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CHALLENGES IN INCORPORATING SUSTAINABILITY INTO PRODUCT DEVELOPMENT: AN EXPLORATORY STUDY

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ABSTRACT

Despite decades of disaggregated initiatives aimed at improving the well-being and quality of life of its employees, their families, communities and stakeholders, many high-technology firms are still struggling to develop an integrated approach to address the triple bottom line aspects of sustainability. In particular how sustainability is being integrated into the product development process, and the challenges that result, is of interest to this work. A literature review into the role of internal factors of how a firm implements a sustainability strategy revealed that it was too normative to guide the implementation of a corporate sustainability strategy at the level of the product development value chain. Therefore, to better understand how senior and mid-level managers actually implement such a strategy, a case study was conducted at two business divisions of two different large, multinational firms that are relatively early in their development of an integrated sustainability strategy. The findings provide insight into the role of internal factors at the level of a business division as it attempts to incorporate sustainability into its product development value chain.

1. INTRODUCTION

At first glance, the world we live in is one of limitless opportunity and abundant resources. However, more than 8 million people, many of them children, die each year because they are too poor to stay alive and fully 1 in 6 people live in extreme poverty (Yang 2005; NetAid 2007; Xiaoyu et al. 2007). In fact, nearly half of the world lives in poverty (PovertyNet 2008) and more than 20% eat less food than their bodies require (Meadows et al. 1992). By the middle of this century, the world's population will have grown to over 9 billion (Strouts 2007). These people will also seek the same basic rights that we all enjoy – to increase their standard of living and to seek a better material life (Strouts 2007).

In our struggle to find a way to produce goods profitably, we have allowed ourselves to pursue paths that are inherently dangerous for the sake of increased yields or better margins. In order to preserve the diversity and quality of life for everyone and everything, it is essential that we adopt practices that conserve, renew or recycle our resources rather than deplete them. We must understand the effects and limitations of the processes that we use to grow, so that development can be sustained and not exploited to the point of destruction (McDonough 1992). Indeed, if we as a global community do not act more responsibly, our future is certainly at risk.

Sustainability is not a new concept, as early as the 2nd century BC, there was concern about the rate of consumption of our resources (Atkinson et al. 2007). In the 20th Century, interest in sustainable development and corporate social responsibility has continued to grow (Elkington 2004).

In 1987, the Prime Minister of Norway, Gro Harlem Brundtland, presented "Our Common Future" to the World Commission on Environment and Development (WCED). The Commission was raising the issue of inter-generational inequity by stating that "future generations do not vote; they have no political or financial power; they cannot challenge our decisions." The Commission claimed that during their hearings, "it was the young, those who have the most to lose, who were the harshest critics of the planet's present management."

Then, Brundtland and her team issued a challenge to humans, who have become the dominant species on this planet:

> "27. Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. … technology and social organization can be both managed and improved to make way for a new era of economic growth. … Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes." (Brundtland 1987)

Brundtland defined sustainable development in the context of human development and prioritized the "essential needs" of those subject to the condition of poverty, however, the imperative to improve the condition of the poor by providing for their essential needs has taken a back stage. This is especially the case for the concept of "corporate sustainability" which has adopted the mantra of "People, Planet and Profit."

In the years following Brundtland several scholars have tried to codify and propose their own specific meaning, but a firm, clear definition still remains elusive (Kates et al. 2005). Holmberg and Sandbrook (1992) suggested that there were over seventy definitions of sustainable development in circulation.

Despite the lack of consensus on a specific definition, it does not reduce or eliminate the compelling need for improving our sustainability. It is clear that government and national agencies have a key role to play in that respect, as do corporations and individual citizens. However, due to the complexities and interdependencies inherent in dealing with sustainability, corporations are struggling to define their specific roles. The corporation already plays a large role in providing jobs and has a significant impact on both the people and environment in which it exists. At what point does a corporation's responsibility begin and end with issues such as the environment and social justice? Moreover, how does society define the issue? This initial problem continues even today, with sustainability often being simply equated to improving the environment (Allocca and Energy ; Huijbregts et al. 2008) or making "green" design choices (Ramus 2002) (Yi-Chan and Chih-Hung 2007).

Some argue that corporations cannot and should not take responsibility for sustainability. Friedman (1970) believed that the only responsibility of a firm was to increase profits (legally and without deception) and that its resources should only be used in this pursuit. Friedman viewed sustainability as a trade-off – to be either "socially responsible" or more profitable. Atkinson et al. (2007) argued that corporations should not be responsible for sustainability but for a different reason. They believe that stakeholders do not properly incent the corporation to deliver in this area and that the current metrics used to measure performance of a corporation are insufficient.

Moreover, there is no consensus on what metrics are suitable. A more moderate approach is proffered by McWilliams et al. (2006) who suggest that corporate social responsibility can be used to create competitive advantage by using "government regulation to impose CSR on rivals who do not employ an appropriate technology, thus raising the costs of those rivals relative to the initiating firm."(McWilliams et al. 2006)

There are others who have posited that adoption of sustainable practices do produce returns for the company (The Economist Intelligence Unit 2008). Butler (2004) and Dearing (2007) suggest that companies can use environmental innovation to gain advantage over their competitors and provide profits for the company while reducing their environmental footprint. DuPont continues to grow profits by adopting sustainable practices (Teresko 2006), and their chairman and CEO, stated, "Our top priority is to create value for [all] our shareholders. We will do that by delivering sustainable solutions through science and innovation." (Teresko 2006)

High technology companies are under pressure to push newer and better products at an increased rate. To maintain compliance with environmental regulations, those that adopt a "green" philosophy toward design and implementation will have a head start on their competition (Yi-Chan and Chih-Hung 2007). There is a lingering debate on whether technological innovation and the use of technology is the panacea to resolve issues of sustainability. Critics of the sustainable development agenda point to technology advances that have abated sustainability threats of the past. Proponents argue that the kinds of critical resources that are threatened by current unsustainable practices are unlikely to be substituted by technological advances (Atkinson et al. 2007).

The incorporation of sustainability into product development should not be disruptive, but should support the decision making process in such a way that the precepts of sustainability are considered and evaluated and integrated in the process (Gibson 2006). The integration of various disciplines is complex and as such, no comprehensive model or approach exists in the literature (Yang 2005). In fact, although many firms have begun to address the issue of sustainability, there is no clear consensus on the most appropriate method for implementation or metrics to measure success.

Difficulties in adopting sustainable practices by corporations include defining sustainability for a company and developing a strategy, identifying the right skills and integrating those skills to produce sustainable results that are profitable and consistent with the firm's goals. Given these hurdles, it is no wonder that corporations struggle with sustainability and its incorporation into their product development process.

The goal of this exploratory study is to generate insights into the barriers and enablers to incorporate sustainability into product development. This goal has been accomplished by examining product development organizations and their value chains in two business divisions of high technology, multinational corporations engaged in global product development. Both are forward-looking, innovative firms whose core businesses have had to respond to the sustainability agenda to varying degrees. Additionally, this research will help to frame areas of study for future exploration.

2. LITERATURE REVIEW

2.1. Tools and Methods

Effective sustainable product design and development requires an approach that embodies a systems-thinking mindset and a holistic toolkit that encompasses more than just a single product and its lifecycle. Bras (1997) conducted a survey of the state of practice with respect to environmental approaches in use in the late 1990's and found that most approaches, such as those that are part of the Design for X (DfX) toolkit[4] were standalone, product lifecycle stage specific and covered a single product lifecycle. The standalone nature of these approaches tended to improve performance in one stage, only to possibly negate the system benefit in a later stage.

Bras (1997) also described how the current approaches fell short of addressing the scale and scope demanded by sustainable development. In Figure 1, it is evident that even approaches such as Design for Environment only address a single product lifecycle in terms of organizational and temporal scale and scope. State of the art approaches such as Industrial Ecology, would require unprecedented levels of cooperation not only among organizations in the firm, but across firms, NGOs and governmental agencies at a local and regional level.
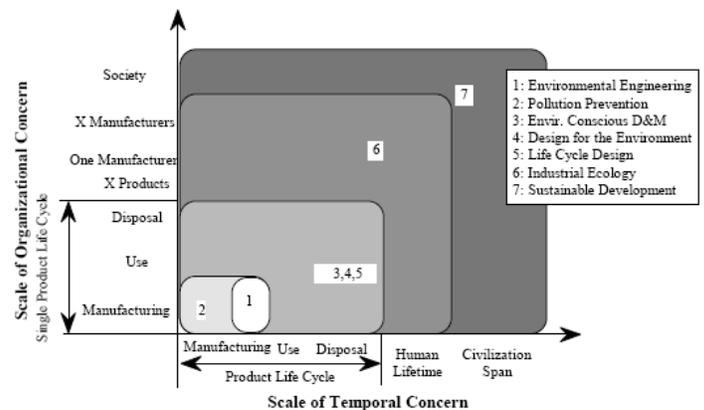
Figure 1: Organizational and Temporal Scale of Environmental Sustainability Approaches (Bras 1997)

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[4] Bras excludes Design for Environment from the DfX set of tools.

Höjer et al (2008) describe the set of environmental approaches that they categorized as environmental systems analysis tools. There are wide varieties of tools available that address the financial and environmental aspects of sustainability. The literature covers cost-benefit analysis, life-cycle costing, life-cycle analysis, materials flow analysis and many other analytical tools – those tools that focus on technical aspects of the analysis. Additionally tools such as Environmental Management Systems (e.g. ISO14000) establish a procedural framework and enables decision-making.

Höjer et al. (2008) point out that these analytical tools require quantitative data, and obtaining such data for future scenarios with longer periods, as required by sustainable development, can be problematic since these data do not exist for future developments. Additionally, longer periods introduce discontinuities due to major shifts in trends.

In a thorough survey of the existing literature since 1970, Baumann et al. (2002) discovered that the majority of the assessment methods reported fell into the category of those which are applied within a single product life-cycle and focus on specific life-cycle stages[5], with guidelines and checklists being the most commonly employed methods. Gutowski et al. (2005) note that in order to deal with the complex nature of environmental impact assessment, tools, metrics and models are "badly needed" to guide improvement and to measure progress.

Interestingly, while Baumann et al. (2002) highlight the need for tools at the conceptual stages of design, they also point out that many designers feel that tools in the early stages of design are lacking and would like to see better methods at the early stages of design. They also highlight the need for tools that, in Bras' categorization scheme, cover the entire life-cycle span and go beyond a single product life-cycle.

Gibson (2006) identifies a key barrier with respect to the integration of tools and methods for sustainable product development: the loci of expertise in financial, environmental and social aspects of sustainability are diffused across the corporation. Consequently, the corporate IT systems needed to integrate financial, environmental and social information systems tend to be disaggregated as well.

2.2. Decision Support Systems

How stakeholders in the value chain make decisions also has an impact on successful incorporation of sustainability into product development. Limited decision support systems are available to organizations to assist in optimizing trade-offs with respect to sustainable development considerations. In practice there is a strong tendency to try to monetize impacts such as the quality of the environment, or many social indicators that cannot be expressed in financial terms(Azapagic and Perdan 2000). Firms are used to using toolsets such as cost-benefit analysis tools, and these tools may not be right ones for a triple bottom line approach.

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[5] Note that Baumann et al. (2002) used a different categorization scheme and the authors of this work are making a rough map to Bras' categories (1997).

Integrated information systems to support decision making for sustainability are lacking. These systems need to tackle the following dimensions: "where" - the breadth of the value chain, "who" - the actors in the various levels of the organizational structure and a temporal dimension that represents "when" in the product development lifecycle and "which" related to each product in the product portfolio. As an example, individuals at different levels in the organization require different views of the information, which changes over time as the product progresses from concept to end of life. Value chain agents such as marketing, research, development, commercialization and service have different information needs. This calls for information technology, tools, and methods that may not integrate well with existing development tools and methods.

2.3. Sustainable Product Development Processes

While there is no shortage of research in sustainable development innovation, (Pujari 2006), the literature does not provide enough information on how to practically incorporate sustainability initiatives within a product development process. In general, the research offers vague, generic recommendations about the importance of sustainability or why it is important (Baumann et al. 2002). Indeed, there are several examples where a general approach is suggested (Pujari et al. 2003; Byggeth et al. 2007) but these fail to provide any meaningful information as to how to integrate sustainability within a specific product development process. The vast majority of articles in this area provide "too many normative suggestions, with little practical relevance or testing: empirical material is presented but often as an illustration rather than as a testing ground for hypotheses" (Baumann et al. 2002).

Byggeth et al. (2007) suggest a framework to incorporate sustainability within a product development process using a series of questions for product development phase-gate reviews. However, within this framework you only need to repackage the activities to show that they are more sustainable than earlier projects. While this is a good first step in sustainable product innovation, it does not answer the fundamental questions of how to enforce it or how to quantify the benefits.

Eco-design innovation pioneered by (Sherwin and Evans 2000) and ENPD (environmental new product development) by (Pujari 2006) are very similar but only addresses the environmental impact of products. They suggest, not surprisingly, that it is easier and takes less time to reduce the environmental impact of existing products than to create a new product design that works in synergy with the environment. Using guiding questions and principles during the product development process, a "greener" product can be produced.

Another framework by (Maxwell and van der Vorst 2003) posits that in order to fully embrace sustainability within new product development, it is necessary to understand where in the supply chain the firm's products or services lie. At each phase-gate review, questions are posed that try to assess and optimize the "level of sustainability". While this method takes into account the supply chain to understand the impact of product

development on the production system, it does not offer any suggestions about how to gain agreements with others in the supply chain or how to proceed if cost is increased.

2.4. Summary

The research that has examined the incorporation of the principles of sustainability into the product development organization can be categorized as either (1) empirical and broad in terms of the number of organizations studied or (2) qualitative and narrow in terms of the number of organizations studied. *Depth into the organization is generally lacking –* meaning that there is a lack of literature that shows how individual contributors, lower and middle level management in product development organizations have incorporated sustainability into their value chain activities. Furthermore, there *is a need for more research into how a product development organization and its value chain actually implements and executes a sustainability strategy or initiative.*

3. RESEARCH DESIGN AND METHODOLOGY

The goal of this research is to perform an exploratory study into the barriers and enablers to incorporate sustainable development principles, tools and methods into the new product development (NPD) process. In order to accomplish this, a case study methodology (Yin 2003) was utilized to gather in-depth data from two multinational manufacturing organizations.

The specific goals of this research consisted of the following: (1) Determine how the principles of sustainability were incorporated into NPD processes; (2) Identify the barriers and enablers that managers and product developers in organizations engaged in NPD faced when they incorporated sustainability into their decision-making.

3.1. Case Study Design

The unit of analysis for this research was the product development organization within a business division and its value chain partners. The value chain includes the supply chain and the demand chain from the perspective of the business division. Value chain partners may be internal as well as external to the firm. The criteria for selection of the business division included:

- the division was part of a multinational firm
- the division engaged in global NPD
- the division had profit and loss responsibility
- the division had relative complex NPD projects

Two specific divisions within two firms and their value chains were selected. Pseudonyms were used for each of the firms to avoid disclosing their identities. The first firm was called Company A, and the business division covered was called the Highly Engineered Materials Division (HEMD). The second firm was called Company B, and the business division covered was called the High End Solutions Group (HESG). Particular attention and focus was placed on the Product Development value chain activities – other activities in the value chain were considered if the division needed to interface with its value chain partners across organizational boundaries.

In order to cover the product lifecycle from concept to end of life, access to managers in the product development value chain was needed. Interviews were conducted with subject matter experts from Marketing, Research and Development, Program Management Commercialization and Manufacturing. This study did not focus on sales and service functions.

To identify the interview candidates, a stratified sampling approach was implemented. The goal was to ensure equitable representation from both Company A/HEMD and Company B/HESG personnel. Interview candidates were stratified by functional job responsibilities. Since it was anticipated that some barriers and enablers might be tied to the organizational structure and reporting hierarchy, interview candidates were also stratified by position in the organization and job titles. Job titles and functional responsibilities were reconciled and normalized at each firm to ensure consistency in reporting.

3.2. Interview Protocol

Semi-structured interviews were conducted with the interview candidates that sometimes consisted of individual interviews or group interviews within the respective organizations. Individual interviews were 45-60 minutes long and group interviews were 60-90 minutes long. Pursuant to the interviewee having provided us with a verbal consent, interviews were recorded and the resulting audio data were transcribed and screened to protect proprietary information.

Interviews from each firm were coded by each team member and the coded segments were compiled into a database per the method defined by (Yin 2003). The information was analyzed to develop themes, patterns and potential propositions. The findings for each company were presented as individual cases, followed by a comparison of each case.

3.3. Research Questions

In order to address the research objectives, more specific research questions were formulated to guide the development of the interview:

- What is each company's goal for sustainability?
- What is one firm doing that the other is not?
- Can path dependencies, industry and market imperatives, position in the customer value chain, culture, and organizational structure explain differences and commonalities?
- Are any of these factors significant as enablers or barriers for integrating sustainability into NPD?
  - o core competencies
  - o processes
  - o organizational culture
  - o organizational structure
    - relative to Environment, Health and Safety
    - relative to Research and Development (R&D)
    - the organization's position in the value chain
  - o manufacturing strategy (component/end product)
  - o product acquisition strategy (make/buy)

- o relative strengths of technology push, market pull and regulatory/compliance push in the served markets/industries
- o NPD product launch velocity and product mix
- o modularity/integrality of the product architecture and its key technologies
- o position of key technologies on the S-curves
- o nature of the business model (aggregated versus disaggregated)

4. CASE STUDY RESULTS

There were 32 identified candidates across both firms, which consisted primarily of senior managers holding titles of Director and above and secondarily managers or individual contributors reporting to Directors. In total, 26 people were interviewed, 10 at the HEMD division at Company A and 16 at the HESG division at Company B.

4.1. Company A/HEMD

4.1.1. Background

Company A has spent over 100 years in manufacturing high end components for a variety of industries. They produce parts for sub-systems that ultimately are a part of a larger value chain. This company has several divisions that operate in very different market segments, but all are tied together by the company's core competencies in materials and processing.

This case study looked specifically at the Highly Engineered Materials Division (HEMD). HEMD makes components that help reduce pollution caused by heavy industry. The products made by HEMD are part of a sub-system assembly and are sent to the next supply chain partner for further treatment. They are, in turn, are sent to others in the supply chain until they are integrated into the final product by OEM's in heavy industry.

Subsequent process steps conducted by other supply chain vendors downstream of HEMD transforms the raw materials in the product as it assembles the other components of the subsystem. These processes and additional components add materials considered as hazardous waste. It is important to note that while HEMD works with the Product Treatment companies, they are not privy to the specific formulations that enable product functionality.

Heavy industry buys these products because they are required by law to do so. In this case, heavy machine operation produces waste that must be treated before it can be released into the environment. There are specific regulations that mandate what amount and type of waste can be released. These regulations are developed several years in advance by governmental organizations and become stricter over time. Moreover, waste limits vary from country to country and can affect the type of product sold in that location.

By design, use of the final assembly in the OEM's product results in hazardous waste being trapped in the material structure. The addition of the pollution abatement system actually decreases overall system efficiency and operating cost slightly, but it dramatically reduces of the amount of contaminants introduced into the environment. The resulting product at end of life (EOL) is considered to contain hazardous materials and must be disposed of accordingly.

HEMD's product is incorporated into a product with very long life (>10 years). The OEM specifies that all sub-systems components should be able to last the lifetime of the product. It chooses to outsource this integral product because they do not have the competencies in pollution abatement or materials expertise to develop the product in house. In fact, no member of the supply chain has chosen to vertically integrate the manufacture of this system due to high barriers to entry for each part of the supply chain. The opportunity for a new product family launch emerges every 3-5 years, driven by the adoption of new regulations. However, product variants can be introduced every 18-24 months, depending upon when OEM's release a newer model.

HEMD manufacturing is primarily located in North America but its products are used in heavy industry globally. These products are manufactured from proprietary combinations of materials and processes. In order to maintain high yields, HEMD sets tight specifications on its material suppliers. This serves to reduce or eliminate contaminants that can affect the final product chemistry. The manufacturing process is very energy intensive, necessitated by having to transform these raw materials into a specific chemical and physical structure. The materials used to make the sub-system product are environmentally safe – HEMD employs sophisticated manufacturing processes to transform a material that is abundant in the earth's lithosphere into their product. In fact, HEMD claims that the product they generate can be recycled into filler or placed into a landfill with no environmental impacts

4.1.2. Corporate Approach to Sustainability

Company A does not have a corporate sustainability program. They do not issue a report on corporate social responsibility report but do take their responsibility as corporate citizens seriously. They prominently display their commitment to the environment and the communities they serve on their website. The corporation does not communicate a global strategy to improve sustainability. When asked whether they were aware of a corporate wide definition of sustainability, all interviewees were unaware of any specific description.

Managers from HEMD do not view this as something that would prevent the company from acting in a sustainable manner. Many saw sustainability as something that would naturally evolve from following the corporate values. To that end, Company A does have a specific goal to reduce the amount of energy they use; this is due to the energy intensive nature of their manufacturing processes. This is the only measurable and publicly communicated initiative that affects all business divisions. This initiative would not only reduce greenhouse gas emission but also reduce the operating costs of their plants.

4.1.3. Sustainability in the Supply Chain

HEMD engages very early in the supply chain, literally, after materials have been mined and refined. HEMD believes that their responsibility begin with the choices that they make in selecting materials. To this end, they specify that the raw materials they use must not contain hazardous elements.

While they work with others in the supply chain, they do not have significant influence in how materials are used or processed. The OEM, which assembles the final product, can dictate specific requirements to supply chain constituents but they typically look for minimal compliance to environmental regulations and performance. The OEM, in general, is not willing to go above and beyond the regulation as it would compromise the overall performance of the final system.

4.1.4. Product Responsibility

Managers within HEMD are proud that their product plays a role in reducing pollution. There is a strong belief that they are "doing their part" to improve sustainability because their product ultimately helps the environment and therefore has strong social benefits that are applicable globally.

Additionally, because they comply with the regulations on the materials used to manufacture their product and because they are using materials that can be recycled (before going to the next step in the supply chain), they believe that they are making the product as sustainable as they can.

The HEMD organization feels that its responsibility to the product ends when the product is shipped for product treatment. The feeling is that when the product is under their control, they have taken all the steps they can to make it as safe as possible. When someone adds unknown combinations of materials to the product, HEMD sees that responsibility as passing from them to the OEM. This is why there is no EOL consideration in HEMD's product development process.

Interestingly, they did not see their responsibility passing to the next step in the process. The logic was that since the OEM has paid for the product, which can only function with these hazardous materials, the OEM must take responsibility for it. Moreover, HEMD and the other supply chain partners build their sub-systems according to specifications set by the OEM.

HEMD is willing to sub-optimize its component so that the final product is improved. While this is not common, they have worked to overcome processing issues in the supply chain by tailoring their product for a specific application. For example, they did reduce the efficiency of their product to alleviate an adhesion problem with the product treatment step at a downstream supply chain partner.

4.2. Company B/HESG

4.2.1. Background

Company B, established over 50 years ago, is a high-technology end-product manufacturer that primarily serves multiple industries across a wide set of market segments. A large, multi-national firm, Company B has many business divisions and consequently a number of product development organizations. In this case study, we focused on a product

development team in a business division called the High End Solutions Group (HESG). HESG has sole responsibility for product design and integration. Company B views the market segment served by HESG as up-market relative to other market segments served by the firm.

HESG develops products and services that are sold globally, but the product development organization is based in North America. One can broadly characterize the product lines produced by this team as capital assets with a price upwards of $200,000. The firm prices its flagship systems upwards of $400,000 and customers expect a product life of greater than ten years. Its products require the use of consumables some of which are produced from renewable natural resources.

The industry that produces the consumables for Company B is very energy intensive and has historically been in the cross hairs of environmental activists for its impact on the environment. The products also require supplies that are proprietary formulations manufactured by Company B. Humans handle the output produced by its systems and although it can be recycled, it is typically one of the most commonly found items in landfills.

Sales by product line on an annual basis are in the hundreds of units. Transactions are business to business (B2B) using a direct sales and service force. Customers can purchase or lease the systems. Customers span the gamut from small mom-and-pop operations to large operations, including multinational corporations, educational institutions and governments.

4.2.2. Corporate Approach to Sustainability

Company B has had a long history of being a responsible corporate citizen. It issues a yearly Citizenship Report and publishes a Corporate Social Responsibility brochure. There is no Chief Sustainability Officer position on the firm's organization charts to date. Corporate communication refers to the Brundtland definition of sustainable development using the term sustainability and articulates the three aspects of the triple bottom line, economic, environmental and social impacts. It describes the value proposition of the firm's technologies products and services in the context of sustainability.

The firm places emphasis on the environmental aspect of sustainability. It recently published a strategy for environmental sustainability of its supply chain and operations. The strategy articulates the intention to assist customers as they seek to improve their own environmental sustainability. It contains elements of climate protection and energy, biodiversity, preservation of clean air and water and waste prevention and management. The strategic planks were selected based on an internal analysis of where and how the firm could make the most significant impact, given its business model and value chain. The firm outlines the framework for execution of the strategy: a quantitative approach, economic focus with quick paybacks, looking for opportunities in the value chain. The firm has established stretch goals for each element of the strategy, but no examples of measurements and targets were seen.

Company B's Beyond Compliance worldview is rooted in one of its corporate values, which affirms its desire to be a good corporate citizen and this aspiration resonates with management. The firm is very concerned about its sustainability talk not exceeding its walk – and wants to avoid the appearance of green washing at all costs. To that effect, the firm will not do something just because it is in vogue and wants to ensure messaging consistency both internally and externally.

One person expressed how challenging it is to have the discipline not to join in the fray and respond to competitor's assertions, which they believe, are unfounded. EHS managers said that direct comparisons were difficult due to:

- not having a baseline understanding of the level of sustainability of its own product portfolio,
- not having access to the assumptions that their competitors used in their assessments (especially the boundaries of any life cycle assessments),
- the lack of a neutral, third-party assessor for comparing products and technologies,
- the lack of recognized industry standards, metrics and measurement systems for conducting the evaluation

The stewardship of the firm's environmental sustainability initiative falls to the EHS organization. It has traditionally played a governance, compliance and auditing role, running like a background process on a server – ensuring that the firm meets its regulatory commitments. They value their independence from the product development teams, which allows them to execute their roles without conflict of interest.

4.2.3. Sustainability in the Supply Chain

Over the past two decades, the supply chain dynamics associated with HESG's products have changed from a predominantly vertically integrated internal supply chain to a combination of internal and external supply chains. The impacts of globalization have diffused and disaggregated HESG's supply chain. The firm has relatively low supply chain power in commodity components due to its low production volumes.

EHS and the supply chain organization have worked closely to establish strong relationships with their suppliers. Company B, as a leader in environmental sustainability in its industry, has rich knowledge about the materials and processes required to build the product line. In many cases, they have established a leadership position by setting a higher bar internally than required by regulations and legislation for environmental, health and safety.

They work with their suppliers to educate them on the rationale for delivering inputs that meet these higher standards without having to incur substantial price premiums. For Company B this approach has significant benefits. Firstly, it harmonizes the supply chain inputs to ease component and assembly integration into the products. Secondly, it establishes a level of trust that can offset the lack of supply chain power.

Company B has established a proprietary set of standards for its design communities, many of which exceed industry-accepted practices and international standards. The firm believes that these standards are a source of competitive advantage. The outsourcing of design is a concern to the design communities, not only from the parochial concerns about their job security, but also from the risk that components and sub-systems that they receive might not meet internal standards.

4.2.4. Product Responsibility

People interviewed in the product development organization and the extended value chain unanimously agreed that the firm's responsibility with respect to the sustainability of the product *ought to* begin in the earliest stages of product and supply chain design and that the firm was responsible for the product from "cradle to grave."

The firm's high-end product line has historically been capable of supporting multiple lives. However, long tenured employees that we interviewed could not recall if design for multiple lives was part of a conscious engineering strategy at the time. Perhaps the ability to obtain multiple lives from their systems came partially from being in an uncontested space, dealing with a highly complex, interactive integral technology set that required judicious use of "safety factors". Other factors may include a dominant engineering culture that was "cost-no-object", performance and feature oriented – a prototypical Stage 1 vertically integrated tinkerer organization (Christensen 1997).

The firm had the foresight, mostly driven by economics, to develop strategies for remanufacturing and converting these assets in order to extract the maximum financial benefits from their investment. A secondary benefit, aligned with corporate values to be responsible corporate citizens, would reduce the environmental impact of placing used equipment in landfills.

Managers said that while end of life was considered early in the development process, the actual process for how the product would be reused and dematerialized was solidified once the product was in the field.

Some managers expressed a belief that supporting a multiple lives strategy through remanufacture and conversion is both a blessing and curse. It is a blessing because financially it enables the firm to amortize capital investments over a longer period of time. It is a curse because it requires managers to balance economic and environmental priorities. If the residual value of the end of life asset is too high, it can be a governor on the rate of introduction of innovations in variants. This is because management will not want to introduce any change that might preclude the reuse of a high residual value asset for fear of having to incur a write-off as well as incur new costs for tooling and higher component prices.

5. CASE STUDY ANALYSIS

5.1. Gaps between the Sustainability Literature and Current Practice

The case study found that both organizations have a rich history of supporting individual initiatives across the three dimensions of sustainability. Yet the development of an integrated sustainability strategy is nascent in both firms, and

consequently in their product development value chains. In both firms an understanding of the intricacies of the holistic view of sustainability were missing.

There is a discrepancy between the academic and philosophical views of sustainability and current practice. The triple bottom line concept, even though it is stated in terms that should appeal to the corporation, was not intuitive to the managers interviewed. In the firms studied, the dominant design paradigm was firmly centered on cost and performance. The individual activities that these firms have been pursuing for decades are strictly in the domain of eco-efficiency – more of a be "less bad" approach (e.g. reuse, recycling, remanufacturing). In many cases, it was felt that managers were missing the connections between the economic and environmental aspects of their eco-efficiency based programs and projects. When does the transformation from eco-efficiency to eco-effectiveness take place? What are the necessary conditions for the transformation? What would motivate a firm to move from eco-efficiency to eco-effectiveness? Are all firms in a position to effect this transformation? These are interesting questions for further contemplation.

The nature of the firm is to maximize shareholder wealth. Despite the recent movement to adopt a broader perspective about the role that business should play, it seems that it has been difficult for firms to advocate for a reduction in consumption.

In this study it was found that both firms are making progress towards making their product development value chains sustainable even though this may be from a be "less bad" perspective. Each organization can point to specific activities across the three pillars of sustainability: financial, environmental and social. Many of these activities have been in place for decades as individual initiatives, disaggregated, and autonomous, yet producing good results.

5.2.

5.2.1. Theme 1 – Integrated Sustainability Strategies versus Targeted Initiatives

The main observation here is that both organizations are progressing without an overall corporate sustainability strategy. Company A/HEMD claims that an umbrella approach is not needed and could be counterproductive. In the absence of this strategy, senior managers rely on corporate values to provide direction for their sustainability activities and initiatives beyond compliance. Company B/HESG is in the process of developing an environmental sustainability strategy led by EHS. While this strategy is being developed at the corporate level, it did not contain a holistic strategy for all three dimensions of sustainability. Yet, each company is clearly making progress towards the goal of being more sustainable.

While not all researchers are in agreement, it is clear that technology has an important role in addressing the sustainability agenda. A question that arises is if the product development process is where the integration of sustainable development considerations should begin to tackle this issue or should the technology development process be the place where these initiatives are first implemented, as the former may only lead to incremental improvements? The nature of product development may cause sustainability initiatives to be treated in the same way as managers treat disruptive innovations (Christensen 1997). Research, on the other hand, with its funding stream from corporate combined with a longer development time horizon might be a better place to develop the appropriate technologies along with the requisite strategies that gives definition to the overarching sustainability strategy.

However, it seems logical that an overarching strategy of some sort will be necessary. An example of why this is so is to consider the case where the first set of technologies with improved sustainability might have a higher commercialization cost than the technologies that they replace. This form of technology lock-in is well documented in the literature (Atkinson et al. 2007). Metrics and measurement systems at the technology transfer boundaries must have associated toolsets that can project lifecycle costs. Without this, all things being equal, product development teams will consistently decide against commercializing these new technologies.

5.2.2. Theme 2 – Firms Focus Their Sustainability Activities on Areas Where They Have Influence

Company A/HEMD and Company B/HESG focus their sustainability initiatives in areas where they have the greatest influence and in areas where they can obtain financial benefit. The scale and scope of their strategic influence are highly localized; neither firm has sought out to influence or understand the impacts from the larger industrial ecosystem they belong to. This is a disparity relative to Bras' (1997) view on the scale and scope that sustainable development requires.

Process versus Product Focus

Company A/HEMD, a keystone component manufacturer, utilizes its core competencies in materials and processing to make its product as sustainable as possible when it leaves the shipping dock. Managers in HEMD expressed their challenges incorporating sustainability into the product development value chain primarily from an operational and process driven focus rather than a product driven focus.

As a keystone component manufacturer that is very early in the OEM's supply chain, Company A/HEMD does not have much influence with downstream value chain partners. This organization is a large consumer of energy, and consequently seeks to reduce its energy footprint. The equipment needed to support manufacturing is very expensive. Furthermore, it is very expensive to retrofit a plant, and so the firm will make beyond compliance investments when new plants are built, regardless of whether these be in the U.S. or overseas.

In discussions related to the challenges in incorporating sustainability into Company B/HESG, the predominant responses had the flavor of sustainable technology injection into new products. Perhaps this is a natural outcome of the strategic mindset of the managers interviewed – scientists and engineers with significant product development experience.

Many of the barriers enumerated below are characteristic problems related to new product development, and do not appear to be specific to sustainable product development. Some examples include:

- Common platforms and modular architectures help reuse and remanufacturing initiatives, but may detract product differentiation.
- Long product lifecycles are particularly challenging – grandfathering, parts obsolescence, scenario planning for sustainability needs 5-10 years in the future.
- Design for multiple lives is challenging – balancing extensibility and robustness with cost management
- High residual value assets from lease-return equipment or parts with high capital tooling needs become barriers to the incorporation of sustainability in product variants[6]. This is because variant product development managers are incented to minimize write-offs associated with changing an architectural element that has a high residual value.

5.2.3. Theme 3 - Differential Awareness of Sustainability in the Product Development Value Chain.

In Company A/HEMD, there is an "Awareness Cliff" between senior management and individual contributors of the organization. Higher-level managers were able to articulate a comprehensive view of sustainability by referring to the corporate values. They provided personal and company anecdotes related to the TBL aspects. While this suggests that Company A's values encompass sustainable initiatives, it begs

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[6] This appears to be no different than incorporating new technologies in product variants.

the question why employees at lower levels of the organization could not provide a similar definition.

One possibility is that senior managers have had broad experience throughout the company and are able to understand how different areas of expertise come together to achieve a larger goal. One could argue that this is why they are in their current roles – to bring a holistic thought process to the decision making. At the individual contributor level, the dictionary definition of sustainability was provided, and the anecdotes were focused on the details of their jobs.

In Company B/HESG, there is differential awareness across organizational boundaries based on their organizational proximity to the environmental sustainability agenda, and their motivation to integrate sustainability into their activities. Managers from EHS, who are accountable for the deployment of the strategy were familiar with the TBL aspects of sustainability, but were quick to emphasize that their strategy was focused on environmental sustainability. Senior managers from Research, who are accountable for developing the next generation of technologies for the firm and who have sensed a market need for sustainable products provided a broad description of Company B's work on all three aspects. Marketing and product development managers, who are still attempting to determine the incremental value of improving the level of sustainability of the products, tended to focus on the financial and environmental aspects of sustainability. There was a relatively strong linkage between the activities described in support of environmental sustainability and its financial impact on the firm.

The general theme is that there will likely be a disparity in the level of understanding of sustainability in large organizations. The interesting observation is that one should not presume that the disparity will always be based on the strata in the organization. In some cases, one may find disparity in the awareness across organizations based on their proximity to the sustainability agenda. The implication is that managers responsible for raising the awareness of sustainability within the organization need to be aware of the type of disparity and design their communication plans and training as needed.

5.2.4. Theme 4 – Measuring Progress

In markets where sustainability is emerging as a selling point, there is a lot of collective consternation within the product development value chain in terms of measuring progress. Levels of guilt were detected from managers as they tried to assess whether their firm was doing enough. Related to this issue is the frustration of assessing the claims of competitors and the product position relative to those claims. A particular concern is engaging the competition without inadvertently engaging in green-washing. The following barriers were identified:

- lack of metrics
- lack of methods to do competitive analysis
- lack of independent 3rd party evaluators or assessment regimes in certain industries
- fear of unintended green washing

- how to market, under the sustainability umbrella, the many disaggregated beyond compliance initiatives that the firm has been doing in the past

6. CONCLUSIONS

Based on this exploratory study the following conclusions have been developed:
- There is no consensus on defining sustainability
- Everyone thinks sustainability is a good idea, but no one knows how to implement it
- A "one size fits all" approach to sustainability may not be ideal
- Corporations do not view sustainability from the ecosystem perspective

6.1. There is no consensus on defining sustainability

During the interview process, many different definitions of sustainability emerged. Depending upon the role or level within in the organization, each person had a different perspective on what sustainability was and what role their firm played (or should play). As (Holmberg and Sandbrook 1992) showed, there are various different interpretations. In each interview, while it could be argued that the interviewee did not provide a "Brundtland-like" perspective, they did provide a view into how they felt sustainability affected their daily job.

Two of the more interesting observations form the case study were that those that understood the corporate goal were generally only able to see how sustainability was tantamount to environmental sustainability and that companies focused their sustainability related activities on where they have influence.

Clearly, companies view sustainability through their corporate filters, thus it will necessarily be interpreted differently by different companies. While a broad, general definition (like that proposed by Brundtland) serves to scope the macro-issue, corporations will choose to respond differently, in part because of the different products and services they deliver.

With few exceptions, employees at both firms did not discuss the social aspect of sustainability. Either they were unaware that sustainability encompassed more than just "being green", did not feel that it was a corporation's responsibility or could not see past the filter of their own job function. It is difficult to tie back this aspect to a corporation's bottom line without a thorough understanding of how social sustainability can improve a firm's performance in the long run.

In order to improve awareness, either the management must show how sustainability is linked to the corporate values or they need to have a separate, corporate sustainability strategy. Additionally, unless the strategy is very detailed, with specific goals for each aspect of the TBL, the firm will end up communicating a sustainability agenda that is incomplete.

6.2. Everyone thinks sustainability is a good idea, but no one knows how to implement it

In all of the interviews, no one questioned the reasoning for us to investigate sustainability; everyone understood (or appeared to understand) the business case for sustainability. Further, employees at both companies believed that their firm could be doing more to incorporate the principles of sustainability into their product development process. When pressed how to do this, they suggested that sustainability should be considered earlier in the process and that all parties (research through manufacturing and sales) should be involved.

These suggestions are consistent with those in the literature (see Byggeth et al. 2007), (Pujari 2006) or (Baumann et al. 2002)) but only point to minor changes in their processes. There could be two reasons for this. First, the people that we spoke with did not have the authority to reformulate their product development process and knowing this, offered what they believed they could do within their spheres of influence. This could lead to incremental process improvement, but cannot address the fundamental need – if sustainability is so important to the corporation, should we change how we make our product development decisions? Secondly, there was no consensus about what the goal was. How can we expect the organization to tell us how to implement sustainability when they cannot even agree on what it means?

6.3. A "one size fits all" approach to sustainability may not be ideal

Both Company A and B are high tech, multinational firms that make quality products. However, they are in different industries, different positions in their respective supply chains and have different organizational structures and culture. There is no reason to believe that a strategy that works for one

As Gunningham et al. (2003) suggest, there are differences within corporations (internal pressures) and in the environment that they exist (external pressures). They suggest that two companies that face the same external pressures will respond differently due to their intra-firm differences (e.g. / decision-making and product development processes). This lends credence to the idea that different companies in different businesses will: 1) Face diverse expectations about sustainability and 2) Address them in a way that is consistent with their own internal policies.

6.4. Corporations do not view sustainability from the ecosystem perspective

Both companies are working to improve the sustainability of their products and processes. They view their responsibility as making the product as sustainable as possible. Company A/HEMD does this by ensuring that the materials used in their product are non-toxic and inert. Company B/HESG leverages their supply chain influence to make component manufacturers use materials that are compliant with regulations. Using Bras' (1997) view of sustainability, their view of sustainability is limited to a product life-cycle.

During the interviews, not one respondent suggested that corporate sustainability was achievable without support from others. They assumed that their corporation was responsible for settings its own targets and goals. As presented by (O'Connor 2006), in order to be truly sustainable, an ecosystem of government and social and financial organizations must work together to set clear targets and responsibilities. Until the corporation views itself as a partner in sustainable development, they will not be able to achieve enduring progress on sustainability.

7. FUTURE RESEARCH

It was the intent of this research to conduct a deep, exploratory study into two different divisions within two firms. It was discovered that sustainability is difficult to understand and to implement for these corporations. The following areas are suggested for further research:

- Investigate smaller companies to see if it is easier or more difficult for them to implement sustainability. Specifically, does the lack of formal product development processes at smaller companies impede or support adoption of sustainable practices?
- Explore more fully the linkages in product development decision-making by including input from sales, human resources and corporate communication. These were areas that we were not able to adequately cover in our research.
- A deep study into a large corporation would be able to highlight any differences in awareness and implementation from division to division.
- Are there any industries that have successfully implemented an ecosystem perspective on sustainability? Why have they been successful or not?

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REFERENCES

Aid, N. (2007). "Global Poverty." from http://www.netaid.org/global_poverty/global-poverty/.

Allocca, C. and S. Energy "Eco-Efficiency and Sustainable Product Development."

Atkinson, G., S. Dietz, et al. (2007). Handbook of sustainable development. Massachusetts, Edward Elgar Publishing, Inc.

Azapagic, A. and S. Perdan (2000). "Indicators of sustainable development for industry: a general framework." Trans IChemE 78(Part B): 243-261.

Baumann, H., F. Boons, et al. (2002). "Mapping the green product development field: engineering, policy and business perspectives." Journal of Cleaner Production 10(5): 409-425.

Bras, B. (1997). "Incorporating environmental issues in product design and realization." Industry and Environment 20(1): 7-13.

Brundtland, G. H. (1987). Our Common Future/World Commission on Environment and Development, Oxford University Press Oxford.

Butler, T. (2004). Leveraging Sustainability: How Companies Enhance Their Eco-Innovation Success, Rensselaer Polytechnic Institute. PhD Management.

Byggeth, S., G. Broman, et al. (2007). "A method for sustainable product development based on a modular system of guiding questions." Journal of Cleaner Production 15(1): 1-11.

Christensen, C. M. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press.

Dearing, A. (2007). "Sustainable Innovation: Drivers and Barriers."

Elkington, J. (2004). "Enter the triple bottom line." The Triple Bottom Line: does it all add up: 1-16.

Friedman, M. (1970). The Social Responsibility of Business is to Increase its Profits. The New York TImes Magazine, The New York Times Company.

Gibson, R. B. (2006). "Beyond the pillars: Sustainability assessment as a framework for effective integration of social, economic and ecological considerations in significant decision-making." Journal of Environmental Assessment Policy and Management 8(3): 259-280.

Gunningham, N., R. A. Kagan, et al. (2003). Shades of Green: Business, Regulation, and Environment, Stanford University Press.

Gutowski, T., C. Murphy, D. Allen, D. Bauer, B. Bras, T. Piwonka, P. Sheng, J. Sutherland, D. Thurston, (2005) "Environmentally benign manufacturing: Observations from Japan, Europe and the United States", Journal of Cleaner Production, 13(1).

Wolff, EgonHöjer, M., S. Ahlroth, et al. (2008). "Scenarios in selected tools for environmental systems analysis." Journal of Cleaner Production In Press, Corrected Proof.

Holmberg, J. and R. Sandbrook (1992). "Sustainable development: what is to be done." Policies for a Small Planet, Earthscan, London: 19-38.

Huijbregts, M. A. J., S. Hellweg, et al. (2008). "Ecological footprint accounting in the life cycle assessment of products." Ecological Economics 64(4): 798-807.

Kates, R. W., T. M. Parris, et al. (2005). "WHAT IS SUSTAINABLE DEVELOPMENT? (Cover story)." Environment 47(3): 8-21.

Maxwell, D. and R. van der Vorst (2003). "Developing sustainable products and services." Journal of Cleaner Production 11(8): 883-895.

McDonough, W. (1992). "The Hannover Principles - Design for Sustainability." Retrieved 8/7/2008, 2008.

McWilliams, A., D. S. Siegel, et al. (2006). "Corporate Social Responsibility: Strategic Implications*." Journal of Management Studies **43**(1): 1-18.

Meadows, D. H., D. L. Meadows, et al. (1992). Beyond the limits. United States, Post Mills, VT (United States) ;Chelsea Green Publishing Co.

NetAid. (2007). "Global Poverty." from http://www.netaid.org/global_poverty/global-poverty/.

O'Connor, M. (2006). "The "Four Spheres" framework for sustainability." Ecological Complexity **3**(4): 285-292.

PovertyNet. (2008). "Poverty Analysis." from http://web.worldbank.org/WBSITE/EXTERNAL/TOP ICS/EXTPOVERTY/EXTPA/0,,contentMDK:201538 55~menuPK:435040~pagePK:148956~piPK:216618~t heSitePK:430367,00.html.

Pujari, D. (2006). "Eco-innovation and new product development: understanding the influences on market performance." Technovation **26**(1): 76-85.

Pujari, D., G. Wright, et al. (2003). "Green and competitive: Influences on environmental new product development performance." Journal of Business Research **56**(8): 657-671.

Ramus, C. A. (2002). "Encouraging Innovative Environmental Actions: What Companies and Managers Must Do." Journal of World Business **37**(2): 151-64.

Sherwin, C. and S. Evans (2000). "Ecodesign Innovation: Is 'early' always 'best'." 2000 IEEE International Symposium on Electronics and the Environment conference proceedings: 8-10.

Strouts, G. (2007). "Bursting point: The World's Unsustainable Population." from http://zone5.org/2007/11/11/ bursting-point-the-world%E2%80%99s-unsustainable-population/.

Teresko, J. (2006). "Winning With Sustainability." Industry Week **255**(12): 22-4.

The Economist Intelligence Unit (2008). Doing good: Business and the sustainability challenge, The Economist.

Xiaoyu, Y., R. M. Philip, et al. (2007). "Product lifecycle information acquisition and management for consumer products." Industrial Management + Data Systems **107**(7): 936.

Yang, Y. (2005). Managing sustainable product design by integrating corporate product development practice with ISO14001 environmental management systems, Arizona State University.

Yi-Chan, C. and T. Chih-Hung (2007). "The Effect of Green Design Activities on New Product Strategies and Performance: An Empirical Study among High-tech Companies." International Journal of Management **24**(2): 276.

Yin, R. K. (2003). Case Study Research: Design and Methods, Sage Publications Inc.