Can Green Be Lean?

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1. Introduction

In the past, efforts to improve the environment almost always led to increased production costs. In fact, some economists have attributed a significant part of the slowdown in productivity growth of the 1970s to increased attention to environmental issues (Gray, 1987; Conrad and Morrison, 1989). This result is in accordance with neoclassical economic theory, which holds that firms maximize profits subject to given constraints. If a constraint (such as keeping emissions below a certain level) is added, then profits cannot be higher than they were before. However, in practice there are numerous examples of firms which have both reduced their emissions and increased their profits and/or their efficiency. (See for example Porter and van der Linde, 1995.)

Concomitantly, a central tenet of strategic management theory is that firms need to focus on only a few distinctive competencies if they wish to be profitable (Hamel and Prahalad, 1990). However, Florida (forthcoming) has found a significant number of firms that are leaders in adopting new forms of both production management and environmental management.

This paper explores these paradoxes: how firms can be both profitable and environmentally conscious, how they can be both innovators in manufacturing and leaders in emissions reduction. The contribution of this paper is to present detailed examples of conditions under which these types of superior performance go together, and to begin to develop a theoretical framework which explains the examples.

The theoretical framework is based on Nathan Rosenberg's (1976) concept of ‘focussing devices’. His argument is that because managers are only boundedly rational, they cannot explore all possible sources of efficiency improvement at once. Instead, they develop worldviews which give them ideas about where might be fruitful places to look. In Rosenberg’s example, nineteenth-century US firms developed many labor-saving innovations because of the salience of high labor costs in this country. Many of these practices increased efficiency and profitability in Europe as well, and were adopted there; however, they were not thought of there because labor costs did not stand out so clearly as a key element of costs.

This paper argues that the recent diffusion of the principles behind the Toyota Production System gives managers a new focusing device, one which allows them to be simultaneously ‘lean’ and ‘green’.

In the next section, we describe the key tenets of the Toyota Production System, and how its emphasis on waste reduction is consistent with pollution reduction. Section 3 describes the detailed interviews with auto supply firms which provide our data. Section 4 looks at our sample firms’ production practices, and section 5 investigates their environmental practices. Section 6 gives examples of how these firms combine production management and environmental management, and section 7 concludes.

2. Lean Production

In the 1950s, Taichi Ohno, the architect of the Toyota Production System, defined waste includes any activity which uses resources but does not create value, such as producing defective products, producing inventory or remaindered goods, using processing steps which do not add to the product=s functionality, movement of the product or of an employee which does not add to functionality, and waiting because an input was not delivered on time.(Womack and Jones, 1996).

Ohno and others at Toyota worked to create a system, christened “lean production” by Womack, Jones, and Roos (1990), which works to reduce each of these seven types of waste. The key elements of the system are reducing inventory to a minimum and working continuously to improve the production process. Lean production can lead to dramatic performance improvements; a 1990 study of automotive assemblers found that lean producers used 1/3 the space and 1/2 the labor hours to produce products with 1/2 the defects of plants using traditional mass production methods.(Womack, Jones, and Roos, 1990).

Lean production requires far-reaching organizational and technological changes. Within a firm's own manufacturing operation, it involves reducing buffers through Just-in-Time inventory systems, producing only what is needed by downstream customers, whether internal or external; pushing down responsibilities for quality inspection and the specification of work tasks to motivated, multiskilled workers organized into teams; eliciting a steady stream of ideas for process improvement (kaizen) from employees at all levels. Added to this, customers are likely to demand that suppliers assume substantial responsibility during product development; accommodate customer requests for engineering changes in their product or manufacturing process; become highly reliable with respect to quality and delivery; and have the ability to respond quickly in case of problems.

Ohno’s definition of waste as activity which does not create value is consistent with the goal stated in a leading textbook on environmental management: AEvery molecule entering a manufacturing facility should leave it as a component of a salable product@.(Graedel and Allenby, 1995, p.186). Each of Ohno's seven types of waste affects business performance in every industrial sector. Use of unnecessary raw materials, for example, adds not only to a firm=s materials costs but also to its landfill or other disposal costs. Reducing the amount of raw material required to make a certain product will reduce both costs. Likewise, wasted motion used by employees may reduce the amount of product they can produce in a given time, and might also contribute to injury. All of these will ultimately cost the firm money. One final example might be poor plant layout, which would manifest itself in wasted time and motion transferring work in process from one location to another. Cell manufacturing and continuous flow processes can eliminate these wastes, and costs, from production.

This approach to assessing waste in the business sector leads to the dual effects of reducing pollution and rendering businesses more effective and efficient. These results apply as much to whole industrial sectors as to individual businesses. For example, an unnecessary process step may be mandated by a firm=s customer; a supplier cannot eliminate such a step without consultation. Waste also leads to the fouling of the environment, and a reduced quality of life for citizens.

Reflecting this approach, in this study we will use the term "waste" to describe all types of resource use which do not add value to a product. We divide waste into two categories: "pollution", which refers to unwanted substances emitted into the environment, and "unnecessary production effort", which leads directly to wasted human effort and indirectly to additional pollution.

3. Methodology

Data for the study came from detailed interviews at auto supply firms in Northeast Ohio. These interviews were conducted in summer and fall of 1996.

Three sources provided names of companies to be contacted for the study. One source was a list provided by the Cleveland Advanced Manufacturing Program of Northeast Ohio firms in SIC's (Standard Industrial Classifications) 34 and 35 (manufacturers of electrical and mechanical equipment). Second was the Elm Guide to Automotive Sourcing (available from Elm, Inc. in East Lansing, Michigan). This guide lists the major first-tier suppliers (both domestic and foreign-owned) to manufacturers of cars and light trucks in the United States and Canada; we contacted only those firms in telephone area codes 216 (Cleveland) and 330 (Akron). A third, and very important, source of companies to contact came from suggestions solicited from interviewees of their own customers and suppliers. These suggestions permitted the targeted completion of supply chains. The following section describes the sample selection procedures. We conclude that the group of companies interviewed provides a representative sample of automotive suppliers in Northeast Ohio.

Contacting companies involved preliminary phone calls briefly describing the project and requesting permission to fax a one-page description of the study. Follow-up phone calls aimed to either schedule interviews or determine a company's unwillingness to participate. At each plant that agreed to participate, we administered a structured questionnaire. All participants were promised confidentiality. In all cases we interviewed at least two people per plant (usually a production manager and an environmental manager) and had an extensive plant tour. In the course of the study, we conducted more than 70 interviews. In some cases, we were accompanied by an environmental engineer from CAMP.

The potential pool of establishments to interview, garnered from the above-named sources, numbered 359. We called every establishment on the Elm list, and randomly selected firms from the SIC lists. (We use the term establishment because some firms have multiple plants in this area.) Of the 142 establishments contacted, 57 either no longer supplied the automotive industry or had never done so. (The majority of the non-automotive suppliers came from the SIC lists.) Leaving aside the 57 non-automotive suppliers, the potential pool of companies for the study was 302. Of these, 85 (27%) were contacted and 30 were interviewed. This meant that 35% of those contacted agreed to be interviewed. Establishments that refused an interview outright numbered 24, while 33 never responded to the request for an interview.

The highest success rate came from the 11 companies whose names were provided by other interviewees. Almost half of this group (45%) agreed to participate in the study. In at least one instance, an establishment that initially declined to participate later agreed to do so when a researcher called with a reference from another subsidiary of the same firm.

The response rate of 35% would have been high for a postal survey requiring 20-30 minutes to fill out. It is quite remarkable for a study which required a 2-3 hour interview of at least two people in the firm. These facts have two important implications: first, that there is a great deal of interest in the subject of pollution prevention, and second, that the sample can be considered representative of auto suppliers in Northeast Ohio.

One caveat is that most of the referred companies that refused to participate were plating companies. Although some of the study participants do sell plating and finishing, the number of electroplaters was low in comparison to those who use less environmentally-damaging finishing methods. Thus, it seems likely that electro-plating companies are slightly underrepresented in the data set. Another almost absent category of automotive supplier is injection molders. Although several companies that make rubber products agreed to participate, no plastic injection molding companies agreed to participate. With the exception of injection molding and plating, however, this data set represents a cross-section of the northeast Ohio automotive supply industry. Certainly metal-forming companies, a major regional industry, are well represented in the data set.

Not all of the supplier firms interviewed delivered directly to one of the automakers' plants; some represented lower tiers (that is, they supplied to firms who in turn supplied the automakers). In contrast to the specialized structure characteristic of the Japanese auto industry (Nishiguchi 1994), only seven of the thirty firms reported that they occupied only one tier. One materials processor we interviewed acted as a first, second, third and fourth-tier supplier. Overall, we interviewed 11 firms which categorized themselves as primarily first-tier, seven who were primarily second-tier, four who were primarily third tier, and seven who provided specialized services to the industry (such as steel processing, or metal finishing).

In addition, a variety of personnel at automotive assemblers were interviewed by Helper as part of on-going research on the automotive industry, though not specifically for this project. These individuals included purchasing and materials management managers, plant managers, design engineers, and line workers at Ford's Ohio Assembly Plant in Avon Lake, Ford's Cleveland Engine Plant #2, General Motors's assembly plant in Lordstown, Ohio, General Motors Delphi Packard Electric, and Honda of America in Marysville, Ohio.

The distinctive feature of this study is its focus on the automotive supply chain, that is, relationships between customers and suppliers. Academic and industrial studies like this one often concentrate on firms of a particular type or size. Individual firms interested in addressing the issue of waste reduction necessarily focus on their own operations, from inputs to products and waste streams. By contrast, this study directs its attention to a group of companies whose common feature is neither similar structure nor similar products or processes. Instead, they represent the northeast Ohio automotive supply chain. Indeed, many companies that were interviewed for the study supply other companies also interviewed, so that the data set consists largely of overlapping supply chains, which the study results suggest are highly representative of the region in general. By investigating waste in an integrated manner, we hope to identify waste prevention opportunities that would be invisible if the companies were investigated individually or grouped by type of product manufactured.

The auto industry is a significant source of pollution in Northeast Ohio. At least twelve plants supplying the auto industry were listed in the 1994 Toxic Release Inventory[1] as having the largest toxic releases in the region of chemicals such as manganese, zinc, hydrochloric acid, sulfuric acid and methane. (We conducted interviews at four of these firms.) The most common waste products in the northeast Ohio auto supply chain are scrap metal, oils, and coolants. Other major pollutants include sludge (usually containing base metals), chemicals and solvents, inert solid waste (rejects and trash), and air emissions.

Section 4. Production Practices

In this section we examine production practices in the Northeast Ohio auto supply chain on five dimensions: relations with customers and suppliers, production methods, relations with employees, performance measurement systems, and design participation. In general, we saw less adoption of lean practices by Northeast Ohio auto supply firms than by their counterparts in the rest of the United States and Canada (see results of a national survey in Helper, 1996). However, this feature of the dataset permitted us to examine not only when leanness and greenness are found together, but also to look at how a lack of leanness may lead to a lack of greenness as well.

a. Customer Relations

In contrast to the mass production philosophy, lean production emphasizes long-term, information-rich relations between customers and suppliers. These relationships allow suppliers to reduce waste by holding less inventory (because they are more sure of their customers' needs), by eliminating unnecessary process steps (because they can communicate with the customer about effective product designs), and by investing in efficient equipment and organizational practices (because commitment from customers allows them to have a longer planning horizon).

Only 11 of thirty companies felt they had long-term relations (either contractual or implicit) with even their most important customers. Short time horizons were particularly felt by firms who were primarily second- or third-tier. Even those firms which did have long-term relationships with their customers typically did not offer such assurances to their own suppliers.

Few of the suppliers had regular discussions about product design with their customers, although several could cite isolated examples of such discussions being helpful. Many opportunities for mutual benefit were not taken advantage of. A striking example of this occurred at a firm which puts anti-corrosion and other types of coatings onto fasteners. Many of the parts require that a thin strip of coating be placed in a precise

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[1] Reprinted in the newsletter *Ecocity Cleveland*, April 1996, pp. 6-11.

location. The firm's competitive advantage is that it has figured out how to use tumblers (big bowls of parts which are jiggled by an electric motor underneath) to orient the small parts so that the coating can be applied by machine rather than by hand. In one case we observed, engineers were trying to figure out how to automate the coating of a part which was almost, but not quite, symmetric. They were working on special feeder trays, and talking about machine vision systems, but had not asked the customer if it would be possible to change the design of the part to make it easier to orient. When asked why they hadn't discussed the matter with the customer, they said they didn't think the customer would be interested, because other coaters wouldn't have the same process. (In most cases, the coating firm doesn't receive any contracts for its work; when it receives a batch of parts from a customer, there is no guarantee that the customer will send another one.)

One reason for the lower levels of commitment and information flow between suppliers and customers in Northeast Ohio is the minimal presence of Japanese customers in suppliers' order books. Only one firm had substantial Japanese business; two other firms had recently obtained small orders from Honda of America. This percentage (10%) of firms with Japanese customers is substantially below that found in the 1993 survey (over 50%). 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.

b. Production Methods

Based on our interviews (and random checks of dates on shipping labels during plant tours) we would classify seventeen of our 30 plants as fairly effective inventory managers, in the sense that they kept one week or less of most types of raw materials, work-in-process, and finished goods inventory. Another six were working toward this goal, while seven were not making efforts in this direction.[2]

c. Quality Assurance

Due to the wide variety of products produced by the automotive supply industry, we were not able to compare levels of quality performance. However, we were able to look at some more indirect indicators.

To categorize our interview results, we used a relaxed definition of leanness with respect to quality method. Companies are considered lean if they have in place quality control measures such as SPC and root cause analysis. Having numerous quality awards also suggested leanness. Companies were grouped as somewhat lean if they were putting in place a quality tracking method, if they had a method that was not particularly effective, or if they had only made modest efforts to track and improve quality. Finally, "not lean" companies were those who had no quality tracking methods. Seventeen companies were considered lean by this measure; ten companies were considered somewhat lean, and three companies were considered not lean. Only 20% of the companies had achieved QS9000 certification by fall 1996.

d. Work Force

The same labels were used with respect to employee relations and involvement with the production process. Companies called lean engage in cross training, involve

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[2] We included the service suppliers in this measure, because they maintain stocks of raw materials (and often work in process as well).

employees in production through quality circles and other such structures, have in place incentive programs or profit-sharing, and generally encourage employee input. Companies were considered somewhat lean if they were just beginning to adopt such practices or if they involved employees to a more limited extent. Companies considered not lean by this measure do not involve employees at all. They tend to have high turnover rates and use unskilled labor. Only two of the plants we visited were unionized; one of these facilities was in the "somewhat" category (except for an exemplary unit), and the other was not lean.

Nine companies were considered lean by this measure;Fourteen were considered somewhat lean, and Six companies were considered not lean. (There was one don't know.)

e. Performance Measurement

Managers are beset by uncertainty about the extent to which their actions really contribute to their firm's goals (be they maximizing profit, growth, and/or community welfare, etc.) Mass production assumes that measuring direct labor time is a good proxy for how well the firm is controlling its costs. Since this is what is measured, managers work hard to reduce direct labor--even if it means adding cost somewhere else. By contrast, lean production techniques have a different, and much less financially-oriented, underlying philosophy. For example, Ohno believed that inventory is costly far beyond the easily-measured expenses of storage and working capital. In addition, excess inventory leads to lower quality, for two reasons. First, defects are found long after they are caused, making it harder to trace their cause. Second, inventory allows mistakes to be covered up, making it possible to avoid fixing their root cause. Therefore, according to the Just-in-time philosophy, firms should not calculate an "economic order quantity" and stick to it; instead they should work to continually minimize the amount of inventory they hold.[3] This is one example of how lean production focusses managers' attention on new questions (how to reduce set-up times, rather than how to achieve long runs to reduce the unit costs of given set up times).

The broad view of waste described in the introduction to this report also poses challenges for performance measurement. Often, pollution control expenditures are put into overhead. Under these circumstances, customers have less incentive to invest in pollution-prevention activities at their suppliers. For example, one firm described how Honda's requirement that a part pass a 1000-hour salt spray test forced the supplier to use toxic chemicals for electrocoating it. Other automakers were content with a 100-hour requirement that could be met using non-toxic processes. However this firm does not have a system for tracking the extra costs of the toxic process throughout the plant.

Few of our interviewees (typically environmental and production managers) could clearly describe how their plant's performance was measured; most of those who ventured a guess mentioned some mix of maximizing output and minimizing defects. Activity-based costing is a system which allocates costs (even overhead costs) according to where they are incurred; it is able to go beyond the simple assumption that all projects incur a similar pollution-control expense. Not one of our interviewees mentioned that their plant had such a system.

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[3] For an insightful treatment of JIT, see R. Schonberger, *Japanese Manufacturing Techniques*.New York: The Free Press, 1984.

f. Product Design

Eight companies say that their customers hand them specifications. Four of these proceed to design the production process to make the part to the customer's specification. There are four additional companies that design processes in-house, three of which say that other design work takes place at headquarters, and one of which says that product design is collaborative. Two companies complained that customers do not fully utilize the company's ability to do engineering design.

Many companies locate design facilities at a headquarters rather than associating design with the production floor. Twelve companies in this dataset (43%) named headquarters as the location for design work. Of these, four claimed to collaborate with customers or suppliers in the design process.

In total, 15 companies in the dataset (50%) collaborate with customers or suppliers in design. Only four companies conduct design entirely in-house, and half of these do so because of their proprietary process.

5. Pollution Control Practices

This section describes our interview data with respect to three mechanisms for pollution control. Eleven of the 30 companies (37%) provided examples of pollution prevention. Fifteen companies (50%) reuse and/or recycle materials. (It was unfortunately not possible to distinguish clearly between these two options.) The majority of companies, (21, or 70%) have in place end-of-pipe treatment.

Three companies gave no examples of either pollution prevention or waste reduction or treatment activities. Of these, two are assembly factories whose waste consists principally of trash. The other has minimal material waste, although poor plant layout due to old age of the facility translates into wasted time and internal transportation. **A. Prevention**

Eleven companies demonstrated actions and decisions that prevent pollution. Of those, 6 also engaged in recycling and/or reusing waste products and 6 have in place end-of-pipe treatments mostly aimed at environmental compliance. About two-thirds of this group (7 of 11) have low environmental liability. Instead of being motivated by environmental regulations, most of the companies that have programs to prevent waste are driven by economic motives, such as reducing landfill costs. In some instances, only one example was offered of pollution prevention. In other cases, companies appeared to seek waste reduction opportunities more systematically.

a. Machine and Process Changes

In five cases, prevention activities consisted of the substitution for older machines of improved machinery or the institution of processes that generate less waste. One company instituted "dry" machining, which uses less coolant. Another installed machines that recaptured coolant and lubricants for reuse. Three switched to an aqueous system for degreasing. And one company, a new state-of-the-art facility, invested in numerous such machines, including replacing quench tanks with forced air for cooling, thus reducing water usage. A steel producer was able to increase the usable with of its product through better process control and more careful packaging.

Two companies in the data set mentioned recent switches to aqueous systems for production steps or de-greasing. Both cited environmental compliance as a benefit of the new systems. One got into aqueous cleaning (from previous vapor degreasing) about 5 years ago. This company learned about the new technology from trade journals, and adopted it because they sensed that the regulatory environment was heading in that direction, following the lead of "bigger plants". Another company switched to a water-based epoxy because of a company policy of environmental concern.

The company that has replaced half of their machining tools to "dry" machining likewise cited environmental motivations for doing so. Their two major waste streams are metal chips, which they recycle, and machine tool coolant. However, it appears that the plant has not completely gained control of the new process of dry machining. The interviewer observed many boxes of parts for scrap or rework, and line's yield is only 87% .

b. Reducing Raw Materials and Materials Substitution

Five companies sought to reduce the amount of raw materials used. Companies that use rubber as a raw material seem particularly motivated to engage in this kind of waste prevention, given the difficulty of recycling or reusing the waste and the cost of landfill disposal. A manufacturer of floor mats engages in routine redesign of products to attempt to reduce the amount of raw materials used. The same company also worked with one of their suppliers (a parent company) to change the dimensions of carpet rolls, which allowed them to cut more mats with less waste from the same amount of material.

Two companies trying to reduce raw material use worked with suppliers to accomplish this. One sought its suppliers' help reducing its use of oil and coolants, while the other looked for a supplier of thinner lubricant. A supplier of surface finishing worked closely with their supplier of paint to produce a low pollution paint that is easier to dispose of. One company described working with a customer to replace a spec for high salt spray resistance for an interior part with a lower resistance spec. The result was cheaper, used less environmentally-harmful materials, and could be done in-house, thus also eliminating extra transportation.

c. Returnable packaging

Although use of returnable packaging by itself was not sufficient to place a company in the "pollution prevention" category, this activity is discussed briefly in this section. Five companies specifically mentioned the use of returnable packaging as a waste reduction effort. The number of companies using returnable packaging could well be higher. However, since the customer dictates the type of packaging, efforts to reduce waste by increasing the use of returnable packaging would require addressing customers, not the lower tier suppliers.

d. Factory Clean-up

Several interviewees asserted that clean factories produced fewer rejects and less waste than disorganized, messy production areas. At one aluminum casting facility, an interviewee pointed to piles of flash, metal scraps, oil, dust, and water around the machines. He argued that a cleaner factory would run more efficiently, but stated that production engineers will not take the necessary steps to clean up the production floor. Part of the problem is structural, since many very heavy machines are located so close together that it is difficult to clean between them. The newer of the two aluminum casting facilities was much cleaner.

The assertion that a cleaner factory floor would improve productivity is amply borne out in the case of another factory, a fastener manufacturer, that instituted a massive clean up of the facilities and experienced dramatic increase in productivity. Their first time quality measure went up from 82% to 97% in two years. They credit this increase to their efforts to clean up the factory environment. When new management took over two years ago, they found a factory in which cleaning the floor was accomplished by pushing railroad ties along with forklifts to clear gunk from the paths. Now the floor, the walls, and the outsides of the machines are virtually oil-free. Interviewees claimed that the company saw an immediate 10% quality improvement just as a result of cleaning and painting the walls, floor, and machines. They are very strict about safety measures (the only company in which interviewers were compelled to wear hearing protection). A worker politely but firmly chided one of our tour guides when we had passed into a zone which required eye protection and our guide hadn't yet told us to put on our glasses. The company has computerized stations for quality control, testing, and checking during production. Timed screen savers remind workers if it is time to check a sample. Although this company made the initial investment in overhauling their production environment, they do not seem to have implemented an on-going dialogue between environmental management and production management. Evidence for this assertion includes the fact that our interviewee focused on safety and training programs (once he had finished describing the initial clean-up effort); and also that the environmental manager had until recently only been in charge of facilities (grounds keeping and maintenance) and was just beginning to learn about his new area of responsibility. The choice of a non-engineer for this position seems to imply the assumption on the part of management that this position has no need for technical knowledge of the production processes.

B. Recycling and Re-use

a. Recycling and reclaiming of scrap metal and oil/coolants

The waste material most frequently claimed by companies interviewed was scrap metal (including aluminum flash). 16 (53%) of the sample set of companies listed scrap metal as a waste product. Of these, 13 (81%) have arrangements in place to sell scrap metal to dealers who recycle or reclaim it. The significant financial motive to recycle scrap metal makes this form of waste reduction almost universal among companies that produce metal waste.

One potentially significant downside to the ease of metal recycling is the possibility that it leads to less effort to reduce raw materials use. In the case of aluminum casting facilities, one interviewee pointed out, high first run reject rates have been the norm in that industry, due to the ease with which companies can "dispense" rejects back into the crucibles to recast them. (This practice of course increases energy use.) The production manager at this plant acknowledged this traditional problem, but told interviewers that first run rejects have been the focus of improvement efforts and have decreased dramatically in the past few years.

A high percent of companies who produce waste oil or coolants also recycle them. 12 companies end up with oils or coolants as a result of their production processes, and 11 of these (92%) have arrangements to recycle them.

C. End-of-Pipe Treatment

It is generally considered more environmentally desirable to prevent pollution than to concentrate solely on waste disposal and end-of-pipe treatment. A continuum of desirable environmental practices would start at the highest level with preventing pollution in the first place, then proceed to reusing waste products. Recycling would be ranked lower than reuse, but higher (of course) than disposal. Although this schema is persuasive, it is important to avoid slipping into the habit of condemning companies that have instituted end-of-pipe treatments. First of all, in most cases these are legally mandated, so that effluent waste streams leave the factory with carefully defined "acceptable" low levels of pollutants.

Secondly, and more relevant to this study, in some cases companies have combined waste treatment systems with process input, so that the waste treatment system is also a very important component of the manufacturing process. In these instances, companies have normally combined end-of-pipe treatment with pollution reduction. The best examples are water treatment systems at aluminum casting facilities. One important function of these systems is, of course, to ensure that outgoing water meets the requirements of local sewer authorities. But these systems also provide process water, which in some cases needs to be cleaned when it arrives from the city water authority, even before it can be used in the manufacturing process. These water systems are designed to reuse water many times before disposing of it, so they could as correctly be considered pollution prevention devices as merely waste treatment facilities. One company's water treatment system recycled 97% of the water used; the water which was returned to the river was cleaner than when it was first taken out.

The remainder of this section briefly characterizes the range of end-of-pipe treatments undertaken by companies in the data set. Eleven of 21 companies that practice end-of-pipe treatments have in place water treatment systems. Three of the 11 systems are run with the intent to prevent pollution (in addition to treating water), primarily through reuse of water and separation of reusable and recyclable oils, lubes, and coolants. Two of the systems concentrate zinc to sell it for recycling. Thus, water treatment facilities often combine end-of-pipe treatment with recycling, reuse, or even pollution prevention.

Seven of the 21 companies have air emissions treatment systems, two to improve interior air quality and five to clean air before releasing it from the factory. Seven companies have in place arrangements for disposal of wastes they cannot, or do not, reuse or recycle.

Five companies expressed interest in learning about alternatives for waste disposal or opportunities for reducing the amount of scrap they paid to landfill. In each of these cases, interviewees described a specific problem and one or several potential solutions of which they were aware. However, in at least 3 of these 5 cases, the companies were not taking active steps to investigate or research the potential solutions. For example, several of the companies pay large landfill costs to dispose of rubber scraps. One company had tried selling the scrap, but that customer quickly decided that using raw material was cheaper. Another company mentioned possible alternatives, including burning the scrap for energy or pulverizing it and selling it for use in compounds. But neither of these companies had an on-going research effort to assess alternatives or come up with new ideas. An interviewee from another company expressed interest in drying sludge to reduce the volume of waste they paid to landfill. The company was not engaged in any efforts to determine whether this step would be economically or technically feasible. In conclusion, even when companies have specifically-targeted potential waste reduction opportunities, they are not always willing to devote resources to research them.

Section 6. Interaction of Lean and Green

In this section, we look at the ways in which lean practices can promote greenness.

Prevention Using Customer Supplier Relationships. The study considered the question: do customer-supplier relationships exist that address waste reduction? In 19 of 30 cases (63%), companies gave at least one example of working closely with either a customer or supplier. Ten of these have relationships used to tackle issues of quality, delivery, and/or design. Nine (30%) gave examples of using those relationships to address environmental issues. Examples are given below to illustrate the experience of companies in the data set. Of the remaining companies in the study, 9 do not have such discussions, and 2 did not provide enough information to characterize such a relationship.[4]

Communication between suppliers and customers is particularly beneficial in increasing the success of pollution prevention efforts. There is a high potential for firms to build on existing relationships with customers, to extend their conversations about cost-reducing design changes to encompass cost-reduction by reducing generation of pollution.

Of the eight companies whose customer-supplier relationships address waste reduction or environmental issues, three are companies that specialize in dealing with environmental problems, that is, plating and hazardous waste disposal companies. Of these three, one gave an example of a customer (Honda) helping to determine the source of an unspecified problem. Another one offers materials substitution advice as an informal but regular part of their service. The third described the close relationships with area aluminum casting companies that allowed him to develop a patented lubricant which he now markets world wide. These customers and potential customers allowed him to test the product in the development stages. He characterized big companies as more helpful during the experiment stage, but small ones as less lethargic about adopting new technical ideas and products. Although this interviewee would not discuss his suppliers, he did credit them with providing a significant amount of technical assistance.

The remaining five companies gave the following examples of customer or supplier involvement in waste reduction or pollution prevention:

- One worked with its parent company/supplier to change the dimensions of the raw

[4] It was not always harder to communicate across firm boundaries within them. We visited two plants owned by the same company which used the same process, yet had very different approaches to water treatment. Each plant was convinced its approach was superior.

material they received. This allowed them to produce their product with less wasted raw material.

- One worked with customers to design machines whose performance criteria include pollution prevention. For example, they built molding systems that yielded a clean surface on the finished part. But this company also pointed out that customers do not always appreciate machines designed with waste reduction in mind. Instead of using a lost foam casting machine (foam is burned away by hot metal, leaving a clean cast and no residue), one customer changed to outsourcing the process.
- One manufacturing firm suggested that their customer review salt spray resistance specifications, which they felt were unnecessarily high for an interior part. The customer, realizing that this specification had carried over from a previous design, decided to make the recommended change. The result was a finish that the supplier firm could do in-house, which not only prevented the use of environmentally-damaging finishing, but also saved time and transportation.
- One company, which claimed much benefit from technical advice and assistance from suppliers, gave one concrete example. Their machined shafts were experiencing high reject rates both in-house and at the customer. They worked with their supplier of forged shafts to get slightly larger ones, which resulted in much lower reject rates. Even though more material went into the forged shafts, the savings across the board (rejects, time, etc.) made this choice worthwhile. This company also mentioned their willingness to experiment with lubricants and coolants according to their supplier's recommendations.
- One company worked with a supplier ("pushed them") to develop a low pollution

paint. The same company also described a relationship with a supplier of coatings and cleaning chemicals in which the supplier sells coalescers that prolong the life of cleaners by skimming oil off the top of the cleaning bath. The company we interviewed said that the coalescer paid for itself in reduced chemical costs in six months; the supplier made up for selling a smaller quantity of chemicals by selling more coalescers.

In general, it seems as though companies engaged in pollution prevention activities have close customer-supplier relationships. All but one of the eleven companies that practice pollution prevention show evidence of such relationships for addressing issues of quality, delivery, design, etc. Half of them (6, or 55%) use that relationship to address environmental and waste reduction issues. By contrast, among the group of companies that engage in reuse and recycling, only 4 of 13 (31%) have customer-supplier relationships that address waste reduction. And, among the 21 companies with end-of-pipe treatment systems, 6 (or 29%) have such relationships. All but two of these companies is an "outsourcee," that is, a company to which other companies outsource either processes such as finishing and heat treating or disposal. It seems, therefore, that companies that supply finishing or disposal services benefit from maintaining healthy customer-supplier relationships. Of the three companies for which not enough is known to determine what pollution and waste strategies they practice, only one has customer-supplier relations that address waste reduction issues. Unlike other companies in the dataset, however, the result is not the reduction of waste in the manufacture of a product itself. Instead, this company works with customers to design and construct machine tools that create less waste.

Although this study finds that companies engaged in pollution prevention enjoy close customer-supplier relationships, the evidence in some cases consists of a single example. Thus, although the potential structure is in place to utilize close customer-supplier relationships to effect pollution prevention, we did not find any examples in which reduction of waste (either due to pollution or due to inefficient production effort) was discussed consciously and regularly. Instead, most companies express concerns about maintaining quality or keeping proprietary information safeguarded. They cited these concerns as reasons for not developing the kind of customer-supplier relationships that could address pollution prevention at the level of materials substitution, decrease of raw materials used, or change to the production process.

Systematic Approach. Another benefit of lean production is its emphasis on systematically looking for ways to improve performance. Production processes are supposed to be "continously improved"; they are not to remain static. This attitude is beneficial in reducing pollution as well as other types of waste.

For the purposes of measuring approximate degree of systematic approach to pollution control, the following assumptions have been made. First, the existence of an environmental manager signifies a systematic approach, compared to those companies that relegate decisions involving environmental issues to non-specialists within the company. Second, the characteristic of having or working towards QS9000 likewise suggests a more systematic approach than not doing so. Third, awareness of ISO14000 indicates that a company makes an effort to keep apprised of future environmental standards.

The following chart grades companies in the data set into the categories of most systematic, moderately systematic, least systematic, and not systematic. The method of determining the category was to assign one point for the presence of each of the characteristics listed above (existence of environmental manager; working towards of having QS9000; and awareness of ISO14000).

	Most Systematic	Moderately Systematic	Least Systematic	Not Systematic
# of companies	4	9	12	3
Percents	14%	32%	43%	11%

A comparison of the degree of systematic approach with company strategy towards environmental issues (the above-described groupings of companies that engage in pollution prevention; those that practice recycling and reuse; and those that rely on end-of-pipe treatment) does not yield any strong relationship between these two variables. One might assume that companies with a more systematic approach to environmental management would be more likely to practice pollution prevention, while those with the least systematic approach would be more likely to practice end-of-pipe treatment. Instead, “most systematic” companies practiced recycling/reuse and end-of-pipe treatment slightly more frequently than prevention. The majority of companies in the “least systematic” category practiced end-of-pipe treatment (8 of the 12, or two-thirds). This is more than the number of “least systematic” companies that practice pollution prevention (less than half do, that is, 5 of 12). However, 55% of the companies that practice pollution prevention fit into the “least systematic” category, while only 40%

of those in the end-of-pipe group were "least systematic".

One possible explanation for the absence of the expected relationship between these two variables was suggested earlier. Some of the companies in the pollution prevention group gave only one or a few examples that demonstrated prevention. The result described here makes sense if prevention is not part of a systematic effort to address environmental issues and integrate them into process engineering and management.

In addition to examining the systematic approach to environmental management, we examine the efficacy of formal environmental positions. If the environmental manager is the locus of decision making, more consistent decisions regarding environmental policy will result. As might be anticipated, a relationship exists between high environmental liability and likelihood that a company has a formal environmental position. The details follow in chart form.

First, this chart divides the data set into companies that do not have an environmental position, those that do have a formal position, those in which environmental decisions are the responsibility of someone at headquarters, and those for which there is no data.

	No	Yes	At HQ	Don't Know
Totals	11	12	3	4
Percents	37%	40%	10%	13%

For companies that do not have a formal position, decisions about environmental and waste issues are made by the owner, vice-president, each department, the quality control department, and the engineers (one case each) or by the plant manager (two cases). For companies with a formal position, in two cases, a separate department or position exists devoted exclusively to environmental responsibilities; in four cases, Environment, Health, and Safety (EHS) is one position; and in two cases, EHS is part of a position.

It seemed at first surprising that companies which regularly redesign process to reduce waste do not have formal environmental positions. Companies engaged in routine redesign are attempting to reduce raw materials consumption, motivated by the desire to lower their production costs as well as costs of landfill disposal. Although several of these companies provided excellent examples of successful waste reduction activities, these reductions require the efforts of design engineers and production managers. A person whose job responsibilities encompassed the traditional universe of "environment, safety and health" would not normally be a part of such a project. Therefore, there should be no reason to expect that companies who redesign the product to reduce waste would have formal environmental positions.

Linking Environmental and Production Management. Although a large dichotomy exists in many companies between environmental management and production management, a few examples suggest that the potential exists for cooperation between these two functions. Two examples are given here of aluminum casting facilities. Both have sophisticated waste water treatment systems that not only treat outgoing water but also treat water that is used in production processes. Therefore, the water treatment systems function both as waste management tools and as a resource for production.

In both plants, one person has responsibility for EHS matters. Both of these people have experience as production engineers or managers in other industries. Unlike some environmental managers (such as one in a fastener-producing company who was promoted from a position managing grounds keeping), both of these people understand the production process and have the experience that would be required to integrate waste reduction efforts and production improvement.

One interviewee in particular was vocal in his criticism of management for not taking advantage of the potential for using the waste water treatment system to track and improve quality. He pointed out that information on the amount and type of waste generated was informative about the production process, especially quality problems. For example, when dies are wearing out, they produce more waste fluid and more flash. Thus, when a monitor shows a spike in the use of a specific fluid, it usually means that there is a problem with a machine. This interviewee advocated implementing a systematic coupling between waste management and quality control, but, at the moment, management is not doing anything to accomplish this.

Although this interviewee criticizes management for not taking full advantage of the potential he sees for linking waste management and production control, this company and another aluminum casting company understand the necessity of devoting the time and expertise of a dedicated engineer in order to develop a functioning waste water treatment system. One interviewee stated that his system "had more bugs than a candy shop in Florida." He has had to tinker with the system to adapt it for use in his plant. By contrast, other companies expect to implement "off the shelf" waste treatment systems without this level of technological and institutional support.

One company that had a disappointing experience with an “off the shelf” pollution prevention technology also provides valuable insight into the role of environmental manager. This company supplies injection molding, sealing and coatings of nylon, rubber, and other materials. Cleaning parts before coating is an important step in their operation. The environmental manager played a major role in the recent (within the past few years) purchase and installation of an aqueous degreaser intended to clean parts destined for a paint-style coating line. This manager has a management/business undergraduate degree and experience as a “Jack of all trades manager.” In his current position, though, he appears officially unconnected to the manufacturing processes at the plant, although he evinced a familiarity with some plant operations during the tour. His official responsibilities include handling certification and dealing with wastes and emissions, along with managing employee safety training. This environmental manager and the plant’s “environmental supervisor” (who was promoted from the rank of operator, without much training) prefaced their remarks about the aqueous degreaser with the admission that “the salesman had done a really good job.” In other words, the machine was oversold; it never did what the firm needed it do to.

Some of the reasons for the machine's failure seem rooted in the disjunction between production management and environmental management. For example, one immediate problem was that the installation of the aqueous degreaser coincided with an increase in volume of parts handled by the coating line. It is possible, though not certain, that a closer working relationship between the production and environmental sides might have alerted the environmental manager to the projected expansion, causing him to look for a larger aqueous cleaning machine. Another problem that arises from use of the aqueous degreaser derives from scheduling. The company interrupts scheduling fairly frequently due to rush orders (a company specialty). Since they prefer to degrease parts ahead of time, they encounter the problem of rust on parts degreased. While this is not an intrinsic problem with the aqueous machine, it is a problem of integrating the characteristics of an aqueous system into the company's production process.

The environmental manager himself explained the source of the problem in precisely these terms: "when I got involved in the aqueous cleaner, that actually involved process engineering." But his training did not cover process or design engineering, nor did he have avenues for seeking the help of engineers within the company. His lack of technical training translated into the naive assumption that such a "plug-in" machine would meld unproblematically into the company's production process. Instead, in addition to the above examples, unforeseen problems arose, such as the need to handle a new kind of waste, the sludge produced by the aqueous degreaser. The solution to this problem entailed the additional expense of an evaporator purchased to reduce the sludge to a solid.

Unlike in the above example, some companies have environmental managers with previous production engineering and management experience. However, that does not automatically translate into effective cooperation between waste management and production management. One example indicates that, in general, EHS issues are not considered a priority to management. One interviewee said that when workers complain that the position of their machines makes them move or bend unnecessarily, he passes the information on to management but is discouraged by how long responses take. If the request or problem is small or easily fixable, he simply asks the hourly worker assigned to help him to make the requested change. By avoiding formal channels changes can be made more quickly, but the disadvantage is that all change is piecemeal and not at all systematic.

Although this example relates to health and safety, it suggests the extent to which the responsibilities of EHS managers can be pushed to the sidelines. In companies dedicated to building effective EHS programs, these managers are given plenty of resources to develop training programs and institute safety measures. However, even when these managers have previous experience that enables them to understand the production processes for which they are developing waste management systems, they are normally kept from "interfering" with production processes.

B. CAN GREEN BE LEAN?

A recurrent theme in environmental management is its cost. It is frequently assumed that various pollution prevention and waste management efforts- ranging from end of pipe clean-up to comply with regulations to environmentally enlightened design-is costly. The conclusion many arrive at is that "good" environmental management puts firms at a relative cost disadvantage in comparison to firms which are not constrained by EPA regulations and environmentally friendly objectives.

In contrast, Florida (1995) attempts to link "good" environmental management practices to competitive advantage.[5] He argues that pollution prevention and waste management efforts, since they effectively reduce waste and increase efficiency within the firm, have met positive results for the practicing firm(s).

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[5] Richard Florida, "Lean and Green", Carnegie-Mellon University Working Paper, 1995.

We analyzed the firms in our sample with respect to the two sets of practices: Leanness and Greenness. Each category was defined using the criteria described earlier in this report. A firm received two points for each category in which it was lean, and one point for being 'somewhat lean'. A firm also received two points for each of the following pollution-control activities: recycling, end-of-pipe, systematic effort, and three points for prevention. Each firm's greenness score was then weighted by its degree of liability, so that firms with lower liability were not penalized for not undertaking as many activities as firm with high liability. (For more discussion of liability, see Clifford, Helper, and Rowzadowski, 1996). After every firm was assessed with respect to its leanness and its greenness, the firms were rank ordered to distinguish the most lean from the least, and the most green from the least.

All the firms in the sample over the median level of 'green' were then categorized as green and all the firms in the sample over the median level of 'lean' were then categorized as lean. This methodology enabled us to empirically test whether a disproportionate number of firms were green, but not lean <u>OR</u> lean, as well as green.

The table follows:

		Lean 0	1
Green	0	8	7
	1	7	8

Our results show an equal distribution of firms in each quadrant of the table. This demonstrates no appreciable bias across the categories lean and green, lean, but not green, green but not lean, and neither lean nor green.

Thus, we note that all categories appear equally likely. Being green neither precludes running an efficient and lean operation, nor causes it. In our interviews we came across examples of lean being a complement to green, as in the effect of housekeeping on quality and productivity. We also came across examples of leanness being in conflict with greenness; most of these occurred due to the 'lean' tenet of being sure to meet customer desires for quality and durability, even if that means extra (non-returnable) packaging, or more toxic chemicals used to achieve a greater degree of rust-proofing.

While this finding supports neither side of the above mentioned controversy, the lack of linkage between lean and green is a hopeful sign in the sense that efforts to become green are not necessarily bad for business.

Section 7. Conclusion

This paper has shown a number of examples in which firms were simultaneously able to reduce pollution and increase efficiency by adopting innovations in manufacturing practice (lean manufacturing) and in environmental management (pollution prevention). We have argued that these results are possible, despite the predictions of both economic theory and strategic management theory due to the new 'focusing device' of lean production. In seeking to improve productivity and quality by continuously reducing waste, this framework focusses managerial attention on new issues, allowing them to transcend traditional trade-offs. These new issues include reducing set-up times, which allows the production of less inventory, and finding the root cause of defects, which reduces scrap.

In sum, these efforts are directed toward preventing the generation of waste in the first place, in ways that actually reduce production cost. This newer view has led to a broader conception of waste, one that includes not only effluent waste, but also any type of resource use that results from unnecessary production. This newer view makes compatible the operations management goals of minimizing costs and maximizing quality with the environmental management goal of reducing emissions.

were substantial opportunities for improvement in waste management practices.

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6 For more on lean production see Womack, J.,D.T. Jones, and D. Roos (1990), *The Machine That Changed the World*, New York: Rawson; and Womack, J., James, and D. Roos (1996), *Lean Thinking.* New York: Simon and Schuster.

7 See *The Bench Press* (Industrial Technology Institute, Ann Arbor), various issues.

8 For the survey data, all differences between Northeast Ohio and other plants described below as "somewhat significant" have a probability of occurrin by chance of between 5 and 10 per cent; differences described below as "significant" have a probability of less than 5 per cent. The Kruskal-Wallis test, a non-parametric version of the t-test, was used to determine statistical significance.

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