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ENVIRONMENTAL PERFORMANCE AS A DRIVER OF SUPERIOR QUALITY*

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We explore theoretically and empirically how efforts to enhance environmental performance may enable other types of manufacturing improvements. Drawing on a unique data set comprised of detailed surveys of 42 automotive assembly plants, associated quality metrics, and in-depth qualitative data from 17 automotive assembly plants, we show that attaining superior environmental performance can be a significant driver of superior quality. We highlight the synergistic and reciprocal nature of environmental and broader manufacturing improvement efforts, and show that environmental improvement tools and know-how can be an important source of competitive advantage.
(ENVIRONMENT; QUALITY; TQM; LEAN PRODUCTION; COMPETITIVE ADVANTAGE)

1. Introduction

An astronomical growth in legislation related to environmental issues, increases in waste disposal costs, decreased availability of raw materials, and shifts in customer preferences have dramatically increased the interest in, and pressures toward, environmentally conscious manufacturing (Porter and Van Der Linde 1995; Shrivastava 1995; Ottman 1992; Corbett and Kleindorfer 2001). A key concern to those involved in manufacturing is whether environmental efficiency and performance is compatible with efforts needed to remain competitive in the global market place—pressures to produce more efficiently, with superior quality, and responsively to shifts in market demand. In this paper, we explore the reciprocal nature of quality and environmental improvement. We show via survey data and qualitative analyses that improvement efforts are complementary across environmental and quality outcomes. We thus move away from recent studies that view environmental outcomes as dependent variables (e.g., Porter and Van Der Linde 1995; Rothenberg, Pil, and Maxwell 2001), to exploring both theoretically and empirically how environmental performance may enable other types of manufacturing improvements.

2. Background: The Environment-Performance Debate

There is on-going debate as to whether superior environmental performance comes at the expense of or complements broader organizational performance. On the one hand are those

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who argue that investments related to environmental regulation and social responsibility more generally are associated with lower performance (Walley and Whitehead 1994; Ullmann 1985; Cordeiro and Sarkis 1997). One view suggests that, as organizations shift their attention to enhancing environmental performance, they are drawing resources and management effort away from other core areas of the business. Investments in environment from this perspective thus represent non-core expenditures, rendering it difficult to attain other competitive improvements (Walley and Whitehead 1994; Klassen and Whybark 1999).

In contrast to the trade-offs perspective, a large number of researchers argue that superior environmental performance can translate into broader improvements in organizational outcomes (c.f. Porter and Van Der Linde 1995; Gupta 1995; Sarkis and Rasheed 1995; Klassen and Whybark 1999; Schmidheiny 1992). For example, in a study of corporations in the Standard and Poor's 500 Index, Hart and Ahuja (1996) found that efforts to reduce emissions were significantly related to an increase in operating performance after 1 year and an increase in financial performance after 2 years. These findings are consistent with those of Morris (1997), who found that among firms filing TRI reports, environmental performance contributed to a cost advantage and higher ROE. Similarly, Klassen and McLaughlin (1996) show that awards for environmental performance lead to superior financial market outcomes in the form of positive abnormal stock returns, and Cohen, Fenn, and Konar (1997) found that portfolios of high-polluting firms do not outperform portfolios of low polluters.

With respect to manufacturing performance specifically, earlier research argued that environmental performance and productivity or cost are negatively related. Christiansen and Haveman (1981), in a survey article on the relationship between regulation and productivity, attribute 8–12% of the post-1965 reduction in productivity growth in manufacturing to the growth of environmental regulations. Similarly, Barbera and McConnell (1990) found that increased pollution abatement was related to lower factor productivity. In contrast to these negative finds, Schmidheiny (1992) argued that environmental practices help reduce costs associated with material waste and inefficient production processes. Klassen and Whybark (1999) found a positive relationship between investments in environmental technologies and a series of self-reported measures of organizational performance in the furniture industry. The positive relationship held for cost, speed, and flexibility performance, but no significant relationship was found between environmental technology and quality. Porter and Van Der Linde (1995) examined the product yield of 20 different waste prevention activities and found that the average yield increases were on the order of 7%. Given the variable association between environment and manufacturing performance, it is important to examine the theoretical foundations underlying environmental improvement and relate those to other aspects of organizational improvement.

There is a growing body of literature linking environmental improvement efforts to lean production (c.f. Shrivastava 1995; Florida 1996; Hart 1997; Golhar and Stamm 1991; King and Lenox 2001; Rothenberg et al. 2001). Earlier literature centers on the connection between batch sizes, just in time, and other specific lean practices, and their implications for the environment (c.f. Florida 1996; Pil and MacDuffie 1999; Holweg and Pil 2001). There is some debate as to whether specific aspects of lean, such as lot-sizes of one, and frequent deliveries might increase environmental burden (Handfield, Walton, Seegers, and Melnyk 1997). However, most empirical research sides with the observation that lean practices are associated with superior environmental performance. King and Lenox (2001), for example, found that there is a strong tie between the low inventories associated with lean and Toxic Release Inventory performance, and Rothenberg et al. (2001) find both qualitative and quantitative links between lean management practices and resource efficiency.

3. Quality and Environmental Improvement Efforts

The main causal link between lean and environmental performance is centered on the notion that the presence of lean reduces the marginal implementation cost of superior environmental practices (Rothenberg et al. 2001; King and Lenox 2001). Specifically, many researchers have argued that the total quality movement is one way in which environmental issues can be integrated into business choices (Walley and Whitehead 1994; Cairncross 1992). Part of the appeal of TQM lies in its emphasis on getting things right from the start, elimination of waste, as well as its focus on continuous improvement (Shrivastava 1995). These same principles hold with respect to environmental matters, leading to the term Total Quality Environmental Management (Willig 1994; Shrivastava 1995; Welford 1992).

In terms of both procedures and implemented practice, TQM and TQEM have much in common. The cross-functional nature of environmental problems is closely paralleled, for example, on the quality front. Lawrence and Morell (1995) found that, out of 8 firms identified as having leading edge environmental practices, only 1 did not have cross-functional teams. Similarly, Angell (2001) examined 10 Malcolm Baldridge award winners and found that key to both successful quality and environmental initiatives was interfunctional coordination. Beyond cross-functional interaction, there are broader synergies between TQM and environmental practices. Both rely, for example, on bottom-up systems for capturing process information, insight, and opportunities for innovation (Angell and Klassen 1999). The focus on continuous improvement as well as the broader planning and implementation of TQEM are believed to parallel those of TQM quite closely and empirically; researchers have shown the use of these often develops in parallel (Clements 1997; Corbett and Kirsch 2001).

There is evidence that manufacturing and technology strategies that enhance quality and efficiency also impact environmental performance *levels* positively (King and Lenox 2001). Firms are able to transfer learning and insight from existing quality programs to their environmental improvement efforts. As Angell (2001) noted, ". . . operations and environmental managers at the grass-roots level can often clearly see the waste and cost reduction opportunities presented by potential environmental initiatives, and may be able to successfully draw on experience with quality tools and processes. . . " Hart (1997) noted that TQM predisposes firms ". . . to accumulate the resources necessary for pollution prevention more quickly than firms without such prior capability." In the presence of existing TQM practices, workers have an easier time understanding the tools necessary for environmental improvements (King and Lenox 2001). Quality and environmental problems have many of the same causal factors, including complex interactions and potential conflicts with day-to-day operations, and they are managed with similarly structured reporting systems and information evaluation models. As a result, environmental performance is often positively correlated with quality (c.f. King and Lenox 2001).

While the connection between quality and environment is clearly established, it is not clear whether environmental improvement efforts can have reciprocal benefits on quality. Porter (1991) and Shrivastava (1995) hypothesized that introducing the management systems associated with TQEM should result not only in reduced pollution, but might also improve manufacturing performance. Enhancing environmental performance involves root-cause analyses, data tracking efforts, and structured reporting and information evaluation systems analogous to those used to enhance quality, and may result in a shift in management orientation toward the tools and systems associated with TQM (Shrivastava 1995; Beechner and Koch 1997).

We hypothesize that the greater emphasis on TQM-related tools and management philosophy at companies and plants focusing on environmental improvement will have spillover effects on the quality front. There is some anecdotal evidence based on a review of 10 corporate success stories of the 1990s that this should be the case (see McInerney and White

1995). However, the causality in that study was hard to prove. It has been argued that environmental improvement efforts are more nuanced than quality improvement efforts (Chinander 2001). The level of technical and managerial sophistication required to attain environmental performance improvements may provide superior understanding and application of TQM procedures and practices to their original mandate of quality improvement. This leads us to our main hypothesis:

HYPOTHESIS 1. (*a*) *Superior environmental performance is associated with superior quality*. (*b*) *Efforts to attain superior environmental performance positively influence quality*.

4. Methods

While much of the research relating to environmental performance is centered on company level data, Angell and Klassen (1999) argue that there is a specific need to examine operations level environmental performance, and to "clarify the mechanisms that act specifically within operations." This is consistent with observations that developing and exploiting environmental efficiencies can provide sources of competitive advantage for business units and establishments within companies (Buzzelli 1991; Roome 1992). Klassen (2001) also observed that manufacturing specifically plays a critical role in determining both corporate environmental performance and ecological impact. This is consistent with the views of Klassen and Whybark (1999), who note that the operations level in factories is where management practice and environmental performance come together. To this end, we are limiting our analyses to manufacturing plants and, to facilitate comparisons, we are limiting our study to a single industry—the auto manufacturing sector—to ensure similarity in products, underlying process technologies, raw material inputs, etc.

We use a two-part approach to explore how environmental performance relates to quality. We draw upon survey data to quantitatively assess the relationship. We then enhance the reliability of our quantitative findings and our understanding of causality via interview data.

4.1. *Survey Method*

To measure environmental performance, we are drawing on data from a global survey of automotive assembly plants, focusing specifically on the paint process. We approached all major automotive manufacturers in the world with a request for help in surveying their automotive assembly plants. We received direct or indirect assistance from every company approached, and received completed surveys from 71 facilities in 2000–2001 representing 17 different OEMs. Because there is no comprehensive data set of all auto-assembly factories in the world, it is hard to determine how these plants are different from non-responding facilities. However, anecdotal discussions and plant visits suggest that many of these plants represent the "better" factories in the eyes of corporate management. Of the 71 facilities, 42 sold their products in the United States at the time of the survey. For these 42 plants, we were able to obtain contemporaneous plant-specific quality performance data from J.D. Power and Associates. The latter data are collected from a large-scale survey of customers after 3 months of ownership, and capture the full range of problems customers could have experienced with their vehicles. All customer data are then linked back to the specific plants that build each vehicle.

Automotive paint application is generally considered the process that has the greatest environmental impact in automotive assembly factories (Rothenberg et al. 2001). We are measuring environmental impact via three paint shop-specific measures—two of them capturing efficient utilization of resources, and one centered on emissions: (a) paint utilization per vehicle, (b) water utilization per vehicle, and (c) Volatile Organic Compound (VOC) emissions per vehicle. We assess paint shop quality via two problem categories on the J.D. Power survey: (a) paint chips and (b) paint blemishes identified by customers. For plants producing more than one product, the J.D. Power quality data for each model built at the plant were weighted by the annual production volume of the model in that plant.

As we have discussed, there is a close relationship between TQM and TQEM, and we are interested in capturing the extent to which environmental improvement is associated with superior quality improvements. We therefore control for exterior vehicle quality in exploring the specific influence that environmental performance in the paint shop has on paint shop quality. There are also a number of factors that can affect paint quality as well as resource utilization and emissions that we need to control for. Specifically, in discussions with plant engineers, paint shop automation has been associated with superior quality. Paint formulation (water-based in contrast to solvent-based paint) and vehicle size are also associated with water and paint utilization and emissions. We therefore have a total of four controls:

- Total Exterior Vehicle Defects measured via J.D. Power Initial Quality Survey;
- Paint Formulation, determined by a dummy variable set at 1 if paint used is water-based, 0 otherwise;
- Paint Shop Automation measured as a fraction of potential manual steps that are fully automated (MacDuffie and Pil 1997); and
- Vehicle Dimensions, measured by vehicle length.

Table 1 provides descriptive statistics for the variables under consideration. Consumers reported an average of almost 7 paint-specific defects for every 100 vehicles considered, and approximately 32 total exterior defects. On average, approximately 1 in 4 plants was utilizing water-born base coat material. The average paint shop automation was 56%, although there was significant variance across plants. The average plant used 16.6 liters of paint and related fluids per vehicle and 5,000 gallons of water. The average plant emitted 11.1 Kg of VOCs per vehicle.

4.2. *Plant Level Interviews*

Data on environmental management practice were gathered via semi-structured interviews at 17 plants (Yin 1994; interview protocol is available from the authors). Each company largely determined plant selection. Therefore, it is likely that plants represented each company's leading plants in terms of environmental management and performance. While no plant can be individually identified for confidentiality reasons, 11 plants were visited in North America and 6 plants in Japan. Visits to Japanese plants were 1–2 days long, while most visits to North American plants ranged from 3 to 5 days. Visits to 4 of the North American plants were a month long in duration. The purpose of these trips was to gain greater insight into the survey results and to obtain more detailed information on environmental management and performance. In all plants visited, we requested to speak to the environmental manger, facility manager, paint shop manager, paint shop engineers, and paint shop maintenance. Environmental and facility personnel are important because they often play critical roles in the environmental performance of the plant. As paint shop operations account for a

TABLE 1
Key Variables

Variable	Mean	Standard Deviation
Paint-Specific Defects per 100 vehicles in 1999	6.77	3.42
Total Exterior Defects per 100 vehicle in 1999	31.8	11.32
Water-Based Top Coat (1 = yes; 0 = no)	28%	
Paint-Shop Automation	0.56	0.202
Vehicle Length (inches)	180.9	19.4
Paint Utilization per Vehicle (Liters)	16.6	15.5
Water Utilization per Vehicle (1000 Liters)	4.73	2.9
VOC Emissions per Vehicle (Kg)	11.1	6.56

large percentage of plant pollutants, interviewing paint shop managers and engineers was critical to understanding paint shop management. When possible, the plant manager, health and safety managers, and logistic engineers were interviewed to obtain additional perspectives on overall environmental philosophy and chemical management. The 4-month-long cases further involved interviews with area managers, quality engineers, process engineers, line workers, team leaders, maintenance personnel, facility engineers, suppliers, waste management staff and cleaning staff, as well as participant observation in environmental and paint shop team meetings.

In contrast to the survey, which focused on output-oriented performance measures, the interviews focused on management practice, processes, and technologies in an effort to explore causal links between environmental performance and quality. First, we coded the interviews according to a number of themes: environmental policy/strategy, environmental management structure, regulation, resource management, paint shop management, solid waste, VOC Emissions, paint shop technology, quality, worker participation, and lean production. Ideas on quality and the environment were coded using Nvivo qualitative data analysis software. As suggested by Miles and Huberman (1994) and Yin (1994), we then placed interview data in a comparative matrix in order to explore how the plants differ from one another. In this matrix, a mixture of key observations, quotes, and summary phrases were used for quick reference. Analysis, however, required that we often referred back to the original interview to look at the comments in context. We used logic of comparative analysis across projects in an iterative manner, with a search for underlying patterns in the data (Eisenhardt 1989). Working in this fashion, underlying patterns emerged in the data regarding how environmental performance and environmental management were related to quality.

Second, for each plant, some data were pulled out and coded numerically. Here, we focused on information that could be coded with little coder bias, such as frequencies, percentages, and other numeric answers. The categories used in this paper focus on measuring and using data. For comparative purposes, plants were divided into two categories based on level of product quality, as obtained from the J.D. Powers index. High quality plants were those below the mean level (i.e., fewer defects), and low quality plants were equal to or above the mean level.

5. Findings

5.1. *Survey Results*

Table 2 provides a correlation matrix for all key variables. There is a clear and positive correlation between the total number of exterior defects, and paint-related defects, suggesting that there are clear plant-level capabilities associated with quality improvement generally. There is also a positive and significant correlation between paint utilization and VOC emissions and paint defects. Because more defects are indicative of poorer quality, the correlations suggest that plants with greater resource utilization and higher emissions levels have poorer associated quality.

Table 3 explores these relationships in a multivariate fashion. The findings suggest that total exterior defects are strongly related to defects related to the paint process. We also note that automation decreases paint-related defects. With regards to the environmental variables, we find strong support for the hypothesis that superior environmental performance is associated with better quality. Since exterior quality captures the plant’s broader TQM capabilities, the positive relationship between paint utilization and VOC emissions and paint-related quality suggests that plants that have reined these in have also attained superior paint-related quality. Likewise, lower paint utilization is actually associated with superior quality. However, this is not true for water utilization. Lower water use is associated with inferior quality.

Due to the cross-sectional nature of our data, we cannot draw causal inferences about

TABLE 2
Correlations

	Paint Def	Total Def.	Water-based	Pnt. Auto	Length	Pnt. Use	Water Use	VOC Emis.
Paint-Specific Defects Per 100 vehicles in 1999	1.00							
Total Exterior Defects per 100 Vehicles	0.575**	1.000						
Water-Based Paint	−0.254	−0.292	1.000					
Paint-Shop Automation	−0.213	−0.114	−0.032	1.000				
Vehicle Length	−0.081	−0.113	0.168	0.356*	1.000			
Paint Utilization per Vehicle	0.440*	0.314	−0.006	0.139	0.209	1.000		
Water Utilization per Vehicle	0.103	0.164	−0.172	−0.086	0.107	0.076	1.000	
VOC Emissions per Vehicle	0.382*	0.104	−0.058	0.004	0.092	0.259	0.289	1.000

*, Significant at 0.05 level.
**, Significant at 0.01 level.

environmental performance and its impact on quality. We can only observe that controlling for overall plant quality-related capabilities, superior environmental performance is associated with superior quality in those areas that have the greatest implications for environmental outcomes.

5.2. *Interview Results*

5.2.1. TRADEOFFS: LINGERING SUPERSTITIOUS BELIEFS. In many of the plants visited, there remains a fear that changing the content or use of materials, such as paint, solvents, and water, for the purpose of environmental improvement may reduce paint quality. As explained by a supplier, “It’s the typical environmental dilemma. Should I save resources or have better quality?” This is particularly believed to be true in the paint shop. One plant in Japan, for example, chose not to adopt a water-saving process in the paint shop because of quality concerns, even though it was being used with success at a U.S. plant.

These concerns exist in all quality-focused plants, even when the concern is not warranted. An environmental engineer discussed how preoccupation with quality at his plant sometimes precluded moving forward with environmental initiatives: “They probably acquired some superstitions along the way—about if a little cleaning solvent is good then maybe more is better, and they just kind of lost track of the environmental values. . . . that’s my interpre-

TABLE 3
Predicting Paint-Specific Defects

Independent Variable	Model 1a	Model 1b
Total Ext. Defects per 100 Vehicle	.193 (.061)**	.199 (.05)***
Water-Based Paint	−.522 (1.26)	−1.52 (.93)
Paint-Shop Automation	−1.3 (3.26)	−5.42 (2.6)*
Vehicle Length	0.009 (0.04)	.015 (.032)
Paint Utilization per Vehicle		.065 (.031)*
Water Utilization per Vehicle		−0.52 (0.17)**
VOC Emissions per Vehicle		0.17 (0.068)*
F	3.35*	6.75***
F Change		6.89***
Adj. R^2	.43	.76

Dependent variable: Paint-Specific Defects per 100 vehicles in 1999.
*, Significant at 0.05 level; **, Significant at 0.01 level; ***, Significant at 0.001 level.

tation of why they don't quite get it. . . . It's the old production mentality. . . They don't understand that maybe they could cut back on purge cycles and not cause a quality problem."

In some cases, these concerns are valid. However, as we shall see in the next section, many of them are indeed superstitions; environmental staff has to work closely with paint shop employees to dispel them. Moreover, consistent with our quantitative findings, our qualitative research found that improving environmental performance can actually improve quality.

5.2.2. QUALITY AND ENVIRONMENT: A RECIPROCAL RELATIONSHIP. Interviews revealed a reciprocal relationship between quality and the environment. As discussed earlier, the more commonly discussed relationship is that quality influences environmental performance. First, the practices associated with increased quality also improve environmental performance. Second, poorer product quality can imply a poorer quality process with higher material use because of rework. The result is decreased environmental performance. As explained by one worker: "the amount [of paint] that they are using varies depending on what quality issues they are having at the time. Sometimes they will have a lot of one type of problem, and then they will use more of a material."

In our interviews, we consistently found that changes in materials or processes that were targeted to improved quality had the additional benefit of enhanced environmental performance. In one plant, a supplier introduced a new "ELPO" solution, which would result in higher quality and lower maintenance. An environmental engineer attended the presentation and saw that the new solution would also reduce lead in the paint shop waste and facilitated the adoption of this new material. In another plant, quality problems were developing when wrenches would slip into the paint vats. Because the vats were difficult to open, the wrenches would be left in the vats, ultimately degrading the product quality. The paint shop's production workers came up with a new valve design that not only eliminated this quality problem but also allowed for more efficient use of the paint.

A detailed analysis of worker level suggestions at one plant further reflects the relationship between quality and the environment. At this plant, 744 suggestions from the suggestion program were reviewed, coded, and analyzed. Eleven percent of all suggestions had implications for both quality and environmental performance. For example, a suggestion to pad a part delivery cart to reduce damage to painted parts might be allocated points for resulting in quality improvement, while it also reduced scrap, paint use, and VOC emissions from rework.

The less intuitive aspect of the relationship between quality and environment is that environmental improvements also lead to improved quality. This was a common occurrence in a large fraction of the paint shops we visited. In most instances, environmental staff is actively engaged with identifying measures to reduce VOC emissions. In one plant we studied, environmental staff members were hard pressed to meet VOC permit limits. An environmental staff member looked at the efficiency of the paint booth, measured the pressure on each of the hoses leading to the paint applicators (mini-bells), and found a significant difference in pressure between the two hoses. Adjusting the pressure not only reduced solvent and paint use, but also allowed the paint shop to have more complete color changes and, as a result, increased quality.

Environmental staff also influenced paint quality by confronting existing norms, discussed above, regarding the use of thinners and cleaners. In one plant, environmental staff worked with the paint staff to reduce thinner usage, fighting the existing norm that "more was better." One paint manager recalled, "Most of them thought, like me, that air pollution was a pain in the butt. . . I have to clean. I have to clean my machines. I have to use thinner. I cannot just pour it here and pour it there." After a period of negotiation between environmental and paint shop staff, the paint shop reduced thinner use and found that paint quality improved as a result. With the former level of thinner use, the thinner went in between the cracks and diluted the paint. In turn, the dry paint would become volatile and go on the car. Through the initiative of the environmental staff, it was discovered that "excessive cleaning was a quality problem."

The contribution of environmental projects to quality is so clear to some environmental staff that they wait until quality problems surface in order to propose environmental solutions that will also address these quality problems. In one plant, the environmental manager wanted to switch to a more efficient type of paint gun to reduce material use and, in turn, VOCs. The paint shop managers showed little interest at the time. When the paint shop received a poor quality review from the corporate office, the environmental manager took this "window of opportunity" to bring attention to his request for the newer paint guns. At the time of the interview, he was planning a similar strategy for addressing a problem with oven moisture, which he was concerned about from an environmental performance standpoint, yet that also had quality implications.

At its core, the reciprocal relationship between quality and environment provides synergistic benefits in the form of a tightly controlled manufacturing process. As a typical paint manager stated, "You can't control the process without controlling the variables." One of the key mechanisms by which plants obtain this control is data collection and use. As shown in Table 4, of the 17 plants visited, plants that had higher quality according to J.D. Powers measures tended to have a greater number of energy and water meters. Plants with better quality reported having on average 3.4 energy meters and 4.1 water meters. In comparison, plants with lower quality reported having on average 2.5 energy meters and 2.2 water meters. Plants with higher quality charted and posted water use at the department level more often than those plants with lower product quality (on average, less than once a year for lower quality plants vs. several times a year for higher quality plants). The same held true with respect to posting purge solvent use (on average at least once a day for lower quality plants vs. at least once a shift for higher quality plants). Similar differences, although not as large, existed for how often plants posted cleaner solvent and energy use at the department level.

Interviews provided further depth to this relationship. Plant employees suggested that identifying changes in environmental data can lead to the identification of quality problems. One environmental manager stated, "I usually catch on to a problem by looking at the data. If I see a change, it may point to a problem with the process. . . I often see a change in the process that adversely affects quality." As an example, an increase in purge solvent use

TABLE 4

Natural Resource Measurement and Use (averages from each category)

Total Number of Exterior Defects	*N*	Number of Energy Meters in Strategic Locations	Number of Water Meters in Strategic Locations	Frequency Chart Water Use Dept. Level[1]	Frequency Post Water Use Dept. Level[1]	Frequency Chart Energy Use at Dept. Level[1]	Frequency Post Energy Use at Dept. Level[1]
Total Defects ≥ mean	8	2.5	2.2	.42	.42	1.42	1.14
Total Defects < mean	9	3.4	4.1	1.8	1.8	1.5	1.62

Total Number of Exterior Defects	*N*	Frequency Measuring Cleaning Solvent[2]	Frequency Measuring Purge Solvent[2]	Frequency Measuring Coatings[2]
Total Defects ≥ mean	8	3.1	3.2	3.7
Total Defects < mean	9	3.6	4.0	3.6

[1] Coding: 0 = Never; 1 = Once a year; 2 = Between once a year and once a month; 3 = Between once a month and once a week; 4 = Once a week; 5 = More often than once a week.

[2] Coding: 1 = Less often than once a week; 2 = At least once a week; 3 = At least once a day; 4 = At least once a shift; 5 = At least every hour.

revealed that workers were purging guns between every vehicle, which was upsetting booth balance and, in turn, the quality of the paint job. Similarly, in another plant, employees in the water treatment facility discussed how changes in the chemistry of the water treatment system reveal when and how the paint process is not operating optimally. Because of their access to this data, environmental staff could catch paint process problems before paint shop staff noticed these problems.

Interviews suggested that, while environmental staff could use their data to identify quality problems, there still is room for greater recognition of this ability from other plant personnel. While environmental staff saw the value of their information, other staff did not always see it as a benefit. One environmental manager stated, “I’m not sure if it’s [seen as] information or condemnation.” The examples cited above involved environmental staff reaching out to paint shop or other employees when something changed in the process. If engineering and other paint shop staff worked closer with environmental staff, or had access to waste-related data, there is no doubt that further quality benefits could be attained.

6. Conclusions

While quality-related tools are used in enhancing environmental performance, we have shown that the application of these tools to environmental issues has corollary implications for quality. Firms that have attained superior performance on the environment front are able to leverage those efforts to enhance their quality profile. This finding is very important in the auto sector, where quality differentials between U.S. producers and their overseas counterparts were a major factor in the decline of U.S. OEM market share (Devaraj, Matta, and Conlon 2001).

From a management standpoint, a survey conducted by the National Association of Environmental Managers suggested that most organizations view efforts to improve environmental performance as a compliance issue (Sarkis 1995). Our findings suggest that, in addition to responding to pressure from regulators, there are opportunities to utilize environmental efforts to further enhance performance outcomes, like quality, that directly benefit the organization. Angell (2001) noted that environmental managers evaluate success by the extent to which implementation has increased management awareness of environmental issues, while quality managers are more concerned with attaining specific quality goal. This paper highlights the importance of cross-fertilization between the quality and environment arena and suggests that a fruitful avenue for environmental managers to gain senior management support is to document quality improvement outcomes incidental to environmental improvement efforts.

The connection between environmental performance and quality parallels findings on the product development front, which suggest that environmental improvement efforts can trigger innovations unrelated to the environmental improvements (Porter and Van Der Linde 1995). A key question is whether this finding translated into other dimensions of manufacturing. For example, Bowen, Cousins, Lamming, and Faruk (2001) found, based on interviews at 24 business units of U.K. corporations, that supply management capabilities are important reasons to engage in green supply. Does focusing on green supply have reciprocal benefits for the broader supply management capabilities? Likewise, Guide and Van Wassenhove (2001) noted that managing product returns is a very important capability associated with remanufacturing. Is it possible that a superior products return model may also be complementary, and provide benefits for, the broader value chain capabilities related to new products?

This paper provides a significant first step in highlighting the reciprocal influences between key environmental performance metrics, manufacturing resource utilization and emissions, and non-environmental outcomes. It reinforces the perspective that environmental improvement efforts may have benefits that extend beyond compliance, and is indicative of fruitful avenues for future inquiry regarding implications of environmental improvement efforts.[1]

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References

ANGELL, L. C. (2001), "Comparing the Environmental and Quality Initiatives of Baldridge Award Winners," *Production and Operations Management*, 10, 3, 306–326.

ANGELL, L. C. AND R. D. KLASSEN (1998), "An International Comparison of Environmental Management in Operations: The Impact of Manufacturing Flexibility in the US and Germany," *Journal of Operations Management*, 16, 2/3, 177–194.

BARBERA, A. J. AND V. D. MCCONNELL (1990), "The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects," *Journal of Environmental Economics and Management*, 18, 50–65.

BEECHNER, A. B. AND J. E. KOCH (1997), "Integrating ISO 9001 and ISO 14001," *Quality Progress*, 30 2, 33–36.

BOWEN, F. E., P. D. COUSINS, R. C. LAMMING, AND A. C. FARUK (2001), "The Role of Supply Management Capabilities in Green Supply," *Production and Operations Management*, 10, 2, 174–189.

BUZZELLI, D. (1991), "Time to Structure an Environmental Policy Strategy," *Journal of Business Strategy*, 12, 2, 17–20.

CHINANDER, K. R. (2001), "Aligning Accountability and Awareness for Environment Performance in Operations," *Production and Operations Management*, 10, 3, 276–291.

CHRISTIANSEN, G. B. AND R. H. HAVEMAN (1981), "Public Regulation and the Slowdown of Productivity Growth," *Journal of Environmental Economics and Management*, 8, 381–390.

CLEMENTS, R. B. (1997), *Complete Guide to ISO14000*, Prentice Hall, Englewood Cliffs, New Jersey.

COHEN, M. A., S. A. FENN, AND S. KONAR (1997), "Environmental and Financial Performance: Are They Related?" Vanderbilt University, Nashville, Tennessee.

CORBETT, C. J. AND D. A. KIRSCH (2001), "International Diffusion of ISO 14000 Certification," *Production and Operations Management*, 10, 3, 327–342.

CORBETT, C. J. AND P. R. KLEINDORFER (2001), "Environmental Management and Operations Management: Introduction to Part 1 (Manufacturing and Eco-Logistics)," *Production and Operations Management*, 10, 2, 107–112.

CORDEIRO, J. AND J. SARKIS (1997), "Environmental Proactivism and Firm Performance: Evidence from Industry Analyst Forecasts," *Business Strategy and the Environment*, 6, 2, 104–114.

DEVARAJ, S., K. F. MATTA, AND E. CONLON (2001), "Product and Service Quality: The Antecedents of Customer Loyalty in the Automotive Industry," *Production and Operations Management*, 10, 4, 424–439.

EISENHARDT, K. M. (1989), "Building Theories from Case Research," *Academy of Management Review*, 14, 4, 532–550.

FLORIDA, R. (1996), "Lean And Green: The Move To Environmentally Conscious Manufacturing," *California Management Review*, 39, 1, 80–105.

GUIDE JR., V. D. AND L. N. VAN WASSENHOVE (2001), "Managing Product Returns for Remanufacturing," *Production and Operations Management*, 10, 2, 142–155.

GUPTA, M. C. (1995), "Environmental Management and Its Impact on the Operations Function," *International Journal of Operations and Production Management*, 15, 8, 34–51.

HANDFIELD, R. B., S. V. WALTON, L. K. SEEGERS, AND S. A. MELNYK (1997), "Green Value Chain Practices in the Furniture Industry," *Journal of Operations Management*, 15, 4, 293–315.

HART, S. L. (1997), "Beyond Greening: Strategies for a Sustainable World," *Harvard Business Review*, 75, 1, 66–76.

HART, S. AND G. AHUJA (1996), "Does It Pay To Be Green? An Empirical Examination of the Relationship between Emission Reduction And Firm Performance," *Business, Strategy and the Environment*, 5, 30–37.

HOLWEG, M. AND F. K. PIL (2001), "Successful Build-to-Order Strategies Start with the Customer," *Sloan Management Review*, 43, 1, 74–83.

KING, A. AND M. J. LENOX (2001), "Lean and Green? An Empirical Examination of the Relationship Between Lean Production and Environmental Performance," *Production and Operations Management*, 10, 3, 244–256.

KLASSEN, R. D. AND C. P. MCLAUGHLIN (1996), "The Impact of Environmental Management on Firm Performance," *Management Science*, 42, 8, 1199–1214.

KLASSEN, R. D. AND D. C. WHYBARK (1999), "The Impact of Environmental Technologies on Manufacturing Performance," *Academy of Management Journal*, 42, 6, 599–615.

KLASSEN, R. D. (2001), "Plant-Level Environmental Management Orientation: The Influence of Management Views and Plant Characteristics," *Production and Operations Management*, 10, 3, 257–275.

LAWRENCE, A. T. AND D. MORELL (1995), "Leading Edge Environmental Management: Motivation, Opportunity, Resources, and Processes" in *Research in Corporate Social Performance and Policy*, J. E. Post (ed.), JAI Press, Greenwich, Connecticut, Supplement 1, 99–126.

MACDUFFIE, J. P. AND F. K. PIL (1997), "Flexible Technologies, Flexible Workers," in *Transforming Auto Assembly – International Experiences with Automation and Work Organization*, T. Fujimoto and U. Jurgens (eds.), Springer Verlag, Frankfurt, 238–255.

MORRIS, S. A. (1997), *Environmental Pollution and Competitive Advantage: An Exploratory Study of U. S. Industrial-Goods Manufacturers*, Academy of Management Proceedings, Academy of Management, Boston, Massachusetts, 411–415.

OTTMAN, J. (1992), *Green Marketing: Challenge and Opportunities for the New Marketing Age*, NTC Business Books, Lincolnwood, Illinois.

PIL, F. K. AND J. P. MACDUFFIE (1996), "The Adoption of High-Involvement Work Practices," *Industrial Relations*, 35, 3, 423–455.

PIL, F. K. AND J. P. MACDUFFIE (1999), "What Makes Transplants Thrive: Managing the Transfer of 'Best Practices' at Japanese Auto Plants in North America," *Journal of World Business*, 34, 4, 372–391.

PORTER, M. E. AND C. VAN DER LINDE (1995), "Toward a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives* 9, 4, 97–118.

ROOME, N. (1992), "Developing Environmental Strategies," *Business Strategy and the Environment*, 1, 1, 11–24.

ROTHENBERG, S., F. K. PIL, AND J. MAXWELL (2001), "Lean, Green, and the Quest for Superior Environmental Performance," *Production and Operations Management*, 10, 3, 228–243.

SARKIS, J. (1995), "Manufacturing Strategy and Environmental Consciousness," *Technovation*, 15, 2, 79–97.

SARKIS, J. AND A. RASHEED (1995), "Greening the Manufacturing Function," *Business Horizons*, 38, 5, 17–27.

SCHMIDHEINY, S. (1992), *Changing Course: A Global Business Perspective on Development and the Environment*, MIT Press, Cambridge, Massachusetts.

SHRIVASTAVA, P. (1995), "Environmental Technologies and Competitive Advantage," *Strategic Management Journal*, 16, special issue, 183–200.

ULLMANN, A. A. (1985), "Data in Search of a Theory: A Critical Examination of the Relationships Among Social Performance, Social Disclosure and Economic Performance of U. S. Firms," *Academy of Management Review*, 10, 3, 540–557.

WALLEY, N. AND B. WHITEHEAD (1994), "It's Not Easy Being Green," *Harvard Business Review*, 72, 3, 46–52.

WELFORD, R. (1992), "Linking Quality and the Environment: A Strategy for the Implementation of Environmental Management Systems," *Business Strategy and the Environment*, 1, 1, 25–34.

WILLIG, J. T. (ED.), (1994), *Environmental TQM*, McGraw-Hill, New York.

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