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Measuring TQEM Returns from the Application of Quality Frameworks

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ABSTRACT
This study addresses one of the major perceived barriers to total quality environmental management (TQEM): cost measurement. Operations managers have difficulty assessing the impact of TQEM programs because of the lack of appropriate measures. In order for TQEM to be given serious consideration, a cost framework is required for evaluating TQEM by appropriately including all the environmental costs and savings for each investment option. At present, frameworks such as life-cycle assessment (LCA) and environmental cost accounting (ECA) exist, but they have both been recognized as too difficult to implement at the plant level among operations managers. This study focuses on identifying and formulating a set of easy-to-use quantitative cost measures. The structure of these measures is taken from the operations management (OM) literature itself, and specifically the total quality management (TQM) and cost of quality (COQ) frameworks developed by Joseph Juran. However, an empirical examination of this remains untested. The findings of this study provide an important foundation for theory development and set the stage for further research in this burgeoning field of TQEM. Copyright © 2005 John Wiley & Sons, Ltd and ERP Environment.

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Introduction

AS FIRMS STRIVE TO IMPROVE THEIR BOTTOM LINE, MANY FIND THAT TRADITIONAL POLLUTION prevention techniques are no longer cost effective. In fact, many manufacturers have found that minimizing or avoiding waste generating activities altogether is a much more cost effective solution than traditional 'end-of-pipe' strategies. Replacing these traditional strategies is a new

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proactive approach known as total quality environmental management (TQEM) (Bhat, 1998). The TQEM concept, based on the theories of Deming, Juran and Crosby to name a few, combines the principals of total quality management (TQM) with the goals of environmental management. This gradual evolution of quality to include aspects of the environment has been anticipated by several authors (Mizuno, 1988; Willig, 1994; May and Flannery, 1995; Sarkis and Rasheed, 1995; Epstein, 1996a, 1996b; Hanna *et al.*, 2000; Curkovic *et al.*, 2000).

TQEM has been defined as an economically driven, system-wide and integrated approach to the reduction and elimination of all waste streams associated with the design, manufacture, use and/or disposal of products and materials (Willig, 1994; Bhat, 1998; Curkovic and Landeros, 2000; Handfield *et al.*, 1997; Melnyk *et al.*, 2001). Fundamental to TQEM is the recognition that pollution, irrespective of its type and form, is waste. Strategies such as just-in-time (JIT), total quality management (TQM) and time-based competition (TBC) have defined waste as any activity or product that consumes resources or creates costs without generating any form of offsetting stream of value (Walley and Whitehead, 1994; Porter and Van der Linde, 1995a, 1995b). By minimizing waste, the firm can reduce disposal costs, environmental health and safety (EH&S) issues and permit requirements, avoid environmental fines, boost profits, discover new business opportunities, rejuvenate employee morale and protect and improve the state of the environment (Hanna *et al.*, 2000).

From an operations management perspective, simultaneous cost reduction and waste reduction have been demonstrated throughout processes in areas encompassing shipping and distribution costs, raw material costs, actual manufacturing and processing costs, packaging costs, costs of treatment or disposal of process emissions, landfill use costs and customer disposal costs (Hanna and Newman, 1995). It would be expected that more managers would be interested in the development and use of TQEM based systems. However, for most firms, TQEM has not achieved the same degree of acceptance as have JIT, TQM and TBC (Angell and Klassen, 1999; Epstein, 1996a, 1996b; Makower, 1993, 1994).

The challenge of determining whether it is better for the firm to simply emphasize compliance or whether the firm wants to become recognized as an industrial leader in the development and application of TQEM based systems describes the first of many obstacles and paradoxes surrounding the TQEM literature. In large part, the failure of management to become more environmentally responsible is really a reflection of its inability to address and resolve these paradoxes and problems. The following are some of the most important paradoxes and problems associated with the development and implementation of TQEM systems.

- Top management must be willing to accept and champion corporate-wide developments if TQEM is to become widespread (Hunt and Auster, 1990; Epstein, 1996a, 1996b; Hanna *et al.*, 2000). However, when dealing with TQEM, there is a strong bias in favor of ignorance at the highest levels of the firm (Makower, 1993, 1994; ReVelle, 2000).
- In the short run, implementing TQEM often causes costs to rise (Palmer *et al.*, 1995; Hanna *et al.*, 2000). However, there is a real concern as to whether customers are willing to pay the added costs associated with having something that is environmentally friendly (Rosewicz, 1990; Willig, 1994; Hanna and Newman, 1995).
- It has been argued that being environmentally responsible ultimately makes a company more efficient and more competitive (Klassen and McLaughlin, 1993; Klassen, 1993; Klassen and Whybark, 1994; Willig, 1994; Geffen and Rothenberg, 2000). However, there are many reported cases of ERM investments that have resulted in negative returns (Makower, 1993, 1994; Walley and Whitehead, 1994; Klassen and Angell, 1998).
- Ideally, the most appropriate place for considering TQEM issues is in the design phase since the amount of waste generated is a direct consequence of decisions made during design (Alm, 1992;

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Fiksel, 1993, 1996; Angell and Klassen, 1999; Melnyk *et al.*, 2001). However, there is a lack of appropriate measures and tools for capturing the environmental impact of designs (Van Weenen and Eeckles, 1989; Allenby, 1993; Graedel and Allenby, 1995; Sroufe *et al.*, 2000).

- Managers need frameworks or guidelines that they can use to better understand what TQEM and its components are (Bhat, 1998; Curkovic *et al.*, 2000; ReVelle, 2000). However, a great deal of the information surrounding TQEM is either legally based or derived from anecdotal stories and case studies (Willig, 1994; Curkovic, 2003).

Finally, and the focus of this research, managers have difficulty assessing the impact of TQEM programs because of the lack of appropriate measures. In order for TQEM to be given serious consideration by a firm, a process is required for evaluating TQEM by appropriately including environmental costs and savings for each investment option (Sarkis and Rasheed, 1995; Epstein, 1996a, 1996b; Klassen and McLaughlin, 1996; Bhat, 1998). There is simply a lack of easy-to-use measures. Such investments would include any capital project, compliance or noncompliance driven, whose major objective is to control, reduce or prevent waste. In order for TQEM to be given serious consideration by a firm, a process is required for evaluating TQEM by appropriately including environmental costs and savings for each investment option (Sarkis and Rasheed, 1995; Epstein, 1996a, 1996b). Unfortunately, many projects that pursue pollution prevention and support TQEM are quickly overlooked in traditional capital budgeting processes (Greer and Van Loben Sels, 1997). The main reason for this is that very few firms fully recognize environmental costs when performing a cost/benefit analysis for each project. A fundamental goal of TQEM is to get companies to recognize environmental costs and incorporate them into the capital budgeting process so that better decisions can be made.

The purpose of this study is to develop a framework for managers to identify and assess the relative costs associated with environmental business practices. The objective from the onset is to identify and capture as many relevant costs as possible (qualitative and quantitative) using existing costing measures, and develop a foundation for evaluating these measures using existing and proven tools from the TQM literature.

The paper is composed of several sections. To start, the background of TQEM and other environmental management tools is used to identify a gap in the literature and establish a need for the research posited. Following the review of the literature, a framework is presented, and implications for future research are discussed.

Background

A review of the relevant literature helps to identify environmental management tools and measures being used, examples of companies implementing programs and possible frameworks to apply. The results of the literature review show that the move to adoption of environmental business practices and TQEM has been viewed from a perspective heavily influenced by either normative or legal considerations (Friedman, 1992; Klassen, 2000a, 2000b; Curkovic, 2003). For most companies, compliance is seen as an adequate position to assume (Epstein, 1996a, 1996b). With compliance, the firm does only what is necessary to meet the letter of the law. It is a reactive position, which means environmental problems are corrected once they have been created. This is a relatively easy stance for firms to take, but ineffective because it does not attack the causal factors of problems, merely the symptoms (Alm, 1992; Allenby, 1993; Gupta and Sharma, 1996; Klassen and Whybark, 1999a, 1999b). It is also a potentially dangerous position given the retroactive and dynamic nature of many laws. That is, what may be in compliance today may be considered to be out of compliance tomorrow. As a result, the firm may find itself

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always allocating scarce resources to bring itself into compliance with regulations that are continuously becoming more stringent.

However, it is now recognized that environmental business practices can be economically justified in terms of the practices' ability to reduce costs, eliminate waste, reduce lead times and improve quality. In spite of this awareness, widespread acceptance of TQEM has been hindered by several factors. First, there is the lack of easy-to-use measures. While life cycle assessment and accounting systems are available, they are generally seen as being very time consuming and difficult to apply, especially by operations managers. Second, there is the lack of clear linkages between environmental practices and corporate strategy. At a roundtable on environmentally responsible manufacturing (ERM) sponsored by the Society of Manufacturing Engineers, a key point raised was that TQEM was often seen as being something that was done to avoid penalties or ensure compliance. Yet, it was also noted that a key element for successful TQEM was top management support. Such support could be secured if a clear link between TQEM and competitive position in the marketplace could be established. Often, this relationship had to be demonstrated in terms of a cost/benefit relationship. Some of the firms that are successfully carrying out TQEM programs have established such relationships and performance measures. These include Dow Chemical with its WRAP (Waste Reduction Always Pays) program, Chevron with SMART (Save Money and Reduce Toxics), Westinghouse and ACT (Achievements in Clean Technology) and Texaco with its WOW (Wipe Out Waste) program. In each case, the goals of the programs are the same – to reduce waste and pollution while recovering lost profits.

The challenge of determining whether it is better for the firm to simply emphasize compliance or whether the firm wants to become recognized as an industrial leader in the development and application of TQEM based systems describes the first of many obstacles and paradoxes surrounding the TQEM literature. In large part, the failure of management to become more environmentally responsible is really a reflection of its inability to address and resolve these paradoxes and problems. At the heart of these problems, and the focus of this research, is that managers have difficulty assessing the impact of TQEM programs because of the lack of appropriate performance measures.

This is a major reason for the underinvestment in TQEM programs. Most TQEM related investments produce cost savings that are largely hidden or misallocated. Furthermore, these cost savings have a payback period of several years. Conventional tools today provide a biased evaluation for TQEM investments and this precludes them from successfully competing for resources with other investment alternatives.

At present, several conceptual frameworks for identifying the various costs associated with waste and pollution have been proposed in the literature. These include *life-cycle assessment* (LCA) (Allenby, 1993; Bhat, 1998), *environmental cost accounting* (ECA) (Willig, 1994; White *et al.*, 1993), *full cost accounting* (FCA) (Popoff and Buzzelli, 1993; Makower, 1994; Savage and White, 1995; Epstein, 1996a, 1996b) and *total cost assessment* (TCA) (Epstein, 1996a, 1996b; Kennedy, 1994; White and Savage, 1995). Of these approaches, LCA has been recognized as extremely information intensive, difficult to implement and somewhat subjective and difficult to defend. With LCA, you must be prepared to show your methodology and open it up to peer review, or public scrutiny. If you are not ready for this scrutiny, then you are not ready for LCA. Currently, LCA has very limited use in industry.

The other frameworks, such as environmental cost accounting (ECA), full cost accounting (FCA), and total cost assessment (TCA) are derived from the same premise that accounting systems need to incorporate environmental information. There is limited use of these accounting approaches in industry, especially at the plant level among operations managers. White and Savage (1995) demonstrated some of the major shortcomings of accounting practices using case studies of capital budgeting for TQEM projects among large US firms. Their results show that traditional accounting systems are developed for compiling and preparing information for external reporting and disclosure. This information by it

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very nature must be aggregated. For operations managers charged with environmental performance, as well as daily production, pricing and product-mix decisions, conventional aggregated financial information is of minimal use.

A previous study by the authors also shows that accounting systems are very problematic for operations managers because they often lack the skills required to use the tools associated with financial analysis (e.g. net present value, internal rate of return and profitability index). While the direct costs are easy to measure and are indeed measured by most, the other costs become much more difficult to quantify. Most managers do not measure future liability costs and less tangible costs because methodologies for doing so are not well developed, and they are very subjective and time consuming. Furthermore, most current accounting systems, especially at the plant level, are not set up to capture hidden or regulatory driven costs, meaning that these costs are usually buried in total project costs. When costs are detached from the activities that generate them, operations managers are faced with incomplete or inaccurate information for the decision-making process.

An Alternative Approach

An alternative approach to the measurement and problem of justifying TQEM investments can be based on drawing parallels between TQM and TQEM. There has been a great deal of discussion within the literature about TQM in environmental programs. It has been suggested by several researchers that significant benefits arise from applying what has been learned about TQM to TQEM (e.g. Friedman, 1992; Wheeler, 1992; McInerney and White, 1995; Shrivastava, 1995; Puri, 1996; Gorman and Krehbiel, 1997; Curkovic and Landeros, 2000; Curkovic, 2003). In these studies, the authors describe how the implementation of TQEM can be made more successful by integrating it into a TQM system.

For example, Klassen and McLaughlin (1993) suggested that firms that have advanced TQM programs in place also have more advanced environmental management programs in place than firms just initiating TQM. A large-scale study by Curkovic *et al.* (2000) identified that a firm's ability to reframe knowledge from quality management programs is crucial to being environmentally responsible. Some researchers, such as Makower (1993) and Willig (1994), bring together first hand reports on how leading companies are going beyond meeting regulatory compliance to gaining a competitive advantage and improved profitability by applying TQM practices to TQEM.

Companies can utilize TQM approaches to developing a system-wide and integrated approach to the reduction and elimination of all waste streams associated with the design, manufacture, use and/or disposal of products and materials. Relevant TQM principles that can be integrated into waste minimization programs include (1) a systems analysis process orientation that aims to reduce inefficiencies and identify product problems, (2) data-driven tools, such as cause and effect diagrams, quality evolution charts, Pareto analysis and control charts and (3) a team orientation that uses the knowledge of employees to develop solutions for waste problems.

Given the numerous company examples involving the successful use of TQEM, why are the majority of companies reluctant to commit to both quality and environmental management? The answer to this question lies in the lack of understanding of the parallels of the two concepts and the idea that new tools and metrics are not necessary. Instead, practitioners need to look no further than the existing concepts, and practices of TQM.

Applying TQM Principles to TQEM

After reviewing several other frameworks such as environmental cost accounting, full cost accounting or total cost assessment, and talking to environmental managers, it becomes clear that the best approach

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to providing a better understanding of TQEM will come from the use of existing quality management practices and a focus on the similarities between TQM and TQEM. This approach is also based on the observed parallels between TQM and TQEM based systems noted by numerous researchers previously cited in this study. They all point out that TQM and TQEM (1) aim to improve a company's final output, (2) require some new definitions of leadership, (3) emphasize long-range planning over short-term considerations, (4) involve changing relationships between companies and their employees, suppliers and customers, (5) strive for a cultural change, (6) stress improved information, communication, training and accountability and (7) demand continual, measurement, self-assessment and improvement.

What is implied by these similarities is that many of the tools of TQM can be adapted for TQEM. TQEM systems are viewed as being TQM systems modified to deal with environmental issues. The 'no waste' aim of TQEM based systems closely parallels the TQM goal of 'zero defects'. TQM focuses on waste as it applies to process inefficiencies, whereas TQEM tends to focus on concrete outputs such as solid and hazardous waste. Because the two concepts share a similar focus, researchers note that it makes sense to use many of the tools, methods and practices of TQM in TQEM based systems (Epstein, 1996; Curkovic, 2000). Therefore, developing a cost framework for TQEM begins with TQM.

Developing a TQEM Cost Framework

This study focuses on identifying and formulating a set of environmental cost measures. The structure of these measures is taken from the TQM literature and frameworks developed by Joseph Juran. At the heart of this framework are several important concepts. The first is that TQEM can never be effective if advocated on the basis of qualitative measures or ethical needs (i.e. 'moral imperatives'). Second, TQEM can be pursued effectively when accompanied by a set of well defined, easy-to-use, quantitative measures. As the old adage in TQM puts it, 'what gets measured, gets managed'.

An alternative approach to the measurement and to the problem of justifying TQEM systems can be based on the cost of quality (COQ) framework developed by Juran for TQM (Hughes and Willis, 1995). The COQ framework was developed by Juran as a means of getting operations managers' attention and having them recognize the opportunities for improved quality. Another way to look at defects involves seeing pollution as a cost and a red flag for poor quality (McInerney and White, 1995). Simply stated, COQ is a type of accounting system specifically designed for an operations environment that captures in dollars and cents all of the costs associated with defective products. These include the costs of making, finding, repairing or avoiding defects. To simplify the tracking of these costs, Juran assigned all costs to one of the four categories: internal failure costs, external failure costs, appraisal costs and prevention costs. Definitions and examples of these four cost categories can be found in Table 1.

The attraction of improved quality becomes evident once management begins to measure on an ongoing basis the cost of quality. In most cases, the cost of poor quality control captured by the sum of internal and external failure costs is quite large. In some cases, it can be between 50 and 80 percent of the COQ. An additional attraction of the COQ approach is that it provides a general guideline for investing in prevention costs. In general, management should continue to invest in prevention costs as long as the total cost of quality does not increase.

Based on conversations with manufacturing managers, a review of the literature and the experiences of the researchers involved in this study, the COQ approach can be modified to become a total quality environmental management cost framework with parallels and examples of environmental costs noted in Table 2.

Prevention costs are associated with preventing defects before they happen and include the design and planning of the TQEM system. The costs of measurement and control equipment are typical of

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Internal failure costs. The costs resulting from the detection of quality defects prior to shipment to the customer. These include costs such as scrap, salvage, rework, excess inventory and inspection.	
External failure costs. These are the costs of quality that are identified after the product has been shipped to the customer. Included in this cost are complaints adjustment, loss of goodwill, returned material and field service/repairs.	
Appraisal costs. These are the costs created when goods and services are examined to see whether their quality levels are acceptable. This category of costs includes incoming material inspection, product/process inspection and maintenance of test equipment and test staff.	
Prevention costs. The costs of preventing the occurrence of defects and of limiting failure and appraisal costs. Included in this category are activities such as quality planning, new product review, training, process control, improvement projects and continuous improvement.	

Table 1. Juran's cost of quality framework

prevention costs. Practices designed to improve processes and decrease waste can be considered preventative and the associated costs of these practices can go a long way toward capturing and controlling processes. 3M, Kodak and AT&T are also excellent examples of companies that were among the first to extend their TQM initiatives to TQEM. These companies utilized TQM approaches to work towards a goal of zero waste discharges. TQM principles that were integrated into their waste minimization programs included the use of Pareto analysis and control charts to signal pollution problems with the manufacturing process. For example, control charts were used to determine the capability of a wastewater treatment system to operate within permit limits. Each company now reports aggregate savings and significant environmental benefits generated by using TQM concepts in environmental management.

Appraisal costs involve assessing the level of performance attained by a firm's processes both in the plant and in the field. These costs should decrease as preventive measures improve performance and include audits, inspections, testing, third party certification and monitoring costs. Proctor and Gamble has used benchmarking techniques to assess conformance with elements of its own TQEM system. The company regularly audits its facilities throughout the world in the areas of government and public relations, people capability, direct environmental impact, incident prevention and continuous improvement. Standards in each of these areas are developed at the facility level ensuring business unit commitment and support, and a score is generated for each facility.

Internal failure costs for firms directly relate to defects, environmental problems or issues found within the firm. Managers should be careful to recognize symptoms versus problems, as many environmental costs are actually symptoms of underlying manufacturing problems. Internal failure cost measurement for many firms already exist with regards to waste management and labeling. Those costs more difficult to quantify can include manifests, recording and notification. This category of expenditures also tends to often include those costs associated with correcting environmental issues found during appraisal. For example, when neighboring communities are discovered to have been exposed to hazardous waste, the company immediately assumes significant liabilities.

External failure costs are typical when a defect or problem is discovered after customers have received the product, and within the TQEM context include costs associated with negative occurrences, such as environmental infractions, citations or accidents identified outside of the originating firm. These external costs at times involve more tangible liability costs while at the extremes can have serious consequences (e.g. the Exxon Valdez incident or Bhopal India) and include less tangible costs of corporate image, reduced sales, or compromised relationships with suppliers and customers. In the last few years alone, several corporations have received substantial fines and penalties, and have been required to clean up their waste (i.e. remediation).

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External failure: costs associated with the occurrence of environmental issues (e.g., waste) outside of the manufacturing facility	**Internal failure:** costs directly related to the occurrence of environmental issues within the manufacturing facility	
* *Contingent liability costs:* future liability costs – treatment or storage in tanks, transportation land disposal, soil & waste removal & treatment, groundwater removal & treatment, surface sealing, personal injury, economic loss, real property damage, natural resource damage, superfund, corrective action, worker illness, downtime for accidents * *Less tangible costs:* lower product acceptance by consumer, negative corporate image, negative impact on sales, lower borrowing capability, strained distributor relations	* *Waste management:* hauling, storage, handling, waste-end fees/taxes, hauling insurance * *Labeling costs:* pre-transportation labeling, hazardous waste package marking, transporter placecarding, hazardous chemical labeling * *Manifesting costs:* generators off-site transport manifesting, transporter shipment manifest, TSDF standard manifesting * *Record-keeping costs:* exporter's reports & notification records, manifesting records, operating record, excess of threshold documentation, notification determination records, startup, shutdown & malfunction records, toxic pollutant effluent discharge compliance records, occupational injuries & illness log & summary, medical surveillance program records * *Notification costs:* emergency follow-up notification, supplier notification requirements, hazardous emissions waste notification, national pollutant discharge elimination system, hazardous pollutant discharge notification, toxic pollutant discharge notification, industrial user slug loading notification, material safety data records	* *Reporting costs:* generators biennial report, primary exporters annual report, TSDF biennial report, release, fire, explosion, & closure reporting, supplemental MSDS report, excess of applicable threshold report, hazardous pollutant emissions reporting, industrial users' continued compliance reports, toxic standards annual compliance report, injury and illness reporting each occurrence, injury and illness annual summary, fatality or hospitalization report, occupational injuries and illness survey * *Medical surveillance costs:* hazardous waste, medical surveillance program * *Contingent liability costs:* penalties and fines (RCRA, CAA, CWA, SDWA, TSCA, FIFRA) * *Less tangible costs:* strained employee/union relations, strained supplier–customer relationship, decreased productivity due to worse employee relations, added future regulatory costs, lower worker retention, worse relationship with regulators * *Training:* SOG emergency response coordinator, SQG waste handling & emergency training, personnel training, TSDF emergency response coordinator training, initial assignment & addition of hazard training, hazardous waste training * *Studies & modeling costs:* final status TSDF detection monitoring program, groundwater outline of interim status TSDFs, final status TSDF compliance monitoring program, emergency & contingency plan procedures, cost estimate for facility closure, hazard communication program, safety & health program, emergency response program

Table 2. The TQEM cost framework

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Appraisal: costs involved in the direct appraisal of environmental issues both in the plant and in the field

* *Environmental audits*

* *Incoming test & inspection & laboratory acceptance*

* *Checking labor*

* *Laboratory or other measurement service*

* *Set-up for test and inspection*

* *Outside endorsements*

* *Maintenance & calibration*

* *Product engineering review & shipping release*

* *Field testing*

* *Inspection costs:* facility/inspection & inspection schedule, LQG tank inspections, SQG tank inspections, fire department inventory inspections, point source inspections, compliance inspections

* *Monitoring & testing costs:* hazardous waste chemical & physical analysis, groundwater monitoring, groundwater monitoring/land-based interim status TSDFs, emissions control performance testing, continuous monitoring system, continuous opacity monitoring system, hazardous pollutant testing, hazardous pollutant monitoring, effluent stream monitoring & sampling, pretreatment standards monitoring, daily toxic pollutant sampling

Compliance driven: costs that are mandated by local, state & federal agencies/governments, and cannot be classified into one of the previous cost categories

* *Notification costs:* exportation of hazardous waste notification, foreign source notification, permit confirmation, local notification of operations, manifest discrepancy notification, facility changes notification, startup, monitoring & operations change notification WEEE-RoHS

* *Reporting costs:* LQG exception report, SQG exception report, primary exporters exception report, TSDF unmanifested waste report, requested MSDS report, inventory report, tier II reporting by request, national pollutant discharge elimination system permit reporting requirements

* *Preparedness/proactive equipment (maintenance) costs:* internal communicating alarm system, fire control equipment, NPDES backup or auxiliary facilities, restricted exposure to certain constituents

* *Closure/post-closure assurance facility specific costs:* financial assurance for closure and post-closure

* *Insurance & special taxes requirement-specific costs:* financial responsibility requirements, taxes on certain chemicals

* *WEEE-RoHS*

Prevention: costs associated with the design and planning of a TQEM Program

* *Administration & systems Planning*

* *Planning* (engineering work) – incoming, in-process, final inspection
Special processes planning data analysis
Procurement planning
Vendor surveys
Reliability studies

* *Measurement & control equipment*

* *Qualification of material*

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Finally, managers and researchers alike find some costs hard to put into the COQ taxonomy and are already capturing compliance driven costs. Here is where we take a step back from the COQ model and add flexibility to the framework while at the same time prompting discussion of just what firms should do with compliance costs and new compliance initiatives such as WEEE-RoHS. If these costs do not easily fit into the COQ framework then there is an opportunity to look at a new COQ dimension. These costs are mandated by local, state and federal agencies. Costs include notification, reporting, preparedness and certain types of assurance cost. This new dimension of the framework brings about not only scholarly debate as to where they can fit within the existing TQM frameworks, but also a quandary for managers as to how to capture this information and use it effectively to move upper management to act upon environmental opportunities.

To assess how the TQEM cost framework might work in practice, one must consider how a company traditionally analyzes an investment decision. White and Savage (1995) and Savage and White (1995) collaborated with the Tellus Institute and several firms to show the inadequacies of traditional company analyses. A traditional analysis consists of the required capital costs and only those operating costs and savings that the company typically includes in projects. These operating costs and savings are usually limited to direct labor, direct material and waste management (e.g. hauling, storage, handling, waste-end taxes and hauling insurance). A TQEM cost framework would contain these and several other operating costs and savings (see Table 2 for examples). In a TQEM-related project, a number of cost items would appear in the framework that are either partially or entirely omitted from a traditional company analysis. For example, these might include savings in raw material costs, savings in fresh water usage and costs and associated fresh water treatment and pumping; savings in energy use for fresh water heating and savings in wastewater pumping and wastewater treatment fees. The financial impact of the omitted savings by comparing the traditional and TQEM cost approaches would generate very different numbers on key financial indicators (e.g. cost savings, net present value (NPV), internal rate of return (IRR), profitability index (PI), payback period etc.). The differential in a TQEM investment could be substantial enough even without inclusion of some of the more indirect, less tangible financial benefits that likely will occur also (e.g. lower future regulatory costs, improved regulatory and community relations, higher worker morale and productivity, better worker retention etc.).

Operations managers who might lack the accounting skills or systems to calculate key indicators such as NPV, IRR and PI can use the TQEM cost framework to make even simpler justifications for environmental investments. With a TQEM cost framework and approach, a manager incorporates both normal costs and savings related to a project as well as environmental costs and savings associated with that project. TQEM is effective when it is shown that the costs of not being TQEM oriented (e.g. costs of compliance and failure – both internal and external) exceed the costs of prevention (e.g. developing and delivering products and services that generate less waste). The more managers spend on prevention and appraisal, the less they will spend on compliance and failure (especially external failure). Alternatively, as Hughes and Willis (1995) pointed out, the goal is to find the level of control at which the marginal costs of prevention and appraisal equal the marginal costs of compliance and failure. This would help managers shift costs away from compliance and failure towards prevention and appraisal.

While TQEM programs must be shown to be economically justified and valid, the successful implementation of a TQEM cost system relies on cost or performance measurement. Performance measurement plays an important role in every organization in that measurement translates an organization's strategy into quantifiable data used for management and accountability (Magretta and Stone, 2002). Performance measurement fulfills the fundamental activities of evaluation, signaling importance, directing, value and benchmarking.

Much of what we currently know about metrics comes from managerial literature (e.g. Brown, 1996; Cooke, 2001; Dixon, Nanni and Vollmann, 1990; Kaydos, 1999; Ling and Goddard, 1998; Lynch and

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Cross, 1995; Maskell, 1991; Melnyk and Christensen, 2000; Smith, 2000; Williams, 2001). While there are numerous examples of the use of various metrics, there are relatively few studies in operations management that have focused on the development, implementation, management, use and effects of environmental metrics within environmental management systems (EMSs) (Melnyk and Sroufe, under review). The impetus for TQEM measurement lies in the fact that it provides a benchmark for managers and personnel to judge and evaluate their performance or the performance of other developments such as LCA or FCA. Managers think in terms of how new developments affect their performance. The better the understanding managers have of performance measurement development and use based on existing practices such as TQM, the better able they will be to measure, manage or hold people accountable for environmental practices.

Unless a different approach to integrating environmental concerns into the existing performance measurement systems, there is the danger of firms and manufacturing personnel experiencing a real problem when trying to identify and exploit environmental opportunities. It is not enough to integrate environmental concerns into performance measurement by simply adding new metrics that are specific to environmental issues. Ideally, the integration of environmental dimensions into existing performance measurement should be done to better understand the hidden cross-functional impacts of environmental processes. The last thing managers need is more performance measures to capture, manage and report on. We are basically arguing for the use of existing systems and metrics such as TQM to support environmental activities within the firm. To do this, management will need to look at an in-depth analysis of the processes to find cross-functional impacts of existing TQM systems and metrics. Unfortunately, other competitive priorities such as cost, lead time and flexibility are constantly fighting for the attention of management. Often, a firm will struggle with the (short-term) importance of keeping costs low while simultaneously being involved with internal process management, putting out daily fires and calls for more external reporting. It may be that management needs to be more innovative in finding and summarizing environmental performance in order to demonstrate the full range of impact on corporate performance measures.

The contribution of this study has several dimensions. To start, practitioners should be able to easily relate their own TQM performance measures to Juran's costs of quality. Next, whether the firm is struggling with new environmental performance metrics or trying to cope with existing quality measures, the information in this study demonstrates that environmental performance measurement does not have to be separate from existing systems and measurement practices. Additionally, the TQEM cost framework and measures presented in this study are not all inclusive, but instead provide a starting point for discussion and/or thinking about how a firm or a manager can approach the daunting task of capturing and effectively using relevant environmental data. Finally, it is the hope of the authors that managers can take the information presented in this study to make a case to upper management for the integration of environmental performance measurement into existing quality systems while simultaneously showing the direct relationships of quality, environmental performance and costs.

Directions for Future Research

After reviewing the background of TQM and frameworks for capturing environmental costs, there is an apparent opportunity for research involving the use of TQM and TQEM. An initial conceptual framework based on Juran's COQ approach to identifying the costs of environmental projects has been introduced. However, an empirical examination of the proposed framework remains untested. The findings of this study provide an important foundation for accomplishing this goal. The first step in future research would be to develop interview protocol and a survey instrument based on this preliminary

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framework. It should be used on a select few firms recognized as being at the leading edge in the implementation and use of TQEM practices. Two major outputs yielded by this exploratory case-based research would be (1) a catalog of the various cost measures and procedures used to implement and carry out a TQEM cost analysis and (2) an empirically refined TQEM cost framework. This cataloging activity would not only describe the tools and measures but also indicate how these measures can be used, types of expected outcome and conditions most conducive to their use. This framework and catalog would consolidate information from a field that is currently considered to be very fragmented. The final outcome would be a demonstration of the framework. This demonstration would identify the ease of use, extent of data requirements and types of decision facilitated by the data provided by the framework.

The significance of this type of research can be evaluated along several important dimensions. First, it would help to close several critical gaps (primarily involving the gaps between strategy and TQEM and the gap between firm-specific tools and general procedures). Second, it would provide alternative measures to the commonly used but complex (and time consuming) life cycle assessment. Third, and last, it would meet a definite need – that of providing a catalog of available cost measures. This will allow TQEM investments to shift from being viewed as strictly compliance-driven projects or 'a cost of doing business' and towards being value-added profit-driven investments.

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