The New Product Design Process and Environmentally Conscious Manufacturing: "Crossing the Chasm" and Other Obstacles

Robert Sroufe, Michigan State University
Frank L. Montabon, Michigan State University
Steven A. Melnyk, Michigan State University
Sime Curkovic, Western Michigan University

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Robert Sroufe, Frank Montabon, Steven A. Melnyk, Michigan State University, E. Lansing, MI 48824
Sime Curkovic, Western Michigan University, Kalamazoo, MI 49008

ABSTRACT

This paper reports the results of a field study based project focusing on the new product design process within 11 American manufacturing firms. The findings reported indicate that the users exhibit strong differences. The users can be categorized into one of five major groups: innovators, early adopters, early majority, late majority and laggards. These groups strongly parallel the model of new product acceptance initially developed in the computer industry, as presented by Moore (1991). Of interest is the gap that exists between the early adopters and early majority users. This gap forms a chasm. Those factors that account for acceptance in the early adopters are significantly different from those factors observed in the early majority. This paper examines these and other differences, and the impact of these differences on the acceptance and use of environmental concerns within the design process.

INTRODUCTION

Given the uneven rate of acceptance and use of Environmentally Conscious Manufacturing (ECM) -related principles and practices (especially within the design process), there is a clear need for an in depth study of new product design and the factors affecting ECM, the role played by ECM tools, metrics, and personnel within this process. This study was specifically designed to address the following issues:

(1) What is the process by which new products are designed and brought to market? Within this process, what are the major concerns, drivers, and stages? What groups are involved in this process and at what stage do they become involved?

(2) What is the role of environmental issues within the “typical” design process? At what stage(s) do these issues and concerns become evident? How do the major players within the design process view these concerns? What metrics, if any, are used in measuring performance along this environmental dimension? What are the major obstacles to the increased acceptance of environmental issues within this design process?

(3) Are all users similar in terms of their attitudes to ECM principles, practices and systems? If differences are present, how do these differences become evident? What is the implication of these differences for ECM acceptance and use?

To address these objectives, we apply the experiences of managers collected from 16 detailed case studies in 11 manufacturing firms. The focus of these case studies is first on the product design process. Next, the role of ECM within this process is examined. Finally, the data generated from these studies is analyzed using the guidelines established by Miles and Huberman (1994) for the analysis of qualitative data. The data is analyzed to determine if any differences between the users can be identified. In all instances, the unit of analysis is at the Strategic Business Unit (SBU) level. Finally, it should be noted that the authors are in the midst of the analysis of the data generated from these case studies. As a result, the findings presented are preliminary in nature. However, as will be show, the findings are both promising and interesting.

PRODUCT DESIGN AND ECM

The first step in understanding this new paradigm is to understand what exactly is meant by the term “environmentally conscious manufacturing.” For the purposes of this paper, we define ECM as: “a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess and manage the flow of environmental waste with the goal of reduce and ultimately minimizing its impact on the environment while also trying to maximize resource efficiency.”

The design system is one of the major tasks within any firm. As such, it is responsible for two major types of design activities: (1) new product design and development; and, (2) process design and development. Both products and processes, while separate, are closely interrelated and greatly influence each other. Both aspects must be considered to ensure that the firm has developed and implemented effective and efficient designs and processes.

These two design activities, when combined, determine and shape the transformation process. They determine the types of inputs required and the types of outputs created. Some of these outputs are desired (e.g., cars built) while others, such as pollution, are undesired. For example, Fabrycky (1987) estimated that up to 85 percent of the life cycle costs are committed by the end of the preliminary design stages. In another study, Ulrich and Pearson (1993) found from a field research study that at least 50 percent of the costs (for a class of mature products) are design determined and that up to 70 percent of costs are affected by manufacturing process decisions. Thus, ECM can have its greatest impact early in the design process.
PRODUCT DESIGN AND DEVELOPMENT

This process embodies all of the steps necessary to take the product from concept to full production. Recently, this process has undergone extensive revision and rethinking (Hall, 1993, Patterson, 1993). These changes have been a result of the increased market pressure to reduce the total cycle lead time (from concept to full production), reduce cost, enhance product flexibility and improve product quality (Cohen & Apte, 1997, Chapter 2). These pressures, in turn, reflect the impact of such developments as Total Quality Management (TQM), Just-in-Time Manufacturing (JIT), Time-Based Competition (Stalk & Hout, 1990; Carter & Melnyk, 1992) and Mass Customization (Pine, 1993).

Traditionally, this process has been envisioned as being sequentially organized beginning with idea generation and proceeding through such stages as business analysis, technical feasibility, technical development, marketing feasibility, pilot production and full scale production. However, as the experiences of companies such as Chrysler and Honda have shown, this process is unable to meet today's increasingly more competitive requirements for products which are produced in less lead time, at a lower cost and with higher quality.

The result has been the development of processes characterized by the use of multifunctional teams and close interaction over the period of the initial design. This process is also integrative, both in terms of functions involved and the breadth of the manufacturing system, (since it considers not only issues of design but also issues pertaining to manufacturing planning and execution). This reorganization of the design and delivery process has been referred to by such names as simultaneous engineering and concurrent engineering. We can envision the product/process design and delivery system as consisting of nine linked stages as described by Meyer, 1993.

QUALITATIVE RESEARCH METHODOLOGY

In instances where there does not exist a well developed set of theories regarding a particular branch of knowledge, Eisenhardt (1989) and McCutcheon and Meridith (1993) suggest that theory-building can best be done through case study research. The case based process involves defining the question, selecting cases, crafting instruments and protocols, analyzing data, shaping hypothesis, enfolding the literature and reaching closure using an relatively small group of research sites. Comparative literature reviews of research on environmental management strategies confirm that this area is at an early stage development (Klassen, 1993; Klassen and Whybark, 1995; Porter and van der Linde, 1995b). In this stage of theory building, a key objective is to characterize the different types of ECM used in new product design and operations management activities.

Methods

The researchers participating in this project, relied primarily on the methods of qualitative data analysis developed by Miles and Huberman (1994), which consists of anticipatory conceptual model development and simultaneous data collection, reduction, display, and conclusions testing. Multiple research sites were used in order to provide a broader taxonomy of new product design and ECM strategies. The process included developing the research questions, building a conceptual model, bounding the research, and analyzing the data.

A case based research approach was used to identify the important issues used in developing a framework for theory testing. The conceptual model for this study was derived from existing literature in the area of ECM and from the researchers' experience in the field. A comprehensive literature survey was conducted to develop a framework for ECM efforts in the product development, manufacturing and supply chain management sectors. One interesting feature of the model developed from the literature is its reliance on the notion that environmental initiatives must span all functional areas and stakeholders throughout a company's value chain to be more effective. For this reason, the "chasm" model developed was used as a basis for evaluating the different environmental initiatives for each of the tasks within the new product development process. This model classifies a firm's environmental status within the continuum developed in the introduction, ranging from innovator to early adopter, early majority, late majority, and laggards.

The Sample

Bearing this advice in mind the researchers initially set out to find a set of organizations which were at different stages of integration with regard to ECM and new product design. Firms from different ECM stages, industries (i.e. chemical, furniture, and automotive), products, processes and size of the firm were used. Each of the firms selected, were chosen to represent a spectrum of ECM status. The objective of this sampling approach was to construct a sample of firms that would be diverse enough to capture the ECM attributes available across firms and products that may be overlooked in a single industry or product sample.

After the initial screening, which also assessed the willingness of the company to participate in the study, the firms were contacted and 16 site visits arranged. The interviews were conducted with several managers responsible for portions of the company's overall New Product Design (NPD) strategy at each site using structured interview protocols.

DATA DISPLAY, CODING, AND REDUCTION

Following each interview, the field notes were typed. To facilitate data coding and analysis a matrix display was constructed. The meta-matrix summarized each of the major
The next step involved coding the data using Nudist qualitative data analysis software. Upon reviewing the first 6 site visit field notes, a list of 146 primary codes was developed to capture information in 19 different meta-environmental categories. The researchers reviewed the transcribed field notes for all 16 of the site visits at least three times in order to code the appropriate environmental response categories and compare field notes taken during the interviews. In doing this, the events and processes observed at each site were classified into an ECM category, and several other complimentary environmental categories. Consulting with each coder until all activities were classified into the appropriate ECM category facilitated joint agreement for the categories.

Miles and Huberman (1994) suggest 70% intercoder reliability is appropriate when using multiple raters to code field notes. If at least two of the three researchers agreed on the coding used within the 19 environmental categories it was then considered an agreement. The total number of agreements minus the number of disagreements comprised the actual number of agreements used in the reliability formula. Intercoder agreement was not pursued at the primary code level. Instead, reliability was assessed at the level of the 19 environmental met-categories. The coding of each interview was found to have a reliability of 0.70 or higher.

PRELIMINARY FINDINGS

<table>
<thead>
<tr>
<th>Role of ECM</th>
<th>Innovators</th>
<th>Early Adopters</th>
<th>Early Majority</th>
<th>Late Majority</th>
<th>Laggards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product &amp; Process Hazards</td>
<td>High for both</td>
<td>Medium</td>
<td>Low</td>
<td>Medium to Low</td>
<td>High for both</td>
</tr>
<tr>
<td>Factors Affecting ECM</td>
<td>Full responsibility, Performance measurement, En. Functional Unit, Culture</td>
<td>Flexibility, Lead time, Cost, Market driven, Performance measurement</td>
<td>Flexibility, Lead time, Cost, Budgets</td>
<td>Focus on Government regulations, nothing is a problem unless the ECM is considered</td>
<td></td>
</tr>
<tr>
<td>Metrics</td>
<td>Present and important</td>
<td>Present, focus on EPA guidelines</td>
<td>Lack of Metrics</td>
<td>Lacking, or use more on waste</td>
<td></td>
</tr>
<tr>
<td>Tools</td>
<td>EMS, ECA, D&amp;F, Familiarity and Availability in house</td>
<td>EMS, ECA, D&amp;F</td>
<td>EMS, ECA, D&amp;F</td>
<td>No tools available</td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td>Focus on pollution prevention and recycling</td>
<td>Focus on pollution prevention and recycling</td>
<td>Compliance, E&amp;I, and Pollution Prevention</td>
<td>Pollution Prevention</td>
<td>No options considered</td>
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<tr>
<td>Opportunities</td>
<td>Pollution Prevention</td>
<td>Pollution Prevention</td>
<td>Pollution Prevention</td>
<td>Pollution Prevention</td>
<td>No options considered</td>
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Role of ECM

Here we find Innovators and Early Adopters having integrated ECM issues into the formal new product design process. Examples of Innovators can be found in the chemical industry. This ECM integration can be due to the heightened legal requirements placed on these industries and firms over the past twenty years. Additionally, the visibility mistakes such as the deaths of 8,000 workers in Bhopal, India in 1984 catch the public's attention more easily. The Early Majority take a more opportunistic, informal approach to ECM, and the late Majority are more periodic, while the late majority may not even consider ECM issues.

Product and Process Hazards

Innovators and Early Adopters are involved in products and processes that range from highly to medium hazardous. The presence of hazardous materials and processes to convert them into products is a substantial cause of ECM integration into new product design. The Early Majority and Late Majority typically deal with medium to low hazards, and the laggards deal with low amounts of hazardous products or processes.

Factors Affecting ECM

While there are many factors affecting ECM, the drivers for Innovators tend to be the formal cross-functional responsibility found within these firms, corporate culture, the use of environmental performance measures, and the presence of an environmental functional unit. The Early Adopters find the factors affecting value (flexibility, lead time, cost), the market, and performance measurement to be important to the integration of ECM into new product design. The Early Majority and Late Majority tend to focus more on the elements of value, and we see some affect of budgets. The Laggards are reactive, tending to focus on governmental regulations to drive ECM policy. This would tend to be more of a focus on OSHA and RCRA regulatory requirements. For laggards, ECM is considered the job of the environmental division, or the lawyers.

Metrics and Tools

Here we see a large separation by the chasm between the Early Adopters and the Early Majority. The presence or lack of ECM metrics appears to be a good indicator as the status of ECM within a firm. If you can not measure it, you cannot manage it. As with the metrics, there is also a significant difference on either side of the chasm when considering the tools available to manage ECM issues.

Options and Opportunities

The focus on pollution prevention, reduction and recycling can be found throughout many of the firms interviewed. Interestingly, here we see the need for justification of ECM projects and ROI coming into play on the right side of the chasm for the Early Majority. As would be expected by reactive firms such as the laggards, ECM options and opportunities are not even considered.

REFERENCES AVAILABLE UPON REQUEST