in farm implements. Relocated to Chicago in 1906 and renamed the Link-Belt Company, the firm soon became well-known for its line of crane-shovels, locomotive cranes, and material-handling equipment. Link-Belt was purchased by FMC Corporation in 1967 and Link-Belt construction equipment products were marketed worldwide as part of FMC's Construction Equipment Group.

The Lexington facility retained the brand name "Link-Belt" subsequent to its acquisition by Sumitomo, and manufactured both excavators and cranes until 1998. In

[11] Plant visit and interviews conducted 1 February 2002. The primary informant was Ken Johnson. Additional information obtained through phone interviews with Ken Johnson, 4 April 2002, and Jim Forshee (Vice-President of Manufacturing), 9 January 2003.

that year the LBX Company, a stand-alone, joint-venture company, was formed between Sumitomo Construction Machinery Company and JI Case Corporation[12] to market and sell Link-Belt Excavators, and afterward the Lexington plant engaged solely in the manufacture of cranes.[13] FMC continues to use the Link-Belt name as well, applied to materials handling equipment including conveyors and mining machinery. In 2000 FMC Corporation was restructured into two companies, FMC Corporation, specializing in industrial, agricultural, and specialty chemicals, and FMC Technologies, which comprises the machinery and equipment businesses retaining the "Link-Belt" brand.[14]

Sumitomo Heavy Industries Ltd., headquartered in Tokyo and part of the Sumitomo Group, manufactures steel, heavy industrial machinery, ships, bridges and many other products through more than thirty subsidiaries in Japan, other Asian countries, the U.S. and Europe.[15] Restructuring in April 2001 led to the creation of a new business unit, Sumitomo Heavy Industries Construction Crane Co., Ltd., which now serves as the parent company for the Link-Belt facility in Lexington.[16] In May 2001 Sumitomo entered into an agreement with Hitachi Construction Machinery Co., Ltd. and Tadano Ltd., forming a strategic alliance in the production and distribution of mobile and cable cranes. Among the terms of this agreement was an arrangement to promote the "mutual supply of components, saving production and purchasing costs and strengthening their competitive position in the market." Under this parts-sharing agreement, Hitachi is to

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[12] Today Case-New Holland (CNH), headquartered in Lake Forest, Illinois.

[13] "The Link-Belt Story," http://www.linkbelt.com.

[14] "FMC Corporation, Company Capsule." Hoover's Online, http://www.hoovers.com.
"History." FMC Technologies website, " http://www.fmctechnologies.com.

[15] "Profile," Sumitomo Heavy Industries website, http://www.shi.co.jp/english.
"Sumitomo Heavy Industries, Company Capsule." Hoover's Online, http://www.hoovers.com.

[16] "Company Profile," Sumitomo Heavy Industries Construction Crane Company website, http://www.sumitomocrane.com/english/10kaisha_f_e.htm.

supply cable-crane parts to Sumitomo, Sumitomo's Link-Belt supplies mobile-crane components to Tadano, and Tadano's wholly-owned German subsidiary, Faun GmbH, supplies mobile-crane components to Link-Belt.[17]

In the broadest sense, like TMMK and Honda, Link-Belt is an assembly plant, producing a large complex product using parts obtained from a great many supplier firms. The resemblance is, however, only superficial since there are more differences than similarities. Whereas a firm such as Toyota in Kentucky produces nearly a half-million vehicles annually, Link-Belt assembles only a few hundred mobile cranes. Many of Toyota's suppliers are dependent upon the automaker for a large proportion of their business; Link-Belt's suppliers provide parts to many different firms. Because of the low number of individual units produced each year, Link-Belt's purchases represent a relatively small percentage of any given supplier's sales and so the firm does not possess the economic leverage of the automakers.

During the last decade, the number of suppliers used by the company has greatly increased. Formerly, most of the components used by Link-Belt were manufactured in-house; as Jim Forshee (Vice-President of Manufacturing) noted: "We used to make everything." Today, however, most components are obtained from outside firms. Most of the company's suppliers are U.S.-based firms rather than Japanese transplants. For its own production needs, Link-Belt currently purchases from about 200 parts suppliers; about 80 percent of its materials and components are provided by only about 50 firms. The Link-Belt facility in Lexington, however, has responsibility for parts purchases for all Link-Belt operations worldwide even though it is now independent from such other

[17] "Strategic Alliance relating to Crane Business," Sumitomo Heavy Industries Construction Crane Company website, news release May 23, 2001, http://www.sumitomocrane.com/english/02teikei_e.htm.

operations. In addition, company policy is to be able to provide customers with parts for any Link-Belt product ever manufactured, even those now considered antiques; in consequence the Lexington firm maintains nearly 700 firms on its vendor list.

Link-Belt does not maintain a specific supplier development program, mainly because so many of its suppliers obtain a greater sales volume elsewhere. The company does work closely with some of the smaller suppliers, sharing what it has learned about lean production and splitting product development costs on a 50-50 basis. Lacking the leverage to do so, Link-Belt has not attempted to impose requirements such as ISO-9000 or ISO-14001 certification upon its component suppliers.

Figure 12.3. 200-ton capacity lattice-boom crane manufactured at the Link-Belt facility in Lexington, one of many crane models produced.
Courtesy Link-Belt Construction Equipment Company.

12.3.2. Organization of production

Production at Link-Belt differs from that of many other machinery assemblers in that the items produced – wheeled and tracked cranes – are truly massive, multi-ton pieces of equipment (Figure 12.3). Cranes at the Lexington facility are assembled from a combination of parts fabricated within the plant and those obtained from outside suppliers. In terms of actual numbers of parts, most are purchased, but by weight the greatest bulk of any crane assembled consists of parts cut from steel plate, machined and welded at Link-Belt. Large sub-assemblies produced in-house include vehicle frames, booms, and outriggers used to support the crane in operation. Operator cab shells are purchased from an outside supplier and outfitted at the plant.

The Link-Belt operation consists of administrative offices, a main manufacturing facility, a parts distribution center, and two additional large but separate production buildings. The main building houses the manufacture of booms and frames, where much of the production operation involves welding. Numerous machining centers are located throughout the welding area of the plant, applied to various aspects of frame manufacture. A limited number of robots are used in production, most involved in the welding operations. Final assembly of cranes from outsourced and Link-Belt produced parts is performed in the main building. Lattice booms are manufactured in one of the two separate buildings, and one of three painting operations is housed in the other. The other two painting centers are attached to the main building, as is a structure used to produce low-volume parts and aftermarket and repair parts.

12.3.3. Production management system

The process of radically transforming an historically embedded pre-existing corporate culture presents a different set of management challenges than are faced in implementing a new manufacturing paradigm in a greenfield facility. The corporate culture of long-established companies such as Link-Belt and FMC developed over a period of, literally, generations, both firmly entrenched within the Fordist manufacturing philosophy of western capitalism. Consequently, the acquisition of Link-Belt in 1967 by FMC involved no radical alteration of the corporate culture. The momentum of cultural tradition is far less influential for a greenfield facility where the majority of employees are newly hired and do not possess a shared corporate heritage, although the existence of trade unions may substitute for corporate tradition in resisting significant change. The general practice by Japanese corporations of establishing greenfield facilities in largely rural areas, distant from traditionally urban, union-dominated manufacturing centers in the United States, has been conducive to minimizing resistance to the implementation of Japanese management practices and corporate culture. The Link-Belt facility in Lexington, being both a greenfield operation and a joint venture between a decidedly Fordist American corporation and a Japanese company, comprised a stage where multiple aspects of the interplay between Fordist tradition and Japanese innovation were successfully resolved. Today Link-Belt, like so many of the transplant facilities, is neither wholly Japanese nor Fordist in its operations, but represents an American hybrid where the most advantageous aspects of both systems have been blended.

The introduction of Japanese management and production systems at Link-Belt was a process of gradual steps over a period of several years. The first significant move toward lean production was the implementation of TQM and quality improvement teams in 1990, following Sumitomo's 1989 assumption of complete control of the facility. Chuck Martz, then Link-Belt's vice-president of manufacturing,[18] led the drive to transform the operation with the guidance and counsel of the Japanese company president and the assistance of the University of Kentucky's Center for Robotics and Manufacturing Systems. The Center, established in Lexington coincident with Toyota's construction of its Georgetown assembly plant, offers a university-level advanced curriculum on lean manufacturing based upon the Toyota Production System. Not surprisingly, Link-Belt chose to adopt the main principles of the Toyota system in its own facility. Nearly every manufacturing supervisor and manager attended courses on lean manufacturing at the Center, and several of the managers were sent to observe production practices at Sumitomo crane plants in Japan. The transformation of manufacturing at Link-Belt to lean production was nearly complete by the late 1990s, following the introduction of just-in-time, kaizen, pokayoke, robotics, and flexible and computer-integrated manufacturing. One of the most significant changes was the separation of low-volume and service parts machining from high-volume machining and assembly operations; most of the machining centers in the main building are high-volume.

12.3.4. Environmental management

The Link-Belt facility does not have either an official environmental policy statement nor a distinct environmental management system in place. The environmental policy of Sumitomo Corporation Group, however, parent of Sumitomo Heavy Industries and therefore of Link-Belt, states that Sumitomo, "as a global organization…through sound

[18] Martz is today president of the American facility.

business activities, will strive to achieve sustainable development aimed at symbiosis between social and economic progress, and environmental preservation." Guidelines associated with this policy include attaching "great importance to protecting the global environment as a good corporate citizen" and "to strictly observe environmental legislation" and to strive "to prevent environmental pollution while conducting the Corporation's business activities." The Guidelines also emphasize the importance of establishing an environmental management system to set "objectives and targets."[19]

Up to the present time Link-Belt has continued to use the policies and procedures of FMC Corporation as environmental guidelines, but is in the process of developing an environmental policy statement specific to the company. Several of the plants in the Sumitomo Group, particularly those located within Japan, have achieved ISO 14001 registration and more certifications are expected over the next few years. Lexington's Link-Belt is not presently seeking such certification but is evaluating the costs and benefits that might accrue from ISO 14001 registration.

12.3.5. Environmental impact

Despite the lack of an official EMS, Link-Belt has continually sought to minimize its environmental footprint. Ken Johnson, whose position is organizationally located within the plant's office for health and safety issues, is responsible for environmental issues at Link-Belt. Johnson is well-qualified for this position, first as hazardous materials coordinator for Lexington and Fayette County and rising to the position of Director of the city's Division of Environment and Energy Management prior to accepting employment

[19] "Sumitomo Corporation Environmental Report 2001," http://www.sumitomocorp.co.jp/english/environmental_e/img/env2001e.pdf.

with FMC Link-Belt in 1988. Initially, the plant had separate coordinators for environmental and safety issues but these two positions were combined in December 2000 and the additional responsibilities fell to Johnson. Significant progress has been made during the last decade to improve the environmental performance of the facility. Particular improvements have been made concerning solid waste, ambient fumes from welding operations, energy consumption, coolant recovery, paint solvents, and parts cleaning solvents.

A decade ago, it was common for three or more 40-cubic-yard waste containers to be picked up each day at Link-Belt. Today the company recycles many materials, including cardboard, wood, plastic sheeting, and white paper in addition to metals such as aluminum and steel that have always been recycled. Non-hazardous solid waste production has been reduced to a single 40 cubic yard container that is emptied once each week.

At Link-Belt in the early 1990s, fumes of vaporized metals produced during the welding together of structural parts were so thick that “you could not see from one end of the plant to the other.” This was an obvious health hazard, but the obvious solution – to vent the fumes outside the facility – not only contributed to air pollution but also wasted energy. It consumes a lot of energy to air condition a large plant in the summer months and heat it during the winter, energy that would be discarded to the external environment with vented fumes. During the early 1990s a system was installed to capture ambient welding fumes at the ceiling of the plant, clean it of pollutants, and return the air to the plant. Not only did this eliminate emissions releases from this source, but also resulted in a significant energy savings. Workers received a healthier environment, and also one that was much cleaner without the accumulation of grime from welding fumes. Good housekeeping is an important part of Japanese management systems, recognizing that order and cleanliness are integral to efficiency. Another step taken to reduce fumes in the plant was to replace flux core welding processes with hard core MIG welding.

Throughout the Link-Belt facility are many work centers with machinery that requires the use of a coolant. Prior to 1996, the coolant was regarded as a consumable and little effort was made to recycle or otherwise manage this material in a manner that was both cost-effective and environmentally sound. As a result, large quantities of the coolant were sent off-site for proper disposal. Furthermore, a number of employees proved sensitive to the coolant used and periodic cases of dermatitis required medical treatment. In 1996 the company installed oil skimmers and particulate filters in the machine sumps in order to extend coolant life and reduce the amount of coolant waste. Although some improvement was achieved, replacement of older machines in 1999 with newer technology requiring larger coolant sumps led to the realization that individual oil skimmers and filters would no longer be sufficient. To address this situation, Link-Belt installed a centralized coolant recycling system that would treat the coolant from the individual sumps more effectively. A training program was initiated to resolve improper coolant management by individual machine operators; previously some had changed coolant too frequently and others allowed it to remain in place beyond its useful life. To eliminate the problem of contact dermatitis, a different coolant was substituted. As a result of these measures, coolant usage and disposal has been reduced by 90 to 95 percent.[20]

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[20] Written response to mail survey.

In order to reduce toxic emissions regulated by the TRI, Link-Belt has replaced the solvent-based paints and coatings formerly used with paints containing solvents that are not considered to be hazardous under TRI, or to those with a minimal content of such solvents. Link-Belt has also developed a two-stage paint-gun cleaning system that reduces the amount of solvent necessary to perform this task. This system comprises two barrels of solvent, one used as a pre-treatment and a separate container for final rinse. In the Link-Belt system, when the final-rinse container has become too degraded for this purpose, it is switched to pretreatment rather than being disposed of at this point. This reduces the total amount of solvent required for cleaning.

Solvents, mainly mineral spirits, are also used for parts cleaning and degreasing. Crystal Clean, a subsidiary of Heritage Environmental Services LLC, provides parts washers and solvent recovery services on contract to Link-Belt. Although this service was formerly provided by a competitor, Link-Belt switched to Heritage because the mineral spirits can be reused by Heritage in their own company operations without requiring treatment. Properly documented, this allows the mineral spirits to be classified by the EPA as a virgin material rather than a hazardous waste attributed to Link-Belt manufacturing operations. Such reuse is yet another example of the type of linkages possible in an industrial ecology.

One area that still presents an unresolved challenge to Link-Belt is the inability to distill and reclaim solvents from paint. Although they have switched to coatings with less hazardous solvent content, the painting operation requires a two-part catalytic paint that resembles epoxy in its action. Once the two parts are mixed, a chemical reaction occurs and the paint hardens; it has not been possible to recover solvents from hardened waste paint.

The Link-Belt operation is classified under RCRA as a Large-Quantity Generator (LQG), with 80.33 tons of "ignitable waste" indicated for 1999, the most recent BRS (Biennial Reporting System) data available. This material consisted of paint cleared out of the paint lines when these line were purged for routine cleaning or a color change, in addition to the solvent injected into the lines for cleaning. This "ignitable waste" was sent offsite to Heritage Environmental Services for treatment and reclamation of the solvent content.

Link-Belt's TRI report for 1999 indicates only three regulated substances were involved in production: chromium, manganese, and nickel. These waste metals were byproducts of welding operations and the majority was reclaimed by the system installed to capture ambient welding fumes. Of a total of 84,730 pounds production waste reported for 1999, only 32 pounds (all but two pounds of this was manganese) escaped to the atmosphere as air pollutants and 1,476 pounds (again mostly manganese) were sent to a hazardous waste landfill. The greater part, more than 83,000 pounds, was sent to off-site recycling where the metals were extracted. Examination of past TRI reports dating to 1987 indicates a continuous effort to meet and exceed federal environmental standards for toxic waste, by deliberate elimination or reduction of specific contaminants. Link-Belt's TRI reports for 1987 and 1988 show the use of toluene and xylene, solvents used in painting operations but highly toxic materials that later would be targeted as part of the EPA's 33/50 program.[21] These materials were eliminated during the following year as a

[21] See Appendix 2.

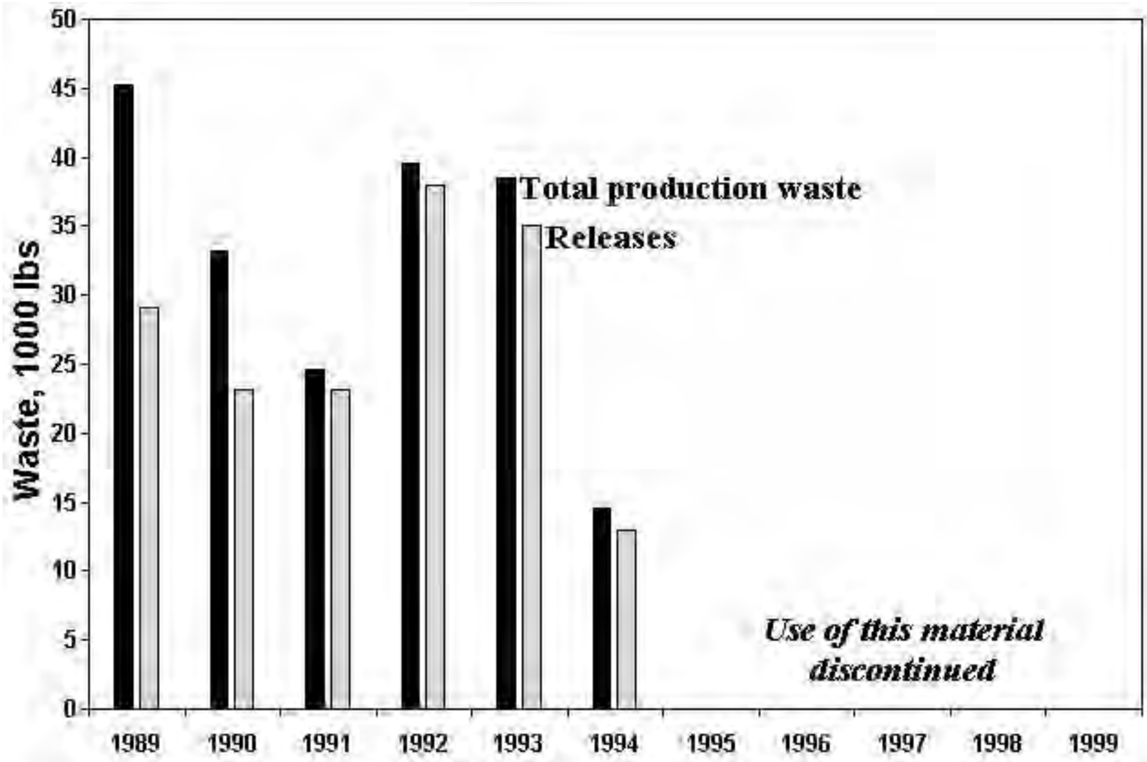

Figure 12.4. Waste generation and emissions for methyl isobutyl ketone at Link-Belt.
Source: RTK NET

result of a switch to a high-solids paint. The new paints contained methyl ethyl ketone and methyl isobutyl ketone, also highly toxic materials included in EPA's Priority Chemical list. Figure 12.4 shows a graph of total production waste and releases for methyl isobutyl ketone for 1989 through 1994. Beginning in 1994, the use of paints containing either methyl ethyl ketone or methyl isobutyl ketone was discontinued, replaced by paints containing solvents not regulated under TRI and therefore considered to be less hazardous. This was a direct response to the EPA's 33/50 program which called for voluntary reductions of the twenty substances considered to be of greatest threat to health and the environment.

Lean production at Link-Belt means both *lean* and *clean*. In the words of Ken Johnson, environmental manager, thinking lean "reaches into the guts of what you are doing, how you run materials through the plant." The effort placed into both implementing the Toyota Production System in this formerly Fordist operation and into reducing the plant's environmental "footprint" is indicative of the holistic approach to production that is often characteristic of Japanese management systems.

12.4. Case studies summary and conclusions

The five case study facilities are all engaged in production related to motorized vehicles, four of the five involving automobiles; the fifth, Link-Belt, produces heavy cranes of which some are capable of highway travel and others are intended strictly for off-road use. Toyota Motor Manufacturing Kentucky produces many automotive components and assembles three vehicle styles, two sedans and one minivan. Madison Precision Products is engaged in the molten-metal die casting of a wide variety of engine components. Mitsubishi Electric Automotive America is a first tier producer of electrical components, starters and alternators, for several vehicle assemblers, both Japanese and non-Japanese. The Yorozu Tennessee facility is involved in stamping and hydroforming of suspension parts for several assemblers. With the exception of Madison Precision, METT Corporation's sole North American facility, all facilities in the case studies represent multiple investments in North America by the parent corporations. With the exception of Link-Belt Construction Equipment, each was a newly constructed or "greenfield" facility.

Link-Belt, originally a joint venture between an American company and Sumitomo Heavy Industries, has gradually implemented lean production methods and today considers itself to be an operation with an eclectic mixture of both Japanese and fordist techniques. For each of the other case study facilities, built as greenfields, there was no pre-existing workforce possessing an institutional cultural tradition and so a newly recruited workforce could be trained in Japanese methods. The manufacturing systems and methods used at Toyota , Madison, Mitsubishi and Yorozu are firmly embedded in the lean production formula, derived originally from Toyota, that has served Japanese corporations so well in their efforts to increase efficiency and competitiveness. The core principles of kaizen and just-in-time are virtually intact in these U.S. transplants, with some evolutionary changes and some concessions to the differing nature of the American workforce, concessions that are primarily social in nature and unrelated to the actual production process.

The specific form of lean production practiced is, for supplier firms, driven by the major customer. In the cases of Madison Precision and Mitsubishi Electric Automotive, this is the Honda "BP" system, where Honda maintains a frequent consulting and advising presence within the plants and trains suppliers in its methods. Production management for Yorozu Automotive, who supplies nearly all major automakers, is not driven by a single dominant client but, as company representative Keith Rogers explained, "by all our customers." By this, he means that Yorozu's lean production system has competitively evolved to meet the product quality and just-in-time delivery expected by clients such as Honda and Nissan. In contrast, Toyota of Georgetown, as a major vehicle assembler served by a wide ranging network of firms located in many U.S.

states, implicitly and explicitly sets standards throughout a supply chain numbering hundreds of companies. Toyota actively promotes its own production system through consultation and educational services provided gratis to the business community at large, not limiting its aid solely to its own suppliers. The Link-Belt company, located in central Kentucky not far from TMMK, models its production system upon that of Toyota, "part of the advanced course curriculum at the University of Kentucky's Center for Robotics and Industry."[22]

Both Toyota and Mitsubishi, representing the purchasing power of two of the largest multinational corporations, are in a position to dictate, to a large extent, the environmental behavior of their suppliers. Thus we see Mitsubishi, a tier one company, imposing "green guidelines" upon its tier two suppliers, and Toyota requiring not only ISO-14001 certification from its dependent firms but also obliging them to eliminate a lengthy list of hazardous chemicals from parts and materials provided.

Although Mitsubishi Electric, in the case study, is a supplier to auto assemblers, its parent company is dependent in large part upon sales of consumer products and is thus very much in the public eye. Companies such as Mitsubishi and Toyota are, in consequence, very sensitive to public opinion and have carefully crafted and detailed environmental policies. Such companies devote ample space and multiple links on their corporate Internet websites to environmental issues, noting policies and practices and providing statistics and examples that illustrate progress toward improved environmental performance. In addition, companies such as Mitsubishi and Toyota have expended considerable effort and expense to produce colorful annual environmental reports at

[22] "About Link-Belt," http://www.linkbelt.com/linkbelt/about/frameabout.htm.

corporate, regional, and (in many cases) individual plant levels. These reports are also available for electronic download through company websites.

In contrast, firms such as Yorozu Automotive and Madison Precision, who supply only auto assemblers and whose names and products are unknown to the public, have little need to provide extensive information to the public. Madison Precision contents itself with a brief brochure and a single page on its website that states its environmental policy and a few related accomplishments, and the parent company MEPP does not have an English language version of its website. Likewise, Yorozu Corporation, parent to Yorozu Automotive Tennessee, also lacks an English version on its company website, and its U.S. subsidiary has no website at all. Link-Belt of Lexington sells its heavy equipment to private contractors and government agencies and so does not provide any environmental policy information on its website.

Link-Belt alone of the five case studies has not achieved ISO-14001 certification, nor does it seek to do so since it does not experience the same pressures for this accomplishment as do automobile manufacturers and their suppliers. Certification was first achieved by the two facilities whose parent companies had adopted a policy encouraging if not requiring this of their subsidiaries: Toyota in Kentucky received certification in late 1998 and Mitsubishi Electric Automotive in mid-1999. Supplier firms representing smaller corporations, who pushed certification for their overseas facilities later than the larger multinationals, followed, Madison Precision in 2000 and Yorozu of Tennessee in 2001.

Declining waste generation and releases, in proportion to the scale of production, was a clearly discerned trend present for all the facilities included in the case studies.

Expansions that doubled or tripled the size and capacity of facilities did not produce corresponding increases of waste. Most remarkably, in the case of Toyota when a major expansion doubled plant size in a single year, although total waste generation and emissions greatly increased following the addition, within a few years these wastes had been reduced to levels less than those prevailing prior to the expansion. Emissions of certain troubling toxic materials for Link-Belt (methyl isobutyl ketone) and Yorozu Automotive Tennessee (glycol ethers) were eliminated completely by substituting less hazardous materials. For Yorozu Automotive Tennessee, this represented a reduction of its total emissions by approximately 99.5 percent to a level very nearly zero. By installing a catalytic oxidizer in line with its exhaust filtration system, Mitsubishi Electric Automotive was able to reduce emissions of styrene by more than 75 percent. Madison Precision Products has, through a program of eliminating hazardous waste materials, changed its regulatory status from that of Large Quantity Generator to Conditionally Exempt (the lowest category), and has reduced its production of landfilled solid waste by more than fifty percent. In none of these cases were radical alterations of production methods nor installation of very expensive equipment required to achieve results. Instead, environmental performance was enhanced simply through the practice of kaizen, the seeking of continuous improvement through small steps.

Chapter Thirteen

Summary and Conclusions

13.1. Introduction

This study was intended to investigate the comparative environmental performance of Japanese transplant firms in the United States, focusing upon firms located within a four state area – Indiana, Ohio, Kentucky and Tennessee – that represents a dense concentration of Japanese capital investment primarily in the automotive industries. This task was to be accomplished using federal hazardous and toxic waste data in the public domain to construct a number of performance indicators, including an indicator based upon the concept of eco-efficiency. Aligned with this goal was a qualitative methodology consisting of a survey and case studies in order to better understand the actual environmental practices and policies of Japanese firms. A secondary objective was to investigate the extent and characteristics of regional Japanese manufacturing investment, through an extensive review of existing literature and also by analyzing available facility attribute and locational data. In so doing, the author intended to fill a gap in the literature for a comprehensive profile of the current state of these transplants. These tasks were perceived as having relevance not only to academic interest in the geography of foreign investment but, more particularly, to the contemporary restructuring of U.S. industry and environmental policy.

The first chapter offered a general overview of the issues and conditions which framed the research questions for this investigation. Chapter 2 discussed the concept of ecological modernization, the theoretical context within which this research is grounded, and provided a review of three key features associated with the ecological modernization movement: eco-efficiency, industrial ecology, and environmental management systems. Chapter 3 provided an overview of the Japanese production system, developed by Toyota Motor Corporation, as this system functions within the Japanese cultural and institutional context. Chapter 4 dealt with the transferal of the Japanese system to North America, where it has become popularly known as "lean production" and has been adapted and hybridized in the new environment. Chapter 5 described the methodology used in the investigation to create a database of firm characteristics and waste management data, and introduced the concept of toxicity-weighting.

Chapters 6 and 7 were concerned with assessing the characteristics of foreign investment in the study area. Chapter 6 was more concerned with placing this investment in the context of changes in the geography of U.S. production and the factors driving overseas manufacturing investment by Japan and influencing site choices in North America. Chapter 7 described the spatial pattern of Japanese investment in the study area, particularly in relation to automobile assembly transplants and their supplier networks, and profiled the general characteristics of Japanese facilities in terms of size and industrial sector distribution. Chapter 8 supplemented these descriptions of general characteristics by providing a discussion and analysis of the results of the mail survey, which focused primarily upon environmental policies and practices of transplant respondents. Chapter 9 comprised the analysis of federal RCRA and TRI program waste management data, making comparative assessments of Japanese and non-Japanese firms initially based upon simple magnitude and toxicity parameters for waste generated and released and graduating to constructed performance and eco-efficiency indicators.

Chapters 10, 11 and 12 focused upon the case studies for five Japanese transplant firms, which included an automobile assembly plant, three automotive component supplier firms, and one firm not involved in production for the automotive industry. These case studies were placed within a context of theoretical discussions of relations between an assembly plant and its network of supplier firms, taking note that the non-automotive facility was an assembly plant that maintained a different mode of supplier relations.

13.2. Contributions to the literature

The pilot study (O'Dell 2001) was the author's initial attempt to develop a means to assess comparative environmental performance for a large number of facilities, and, while less sophisticated than the present endeavor, introduced the idea of measuring performance as a ratio of a size factor (workers, facility square feet) to waste releases. The present investigation adopted this methodology and improved upon it by weighting released quantities according to their relative toxicity, borrowing the technique from King and Lenox (2000). This represents, to the best of the author's knowledge, a new approach. Support for this belief was received from an unanticipated quarter, when a copy of the Toyota case study (Chapter 10) sent to that firm for review and correction of errors in fact was returned after circulating among the plant's supervisory and executive hierarchy. Attached to the review copy, on the page where Table 10.3 appears in the present volume, was a handwritten note that exclaimed, "I've never seen this sort of comparison made before!" referring to the releases-per-worker ratio.

An innovative approach has little value unless it is also meaningful in the context in which it is used. A close examination and comparison of Table 9.13, "Characteristics of automobile assembly plants in study area," and Table 9.13, "Environmental indicators for automobile assembly plants in study area," suggests that the values derived using the release-toxicity/worker approach bears some correspondence to real performance. For example, compare the Honda East Liberty plant and the DaimlerChrysler Toledo plant; each has a very similar eco-efficiency value, 0.81 and 0.82 respectively. The Honda plant has about 2,400 workers and produced 1,960 pounds of toxicity-weighted releases; the Chrysler plant had about 5,600 workers and released 4,569 pounds. Both of these are relatively high values compared to other firms, and if the release toxicity ratios are also contrasted, they are also proportionately higher than other firms.

Eco-efficiency values and release rations are not, however, precisely comparable since they have different conceptual bases and measure different aspects. This is illustrated by comparing Honda of Marysville and the GM plant in Lordstown, Ohio. Both have similar release toxicity ratios, 45.7 percent retained toxicity for Honda versus 46.4 percent for GM. Yet the eco-efficiency values are very different. The Honda plant has an eco-efficiency value of only 0.02 compared to the significantly larger 0.60 for GM. The difference is a result of waste management efficiency; comparing Honda's unadjusted releases (970,265 pounds) to weighted releases (189 pounds), it is evident that Honda has done an astoundingly effective job of enduring that release toxicity is minimized. In contrast, GM's 1,560,806 pounds of unadjusted releases convert to 707,755 toxic-weighted pounds. From these examples it appears that an eco-efficiency value based upon toxic-weighted releases per worker is a reasonable representation of performance.

The results of the pilot study had suggested that Japanese firms would display a superior environmental performance, and it was in this expectation that the present investigation was undertaken and research questions framed. The results of the more detailed analysis conducted for the present study are not, however, so clearly indicative of Japanese performance superiority as the earlier research. Japanese firms, for the most part, did exhibit better environmental performance than non-Japanese firms, but not under all circumstances (size, sector) and the differences were modest and possibly, as suggested by the regression analysis at the beginning of Chapter 9, not statistically very significant.

It may well be that the failure to discover significant performance differences is a result of a flawed assumption that in turn influenced the methodology. The analysis was predicated upon the assumption that Japanese transplant firms would be more likely to possess more complete and fully integrated and therefore more effective versions of lean production systems. This may have been the case for the pilot study, which relied upon 1996 federal data. Japanese methods have been rapidly diffusing into the population of manufacturers in North America, and with additional innovations, transformations and hybridization, may well have largely closed the efficiency gap between domestic and Japanese firms. The present study employed 1999 federal data, and during the passage of three years differences may have been minimized. The concept of superior Japanese production management may be moot when the majority of firms employ advanced manufacturing systems.

The results of this research, in both its quantitative and qualitative aspects, lends support to claims that the concept of ecological modernization, along with those features such as eco-efficiency, industrial eco-systems, and environmental management systems, may be an appropriate model for short-term industrial sustainability. The responses from the mail survey, and particularly visits made in connection with the case studies, indicate that firms are increasingly assuming responsibility for the environmental consequences of their activities, and are proactively seeking solutions to reduce negative impacts. This is also borne out by available data. Admittedly, federal data concerning hazardous and toxic waste represents only a very small part of the entire scope of environmental influences resulting from human activity, but that data is encouraging. Toxic releases to the environment have declined substantially during the period of record, and continue to decline (Figure 13.1).

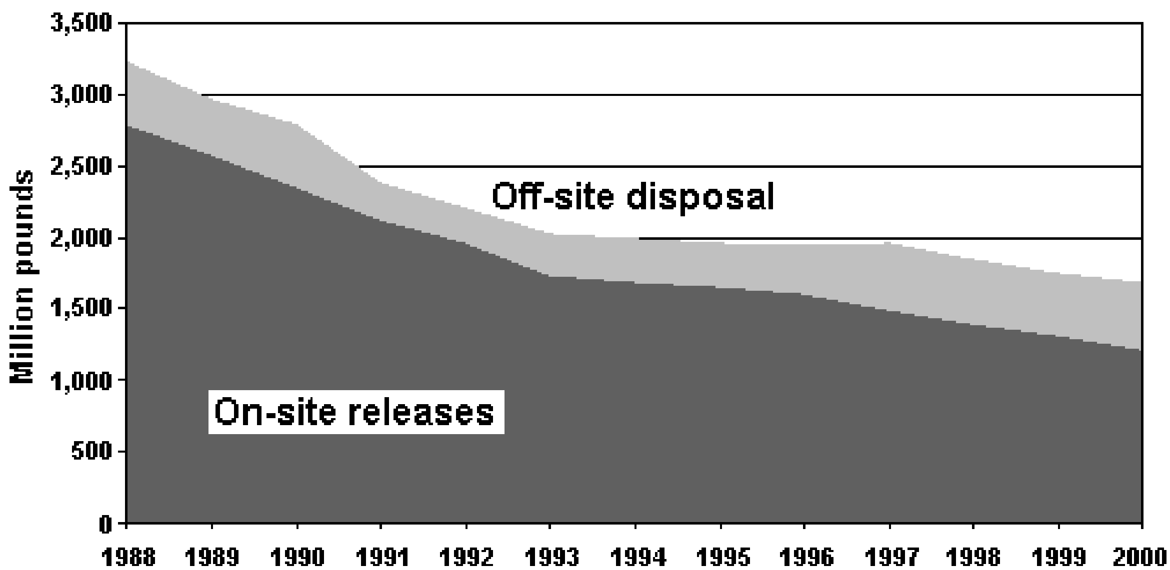

Figure 13.1. Distribution of TRI on-site and off-site releases, original manufacturing industries, 1988-2000 *Source: USEPA (2002)*

Does not include delisted chemicals, chemicals added in 1990, 1994 and 1995, aluminum oxide, hydrochloric acid, PBT chemicals, sulfuric acid, vanadium and vanadium compounds.

Resource productivity is of equal importance to pollution prevention, and the trend is less encouraging. For the period 1970 to 1995, while U.S. materials consumption rose from 2.0 billion to 2.8 billion tons, materials consumption in the rest of the world increased from 5.7 billion to 9.5 billion metric tons, a growth rate nearly double that of the U.S. (1.8 to 1) (Matos and Wagner 1998, 113). Ecological modernization is concerned not only with transformation of the mode of production to one that is sustainable, but recognizes the need to achieve a transformation in the patterns of consumption.

13.3. Conclusion: Implications for future research

The results of this investigation have suggested three areas in which future work may be both productive and useful to other investigators: (1) development of a method to effectively differentiate the degree of firm "leanness"; (2) development of a system to more accurately represent the ecological hazards posed by specific chemicals; and (3) development of more flexible and widely applicable eco-efficiency indicators.

The analysis conducted in this investigation may have been flawed by the assumption that "Japaneseness" was capable of serving as a proxy to indicate the most capable lean production systems. Due to the widespread diffusion of core features of the Japanese system into Western production practice, and adoption of many Fordist practices by certain Japanese transplants, this may not be sufficient to distinguish those firms in which lean systems are effectively integrated. Most other studies comparing environmental performance have not differentiated by nationality but have instead used a few specific firm characteristics, such as the presence of a just-in-time system, to indicate a lean production system. The use of one or two proxies is also flawed, in that the presence of a feature does not necessarily imply that it is well integrated into the production system or is used effectively. Continued research is needed to identify those firms in a population having the most advanced and efficient manufacturing systems, so that their potential for generating environmental benefits can be better evaluated.

Secondly, the toxicity-weighting method used in this investigation, based on King and Lenox (2000), is only able to address a very limited aspect of the total range of toxic effects. The values are based primarily on human acute toxicity and do not address chronic toxicity, carcinogenic, mutagenic, or teratogenic effects, nor impact upon ecosystems. The complexity and controversy involved in developing a rating system for toxicity was discussed in Chapter 5. Many researchers, in government and academic settings, are working to devise a system that would address the various issues, but an effective rating system that assigns a single toxicity value does not currently exist. This is something that is badly needed.

Finally, there is a pressing need to develop a standardized eco-efficiency indicator that can use readily available information and thus be widely applied across a broad spectrum of industries. The toxicity-weighted releases per worker indicator used in this study is one possible approach, but will require more testing to ascertain its validity and utility and, at best, can only be applied to the relatively small number of firms regulated under the TRI program that provide waste management information to the EPA.

Appendix 1: RQ factors for TRI chemicals relevant to the study area

1/RQ	Established by 302.4	MIT	Scorecard (EDF)
1	1,2-DIBROMOETHANE ACROLEIN ARSENIC ASBESTOS (FRIABLE) BENZIDINE CREOSOTE DIAZINON HYDRAZINE MERCURY PHOSPHORUS POLYBROMINATED BIPHENYLS VINYL CHLORIDE	POLYCHLORINATED BIPHENYLS	
0.1	1,3-BUTADIENE 2,4-DINITROTOLUENE 4,4'-METHYLENEBIS (2-CHLOROANILINE) 4,4'-METHYLENEDIANILINE 2-METHYLLACTONITRILE 2-NITROPROPANE BENZENE BERYLLIUM BIS(2-CHLOROETHYL) ETHER CADMIUM CAPTAN CARBON TETRACHLORIDE CHLORINE CHLOROFORM DIBUTYL PHTHALATE DIETHYL SULFATE ETHYLENE OXIDE ETHYLENE THIOUREA HEXACHLOROBENZENE HEXACHLOROCYCLOPENTADIENE HYDROGEN CYANIDE LEAD PHOSGENE QUINONE THIOUREA THIRAM TRIFLURALIN	4,4'-DIAMINODIPHENYL ETHER 4,4'-ISOPROPYLIDENEDIPHENOL BENZOIC TRICHLORIDE CHLOROTHALONIL P-CRESIDINE CUMENE HYDROPEROXIDE CYANIDE COMPOUNDS DECABROMODIPHENYL OXIDE DIAMINOTOLUENE (MIXED ISOMERS) TETRACHLORVINPHOS	BORON TRIFLUORIDE ETHOPROP TRIPHENYLTIN HYDROXIDE
0.01	1,1,1,2-TETRACHLOROETHANE 1,1,2-TRICHLOROETHANE 1,2,4-TRICHLOROBENZENE 1,2-DICHLOROBENZENE 1,2-DICHLOROETHANE 1,3-DICHLOROBENZENE 1,3-DICHLOROPROPYLENE 1,4-DICHLOROBENZENE 1,4-DIOXANE 2,4-D 2,4-DIMETHYLPHENOL 2,6-DINITROTOLUENE 4-NITROPHENOL ACRYLONITRILE ALLYL ALCOHOL AMMONIA O-ANISIDINE BENZYL CHLORIDE BIPHENYL CARBARYL CARBON DISULFIDE CARBONYL SULFIDE CATECHOL CHLOROBENZENE CHLOROETHANE CHLOROMETHANE *Continued*	1,2,4-TRIMETHYLBENZENE 1,2-BUTYLENE OXIDE 2-PHENYLPHENOL ACETAMIDE ALUMINUM (FUME OR DUST) BENZOYL PEROXIDE ETHYL CHLOROFORMATE NITRILOTRIACETIC ACID PERCHLOROMETHYL MERCAPTAN VANADIUM (FUME OR DUST)	2,4-DP ACEPHATE BIS(TRIBUTYLTIN) OXIDE BROMINE CHLOROPICRIN DICYCLOPENTADIENE ISOFENPHOS MECOPROP METHAM SODIUM POLYCYCLIC AROMATIC COMPOUNDS TRIPHENYLTIN CHLORIDE

1/RQ	Established by 302.4	MIT	Scorecard (EDF)
0.01	*Continued* CHLOROPHENOLS CHLOROPRENE CRESOL (MIXED ISOMERS) M-CRESOL O-CRESOL P-CRESOL CROTONALDEHYDE DI(2-ETHYLHEXYL) PHTHALATE DIBENZOFURAN DICHLOROBENZENE (MIXED ISOMERS) DIETHANOLAMINE N,N-DIMETHYLANILINE N,N-DIMETHYLFORMAMIDE DIMETHYL SULFATE DIURON EPICHLOROHYDRIN FORMALDEHYDE HEXACHLOROETHANE HYDROGEN FLUORIDE HYDROQUINONE MALATHION METHYL IODIDE NAPHTHALENE NICKEL NICOTINE AND SALTS PHOSPHINE PROPYLENE OXIDE QUINTOZENE SACCHARIN SELENIUM SODIUM NITRITE TETRACHLOROETHYLENE THALLIUM COMPOUNDS TOLUENE DIISOCYANATE (MIXED ISOMERS) TOLUENE-2,4-DIISOCYANATE O-TOLUIDINE TRICHLOROETHYLENE VINYLIDENE CHLORIDE XYLENE (MIXED ISOMERS) P-XYLENE		
0.001	1,1,1-TRICHLOROETHANE 1,2-DICHLOROETHYLENE 2-ETHOXYETHANOL ACETALDEHYDE ALLYL CHLORIDE BENZOYL CHLORIDE P-CHLOROANILINE CYCLOHEXANE DICAMBA DICHLOROMETHANE DIMETHYLAMINE ETHYL ACRYLATE ETHYLBENZENE MALONONITRILE METHACRYLONITRILE METHYL CHLOROCARBONATE METHYL METHACRYLATE METHYL TERT-BUTYL ETHER NITRIC ACID NITROBENZENE PHENOL PROPARGYL ALCOHOL PROPIONALDEHYDE PYRIDINE SILVER STYRENE SULFURIC ACID AEROSOLS THALLIUM TITANIUM TETRACHLORIDE TOLUENE M-XYLENE O-XYLENE ZINC (FUME OR DUST)	BROMOMETHANE BUTYRALDEHYDE CERTAIN GLYCOL ETHERS CHLORINE DIOXIDE ISOBUTYRALDEHYDE MOLYBDENUM TRIOXIDE PERACETIC ACID	1,2-PHENYLENEDIAMINE 1,3-PHENYLENEDIAMINE 2,4-D 2-ETHYLHEXYL ESTER 2-MERCAPTOBENZOTHIAZOLE 3,3'-DICHLOROBENZIDINE DIHYDROCHLORIDE ALUMINUM OXIDE ATRAZINE BENFLURALIN BROMOCHLORODIFLUOROMETHANE BROMOXYNIL BROMOXYNIL OCTANOATE CHLOROTRIFLUOROMETHANE CHLORPYRIFOS METHYL DAZOMET DIPHENYLAMINE LITHIUM CARBONATE OXYDIAZON OZONE PENDIMETHALIN PERMETHRIN POTASSIUM DIMETHYLDITHIOCARBAMATE SODIUM DIMETHYLDITHIOCARBAMATE THIOPHANATE-METHYL TRANS-1,3-DICHLOROPROPENE

1/RQ	Established by 302.4	MIT	Scorecard (EDF)
0.0002	ACETONITRILE ACETOPHENONE ACRYLAMIDE ACRYLIC ACID ANILINE ANTHRACENE ANTIMONY BENZAL CHLORIDE N-BUTYL ALCOHOL CHROMIUM COPPER CUMENE DICHLORODIFLUOROMETHANE DICHLOROFLUOROMETHANE DIMETHYL PHTHALATE ETHYLENE GLYCOL ETHYLENEBISDITHIOCARBAMIC ACID, SALTS AND ESTERS FORMIC ACID N-HEXANE HYDROCHLORIC ACID AEROSOLS MALEIC ANHYDRIDE METHANOL METHYL ETHYL KETONE METHYL ISOBUTYL KETONE PHENANTHRENE PHTHALIC ANHYDRIDE P-PHENYLENEDIAMINE QUINOLINE TRICHLOROFLUOROMETHANE TRIETHYLAMINE VINYL ACETATE	2-METHOXYETHANOL 2-METHYLPYRIDINE ANTIMONY COMPOUNDS ARSENIC COMPOUNDS BARIUM BARIUM COMPOUNDS BERYLLIUM COMPOUNDS BUTYL ACRYLATE CADMIUM COMPOUNDS CHROMIUM COMPOUNDS COBALT COBALT COMPOUNDS COPPER COMPOUNDS ETHYLENE ISOPROPYL ALCOHOL LEAD COMPOUNDS MANGANESE MANGANESE COMPOUNDS MERCURY COMPOUNDS METHYL ACRYLATE NICKEL COMPOUNDS PROPYLENE SEC-BUTYL ALCOHOL SELENIUM COMPOUNDS SILVER COMPOUNDS TERT-BUTYL ALCOHOL ZINC COMPOUNDS	1-(3-CHLOROALLYL)-3,5,7-TRIAZA-1-AZONIAADAMANTANE CHLORIDE 1,1-DICHLORO-1-FLUOROETHANE 1,2-DICHLORO-1,1-DIFLUOROETHANE 1-BROMO-1-(BROMOMETHYL)-1,3-PROPANEDICARBONITRILE 1-CHLORO-1,1-DIFLUOROETHANE 2-CHLORO-1,1,1,2-TETRAFLUOROETHANE 2-CHLORO-1,1,1-TRIFLUOROETHANE 3-IODO-2-PROPYNYL BUTYLCARBAMATE BROMOTRIFLUOROMETHANE C.I. DIRECT BLUE 218 C.I. SOLVENT YELLOW 34 CHLORODIFLUOROMETHANE DICHLOROTETRAFLUOROETHANE FOLPET HEXAZINONE NITRATE COMPOUNDS N-METHYL-2-PYRROLIDONE N-METHYLOLACRYLAMIDE PIPERONYL BUTOXIDE

For the following chemicals, no toxicity ranking is available, although most are suspected carcinogens:

DIISOCYANATES
DIOXIN AND DIOXIN-LIKE COMPOUNDS
DISODIUM CYANODITHIOIMIDOCARBONATE
POLYCHLORINATED ALKANES
TETRAMETHRIN
TRIBUTYLTIN METHACRYLATE

Appendix 2. Characteristics of the 33/50 Program chemicals

Source: "ToxFAQs" database http://www.atsdr.cdc.gov/toxfaq.html

Substance	Usage	Health Effects
1,1,1-trichloroethane	Many uses as solvent and cleaner.	Exposure to high levels may cause death from depression of central nervous system. Dermal and mucosal irritant at lower exposures.
benzene	Used in the manufacture of many products and to make intermediate chemicals. A component of gasoline.	Known carcinogen. Chronic low level exposure may result in damage to internal organs; exposure to high concentrations may cause death in minutes.
cadmium & compounds	Used for metal plating, in the manufacture of nickel-cadmium batteries, in pigments and plastic stabilizers, numerous other applications.	Probable carcinogen. Chronic low level exposure may cause lung or kidney damage.
carbon tetrachloride	Formerly widely used as cleaner in home an industry, now only a few industrial applications in chemical synthesis, petroleum refining, pharmaceutical manufacturing and as solvent.	Suspected carcinogen. Exposure to high levels can cause damage to liver, kidneys, and nervous system; in severe cases can result in coma or death.
chloroform	Formerly many commercial and industrial applications as a solvent but now mainly used in the synthesis of other chemicals.	Suspected carcinogen. Exposure can cause dizziness, fatigue and headaches. Long term exposure may damage liver and kidneys.
chromium & chromium compounds	Used in metal alloys, in plating , in the manufacture of various compounds and in many other applications.	Known carcinogen. Has a wide range of possible health effects from minor to severe depending upon compound form.
cyanide compounds	Used primarily in electroplating, metallurgy and production of organic chemicals, the making of plastics and other applications.	Acute and deadly poisons.
dichloromethane	Used in metal cleaning and as solvent in the production of other organic chemicals. Also used as a degreaser and in the electronics industry. Used in a wide range of consumer products.	Known carcinogen. Exposure has irritant dermal and mucosal effects and may cause central nervous system depression
lead & compounds	Used in production of batteries and certain other items and in metal products such as solder and pipes.	Probable carcinogen. High exposure levels may cause brain and kidney damage. Bioaccumulative, chronic exposure may cause death or damage to internal organs. May impair child development.
mercury & mercury compounds	Metallic mercury is used to produce chlorine gas and caustic soda; mercury salts are used in some creams and ointments.	Suspected carcinogen. Nervous system is very susceptible to mercury in all forms, high exposure levels may damage brain, kidneys or developing fetus. Effects include irritability, shyness, tremors, changes in vison, hearing, memory.
methyl ethyl ketone	Used as solvent, catalyst, and in the manufacture of several derived chemical substances including paint removers, cleaning fluids and adhesives.	Irritant, wide range of possible health effects including dizziness, dermatitis and vomiting. Chronic exposure may cause central nervous system depression.
methyl isobutyl ketone	Used primarily as additive to protective surface coatings, also in the manufacture of adhesives, ink and certain oils. Numerous other uses.	Exposure has irritant dermal and mucosal effects and may cause central nervous system depression
nickel & compounds	Used to make steels and alloys, permanent magnet materials, nickel-cadmium batteries, and in electroplating and ceramics.	Several compound forms are probable carcinogens. Chronic low-level exposure produces dermatitis and mucosal damage.
tetrachloroethylene	Used in dry cleaning of fabrics, metal degreasing and in some consumer products.	Suspected carcinogen. Exposure to high levels can cause dizziness, headaches, sleepiness, confusion, difficulty in speaking or walking, unconsciousness or death.
toluene	Primarily used as a component of gasoline; also as a solvent in paints, inks, adhesives, and cleaning agents and in chemical synthesis.	Primary health effect is dysfunction of central nervous system through inhalation. May produce birth defects.
trichloroethylene	Used primarily as solvent and cleaner, particularly in automotive and metals industries.	Known carcinogen. Possible death from exposure at high levels and damage to internal organs from chronic exposure.
xylenes	Used as solvent, and in gasoline manufacture, raw material for production of certain organic chemicals, dyes and insecticides	Flammable. Exposure to high levels may cause dizziness, unconsciousness or death. Chronic exposure may damage bone marrow or developing fetus .

Appendix 3: Instrument for Mail Survey

Note: The original form was printed on one side of 8-1/2 by 14-inch (legal size) paper.
The form shown here has been reformatted in two parts to fit the necessary size requirements.

1. Employment
What is the total number of workers at this location engaged in manufacturing (mgmt & floor workers, but not sales force nor R&D)

- ☐ Less than 25
- ☐ 25 to 50
- ☐ 51 to 100
- ☐ 101-250
- ☐ 251-500
- ☐ 501 to 1000
- ☐ 1001 to 2500
- ☐ More than 2500

2. Facility Size
What is the approximate size of the manufacturing facility, the number of square feet under roof?

- ☐ Less than 10,000 sq ft
- ☐ 10,000 to 50,000 sq ft
- ☐ 50,001 to 100,000 sq ft
- ☐ 100,001 to 250,000 sq ft
- ☐ 250,001 to 500,000 sq ft
- ☐ 500,001 to 1,000,000 sq ft
- ☐ More than 1,000,000 sq ft

3. Products Manufactured
Please provide a brief description of the product(s) made at this facility.

4. Product End Use
Approximately what proportion, if any, of your products are used in the automotive industry?

- ☐ None or not applicable
- ☐ Less than 10 percent
- ☐ 10 to 25 percent
- ☐ 26 to 50 percent
- ☐ 51 to 75 percent
- ☐ 76 to 99 percent
- ☐ All products so used

5. Parts Outsourcing
Percent of parts, used in assembly, obtained from other suppliers

- ☐ None or not applicable
- ☐ Less than 10 percent
- ☐ 10 to 25 percent
- ☐ 26 to 50 percent
- ☐ 51 to 75 percent
- ☐ 76 to 99 percent
- ☐ All parts obtained from outsources for assembly

6. Production Operations & Mgt Style
Production operations and management at this facility are primarily influenced by:

- ☐ Japanese Management Systems (derived from or influenced by the Toyota Production System – see adjacent Box 7 for examples
- ☐ Traditional Western manufacturing, known as Fordism; using mechanized technology to facilitate high-volume standardized output in long production runs, Fordism embodies a work design using unskilled and semi-skilled workers performing routinized simple tasks to produce standardized products.
- ☐ Other (describe below or on reverse of page)

7. Production Operations & Management Techniques Used

Different companies may use different terms than those given, or may use a company-developed variation. Use your best judgement as to whether these concepts apply to your firm.

	Fully implemented thoughout facility	Implemented only in some departments	Plan to implement in near future	Tried it out, was not successful here	Not applicable to this type production	Year in which implemented, if applicable
Just-in-Time (JIT): elimination of wasted time, space and materials	☐	☐	☐	☐	☐	________
Kaizen: continuous incremental improvement	☐	☐	☐	☐	☐	________
Total Quality Control (TQC) or Total Qual. Mgt (TQM): statistical approach to problem solving	☐	☐	☐	☐	☐	________
Quality circles & other small-group activities	☐	☐	☐	☐	☐	________
Kanban card system: pulls materials into system as needed	☐	☐	☐	☐	☐	________
Pokayoke: mistake-proofing	☐	☐	☐	☐	☐	________
Robotics	☐	☐	☐	☐	☐	________
Flexible manufacturing systems	☐	☐	☐	☐	☐	________
Computer-integrated manufacturing (CIM)	☐	☐	☐	☐	☐	________

Note: On original form, considerably more space was provided in Box 13 for response.

8. Environmental Management

a. Is there an Environmental Management System (EMS) in place?

☐ Yes ☐ No

b. Is there a specific company environmental policy statement?

☐ Yes ☐ No *(if possible, please provide copy)*

c. Is there a specific company waste reduction program?
(For example, the "Pollution Prevention Pays" (PPP) program at 3M Company)

☐ Yes ☐ No *Name?*____________________

c. Do you have ISO 14001 certification?

☐ Yes ☐ No ☐ Pending

d. If not, do you plan to seek this certification?

☐ Yes ☐ No

e. At what level are environmental practices or innovations decided?

☐ Main office Japan

☐ Main office USA (where located? ____________________)

☐ Local / this facility

f. How many persons at this facility hold full-time positions dedicated solely to environmental management issues? (Mark best answer)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 -10 ☐ > 10

☐ No such environmental staff on site

☐ Health & safety personnel on site handle environmental policies & issues

☐ Environmental issues are part-time duties of engineering or other technical/management staff on site

☐ Environmental personnel are associated with USA or regional office, not resident at this facility

9. Waste Generation – Significance Ranking

Please rank the following as to whether they represent significant constituents of production waste at your facility.
NA=not applicable to this facility,
1=least significant 4=most significant

NA 1 2 3 4 Airborne emissions

NA 1 2 3 4 Wastewater

NA 1 2 3 4 Solid waste, non-hazardous

NA 1 2 3 4 Hazardous/toxic waste

10. Methods of Waste Disposal

For each method, please estimate percentage of your total generated waste managed in this way.

__________ Burned for energy

__________ Recycled on site

__________ Recycled off site

__________ Treated on site

__________ Treated off site

__________ Disposal to solid waste landfill

__________ Disposal to haz. waste landfill

__________ Disposal to special waste landfill

__________ Released to environment

11. Resource Conservation & Pollution Prevention

Please rank the effectiveness of following conservation and control strategies for your facility. NA=not applicable to this facility, 1=least effective, 5=most effective

NA 1 2 3 4 5 Process management:
Design of process layout and/or waste stream flows to minimize resource consumption & waste generation

NA 1 2 3 4 5 Materials substitution:
Replacing a hazardous sustance with a less- hazardous or non-hazardous material

NA 1 2 3 4 5 Dematerialization:
Product redesign for a lower material content

NA 1 2 3 4 5 Internal recycling/reuse:
For example, reuse of plastic scrap in injection molding

NA 1 2 3 4 5 Proactive energy efficiency:
Use of most energy efficient machinery, lighting, HVAC etc.

12. Driving Factors for Waste Reduction or Better Waste Mgt

Please rank as to which have the greatest impact for your facility, where NA=not applicable to this facility, 1=least significant, 4=most significant

NA 1 2 3 4 Cost of pollution control technology

NA 1 2 3 4 Public opinion

NA 1 2 3 4 Compliance with state & federal regs

NA 1 2 3 4 Need to maximize economic efficiency

13. Success Story. Please describe, in general terms, an example of successful implementation of a strategy, system, process change or technology to reduce the environmental impact of this facility.

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