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The Importance of Understanding the Business Context when Planning Eco-design Activities

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Abstract

The implementation of eco-design within any existing business requires change. This is a requirement because eco-design involves the introduction and integration of new design criteria within an existing product development system. To support meaningful change, it is important to understand the present situation, or business context. The eco-design case study detailed in this paper, failed to appreciate the importance of understanding the business context within which it was taking place. Through a retrospective analysis of this case study, a Company Characterisation Process (CCP) has been developed. The CCP is presented in this paper, and a theoretical application is provided to help exemplify its application. The CCP has been designed to support the development of effective and efficient eco-design projects. The tool is of particular use to academics and industrial eco-design practitioners, who are externally supporting company efforts.

1. Introduction

The implementation of eco-design within any existing business requires change. Change is required because eco-design involves the introduction and integration of new environmental criteria within an existing system [1]. Historically these changes have been viewed from one of two perspectives; a top down management approach, or a bottom up design approach. These two perspectives have led to a wealth of tools supporting environmental management and practical eco-design activities [2]. However, they have also introduced polarisation within eco-design that has limited the integration between eco-design and environmental management [3], to the detriment of the projects and company's involved [4, 5]. As the importance of a combined management and design approach becomes apparent [6], a growing body of research is developing within the field of eco-design management [7-9]. These researchers understand that the process of eco-design implementation is a change process that must be carefully managed. This means that the application of eco-tools and the selection of eco-design activities must reflect the business context within which they take place.
The research documented in this paper adds to this emerging understanding, by presenting an experimental case study of an industrial eco-design implementation project that failed to address the wider business context. Through the thorough description and discussion of the case study, the paper provides empirical evidence of the implications of this failure. From this analysis a new eco-design management tool, the Company Characterisation Process (CCP), is developed and presented. The CCP is a four step process that supports the planning of eco-design implementation activities, by ensuring that they reflect the company's current business context. The tool is of particular use to eco-design practitioners

who are acting as external eco-design change agents within small to medium sized enterprises (SME's), however the paper's learning outcomes are relevant to any academics and industrial eco-design practitioners.

2. Methodological Approach for Retrospective Analysis

The methodology taken in this research combines phenomenological and positivistic approaches to help support its inductive nature [10]. The primary data upon which this case study is based, comes from the first author's overt ethnographical observations. These observations were gathered during a two year placement within the company's design department. To prevent this data source being too heavily weighted by its retrospective nature, observations were cross checked against real-time project documentation, including meeting minutes and internal project reports. Two retrospective interviews were then held with the company's managing and technical directors, two years after the project's completion. This helped provide longitudinal insights into the impacts of the eco-design project and support the observations made during the ethnographic study. The combination of these data sets has enabled the development of the Company Characterisation Process. The next stage in this wider research project is to apply this process within an action research study conducted at a different manufacturing firm [11].

3. The Case Study

3.1 The Project

The project being analysed in this case study was an eco-design focused Knowledge Transfer Partnership (KTP), lasting two years. The Knowledge Transfer Partnership scheme brings together a research partner (typically a university) and SME, with the aim of conducting a commercially-beneficial research and development (R&D) project. The goals for this KTP were to *"conduct a strategic review of [the product] design against environmental impact, carbon footprint, complex changing market and developing legislation issues."* and *"Design [the product] family for 2012 onwards."* The project plan consisted of a typical product design and development process [12], with the addition of a streamlined Life Cycle Assessment (sLCA) [13], to identify the product's most significant environmental impacts.
To conduct the project, a project team was constructed. The team was led by an environmental designer (known as "the Associate" and first author of this paper) who was employed by the University and based at the company full time. Also in the team were the company's managing-, technical and design-directors and three University lecturers chosen for their relevant research fields. The Associate was the only team member who worked on the project full time.
The activities involved in the eco-design implementation project are summarised in Figure 1.

Activities Conducted During the Eco-design Implementation Project

1. Streamlined LCA conducted on a representative, mid-range product.
2. Completion of a customer questionnaire focused on the product's use phase.
3. Defined improvement goals based on the outcomes of the sLCA.
4. Conducted research and development activities addressing each improvement goal.
5. Developed product concepts and prototypes.
6. Conducted product testing and refined concepts.
7. Presented concepts to product development team and defined design.
8. Detailed design and generated Computer-Aided-Design (CAD) model.
9. Supported first production run and refined design.
10. Supported product launch and media outreach.

Figure 1: The activities conducted during the company's first eco-design project

3.2 The Company

The company that participated in this case study are a family-run design and manufacturing SME, who have been in operation for over sixty years. The managing director, son of the previous manager, has been at the firm for 17 years, working his way up through the design and engineering functions. The management structure is highly hierarchical, with the managing director paying particularly close attention to the functions he previously contributed to.
Despite the conservative market within which they operate, this company have developed an innovative reputation. This has been fostered through a longstanding relationship with the University, which the company have used intermittently to develop knowledge and support research and development activities. When the KTP began, the company were enjoying a particular boost to their innovative reputation, due to the recent and total overhaul of the product's design and the manufacturing process. The improved product offering was the result of a two year design development project that was being marketed as *"the most significant development in [the product's] production technology for over thirty years."*
The company had previously undertaken environmental initiatives but had no previous experience of eco-design. Onsite initiatives included the introduction of a companywide recycling scheme, to reduce factory waste sent to landfill; 100% use of water-based adhesives, to reduce hazardous substances; and insulation of the factory roof. The company had no understanding of the relative environmental impacts made by the life cycle stages of their operations and had never focused their environmental efforts on the design of the products themselves.

3.3 The Outcomes – Project Activities 1-4

The early stage project activities provided a wealth of new information for the company and University. The first outcome was the completion of the streamlined LCA that calculated the energy consumption and CO_2 emissions related to the materials, manufacturing, transport and use of the product. Disposal was omitted from this study due to a lack of data and inert nature of the material composition. This identified the use of the product as the most environmentally significant

lifecycle phase (79% for both), with materials contributing a further 19% for both impact categories.
As the product being analysed is towed behind a car, the in-use figures are predominantly related to three design features; the product's weight, the aerodynamic drag and the rolling resistance of the tires. As such, the following four design criteria were identified for environmental improvement:

1. Reduce aerodynamic drag
2. Reduce weight
3. Reduce rolling resistance
4. Identify material alternatives that reduce embodied energy without raising the products through life impacts.

To inform the LCA's in-use phase, a customer survey was also completed. Low, medium and high use patterns were extracted from this data allowing the team to address the inherent variation in this phase.
The first stages of this project took 10 months to complete. During this time the company had gained a solid introduction to lifecycle thinking and an understanding of environmental improvement within their industrial context.

3.4 The Outcomes – Project Activities 5-10

The activities conducted during the latter part of the project involved the development of four design development projects to address each of the criteria identified. Table 1 details the activities and indicates their duration and long term achievements.

Criteria and Project Duration	**Design Development Activities**
1. Reduce Aerodynamic Drag (5 months)	- Aerodynamic study conducted on existing design. - Results shared with managing and technical directors. - Product concepts developed, prototyped and tested by associate.
Long Term Outcome	- Design changes not pursued by company due to recent investment in manufacturing process.
2. Reduce Weight (7 ½ months)	- Weight study completed by associate. - Development of a reduced functionality product, selected as only currently viable weight reduction strategy. - Low specification product designed, prototyped, developed and taken to market.
Long Term Outcome	- Low specification product discontinued due to poor market response.
3. Reduce Rolling Resistance (1/2 month)	- Low rolling resistance tires investigated. - Work with supply chain identifies upcoming legislation, requiring all tires to be marked with rolling resistance.
Long Term Outcome	- Low rolling resistance tires selected for use when figures became available.

4. Identify material alternatives (1 month)	- Several low embodied energy alternatives investigated. - Complex relationship between materials and through-life impacts makes evaluation of alternatives difficult.
	- New material selection has lower embodied energy, but decision is based on performance improvements due to a lack of reliable through life data.

Table 1: Design Development Activities Conducted to Address Design Criteria

The most important contributions made during these latter stages, largely came from the continued research conducted to support concept development and prototyping. These activities further increased the company's knowledge relating to their impact reduction and provided tangible ideas around future design directions. What Table 1 reveals, is that the difficulty lay in the integration of this new knowledge within industrially relevant product concepts. Both the novelty of the environmental information and the current resource availability at the company hindered their ability to act.

4. Using the Business Context to Improve the Eco-design Project Planning

The case study review reveals how eco-design outcomes were hindered by activities that did not compliment the company's current business context. From this observation this research hypothesises that incorporating a better understanding of the business context within the development of eco-design activities, will improve outcomes. To this end the following section introduces the Company Characterisation Process (CCP) shown in**Error! Reference source not found.**. The CCP is a three step process that begins with a thorough study of the company's existing internal and external business context. The business context features of most relevance to eco-design implementation were identified by the case study review, the retrospective interviews and the product documentation review, as detailed in Section 2.
For clarity the CCP and business context features are presented upfront*Figure 2*). The subsequent sections then describe the evidence used to identify each of these features.

The Company Characterisation Process	
1. Define the company's current capabilities in each of the following internal and external business context features.	
Internal Business Context - Management structure and hierarchy - Existing design process and new product development timeline - Environmental knowledge throughout the business - Strategic intentions for project	External Business Context - Business drivers for environmental focus - Value chain and roles within it - Environmental knowledge throughout value chain
2. Identify Key Eco-design Capability Development Areas that Reflect the Company's Existing Business Context	
3. Develop a Company Specific Eco-design Introduction Plan	

Figure 2: The Company Characterisation Process and Business Context Features

4.1 Management Structure and Hierarchy

The company involved in this case study were a family run SME, with an extremely hierarchical management structure. The managing director closely controlled all areas of the business, particularly the design direction. The project manager's use of the first person in the retrospective interviews reveals this central control.

"if I don't sell that's my fault because I made the product wrong"

Despite the hierarchical nature of the company, the project outsourced design to the Associate. As a result, the project activities operated outside of the day-to-day and were disconnected from the established flows of information and instruction. This disconnection meant that many employees simply ignored the project activities and requests.
A clearer understanding of the company's management structure and decision making hierarchy would have identified their rigidity. Introductory eco-design could then have been planned to work within this organisational structure.

4.2 Existing Design Process and New Product Development Timeline

The company had recently completed a large design development project, supported by high financial and resource investment. While this had boosted their appetite for innovation, it had also heavily limited the availability of resources.
Due to the nature of aerodynamics, the impact of these resource limitations were most evident in this development project. Large aerodynamic improvements inherently require large shape changes, which in turn demand large manufacturing changes. Small aerodynamic changes demand detailed and expensive testing to determine impact. The following extract from the meeting minutes show how restricted this project was due to these resource limitations.

"[MD] asked how we could determine what saving this [aerodynamic design change] would offer. [University] noted that this was one of the down sides to the [low detailed, low cost] testing method as it would never offer us a drag figure, so it would be difficult to justify changes."

While the project had succeeded in highlighting the importance of aerodynamic improvements, the pursuit of immediate design changes failed to address the present resource constraints. The result of this was to limit the company's ability to commercially utilise the information generated during the 5 months aerodynamic prototype development work. A better understanding of the company's new product development timeline and their current position within it, would have helped identify the existing restrictions. Introductory eco-design activities could then have been planned to align with this timeline and maximise their efficiency.

4.3 Environmental Knowledge throughout the Business

The company had no previous experience of eco-design and very limited understanding of what 'eco' meant in their context. Introducing this new concept, required a large amount of knowledge development both within the design department, and the supporting business functions (marketing, production, purchasing). The LCA, weight and aerodynamic design projects made a significant contribution to the environmental understanding within the project team. However outside of this, very little knowledge development took place. The retrospective interviews highlight the impact this had on the market launch of the low-weight product, and help identify a key reason for its poor market performance.

"[The marketing department] couldn't see the benefits of it and [didn't try] to promote that."

An understanding of the environmental knowledge and awareness throughout the business would have highlighted the scale of knowledge development required. Mapping the environmental knowledge throughout a company may also uncover previously unexpected awareness that can be utilised. Eco-design activities can then be planned to build knowledge where required. If as in this case, knowledge development is needed throughout, a long-term knowledge development plan can be developed starting with the most important product development functions.

4.4 Company Requirements and Expectations

The project plan aimed to establish the environmental impacts of the company's current design and then develop a new product that addressed these impacts. The retrospective interviews reveal how closely this mirrored the company's expectations for the project.

"we wanted a greater understanding of what quantifies an eco-product…and how can we make ours more eco-friendly."
"trying to find new products and new markets"

What can be seen from the other business context features already documented, is that these requirements and expectations were not informed by environmental awareness, or an understanding of what was involved in tackling the environmental impacts of their products. These were in effect, ill-advised goals, which remained throughout the project. A better analysis of the company's aims and expectations could have revealed this limited understanding. The development of more realistic goals for this project could then have been supported by longer-term activities with more impact, reflecting the company's ability to act. Such a plan helps manage expectations whilst ensuring that current project activities are focused in areas of necessity.

4.5 Industry and Business Drivers for Environmental Project Focus

The company's interest in eco-design was heavily influenced legislation governing tow-vehicle emissions. These legislative drivers were reducing the weight and power of the tow-vehicles and limiting the weight that they could tow. The need for

weight reduction was so great that the company saw it as a major threat to their ongoing existence, as shown in the retrospective interviews.

"Every tow car is getting lighter, every manufacturer. Now cars are saying at their launch, "yes, we've made it 50 kilos lighter" and if we want to have a market we've got to make it lighter."

Despite the importance of weight reduction, no prioritisation was performed amongst the product development projects. The LCA had introduced new design drivers, such as aerodynamics and rolling resistance. Failure to prioritise these new drivers by aligning them with the existing business drivers, introduced a separation between the focus of the project and the focus of the company, further limiting the relevance of some project activities.
By developing a complete and in-depth understanding of the drivers for eco-design this project's focus would have more closely emulated that of the company's. Mapping the business drivers could also have helped justify environmental improvements from a traditional, and therefore more easily understood, perspective.

4.6 Value Chain and Roles within It

The value chain is defined as the chain of activities required to deliver a product to a market [14]. In this case the value chain involves the suppliers, the company, the dealers and the transportation companies. All actors in this value chain are important to the delivery of *any* product and yet no mapping of this chain was completed. Failure to complete this mapping delayed the identification of key supply chain relationships, needed when tackling the high environmental footprint of bought-in components. More importantly however it also prevented the Associate from identifying the real 'customers'. Throughout the project the end users were taken to be the customers, while the role of product dealerships was largely overlooked. The retrospective interviews revealed this oversight and the impact this had on the market launch of the low weight product.

"our customers are the dealers"
"[The dealers] didn't understand the product, the eco-ness, the environmental issues. The dealers didn't see that."

Careful mapping of the product value chain would have ensured that all links in the chain were identified. The communication of eco-design activities and the development of knowledge within the value chain could then be effectively and efficiently directed.

4.7 Environmental Knowledge throughout the Value Chain

The low level of environmental knowledge within the company, was mirrored throughout the supply chain, market place and dealer network. Introduction of this new design criteria required increases in awareness and knowledge throughout the value chain. The project started some important conversations with the supply

chain, and drew attention to environmental issues within the market for the first time. However, activities were often limited by a lack of environmental information upstream, and a lack of environmental understanding downstream.
The lack of environmental awareness throughout the supply chain, market and industry presents a huge challenge for any company attempting to make environmental improvements. A more informed understanding of the level of environmental awareness in the value chain could have helped the project assess the challenge ahead more accurately. Eco-design activities could then have been developed to reflect and address these challenges.

5. Applying the Company Characterisation Process Retrospectively

The previous descriptions explain how the relevant business context features have been identified from the retrospective analysis of the eco-design project. Improved understanding of these features would have improved the effectiveness and efficiency of the eco-design implementation activities, within this case study. To further explain the basis of this hypothesis, the subsequent sections retrospectively apply the CCP to this case study company. The retrospective exercise also helps exemplify the process of applying the CCP.

5.1 Mapping the Company's Business Context Features and Identifying Key Development Areas

The first two steps of the CCP involved the description of the relevant business context features and the identification of key development areas. Both stages are summarised below for this case study company.

5.1.1 Hierarchical management structure; MD is key strategic decision maker, secondary design decisions are made by the marketing, purchasing, production and design managers.

5.1.2 Radical and recent product development; company resource availability can only support incremental product changes. Project should focus on supporting incremental changes or generating knowledge to inform future development.

5.1.3 Very low level of environmental knowledge; all areas of the company are in need of environmental knowledge development. Project should prioritise the company functions in accordance with the business and company drivers. A long-term knowledge development plan should then be used to ensure all areas are researched in a structured and strategic manner.

5.1.4 Company has high expectations for project, but low capabilities; careful management of these expectations is required. Short terms activities should be highly focussed to produce small, yet significant environmental improvements. These should be supported by a long term plan for more in-depth development once the company's capabilities have improved.

5.1.5 Legislation is the key eco-driver, with a focus on weight reduction; project plan must prioritise weight reduction to help encourage environmental and business win-wins.

5.1.6 Product value chain consists of suppliers, company, transportation companies, dealers and end user.

5.1.7 Environmental knowledge is low throughout value chain; knowledge development activities are needed in all areas. Again, the project team will need to identify key areas and select according to environmental and business drivers and current project resource.

5.2 Redesigning the Project

The final stage of the CCP incorporates the understanding derived from the business context features to develop an effective and efficient eco-design implementation project. Figure 3 shows how the CCP would have impacted the case study project by listing the activities it would have included. The eco-design activities can be compared with Figure 1 to exemplify the effect of using the CCP.

Activities Conducted During the Eco-design Implementation Project
1. Document the business context features listed in Step 1 of the CCP 2. Establish Project Team (key decision makers). Share the CCP, stage 1 results. 3. Conduct a streamlined LCA of a representative product 4. Conduct a market study (to inform the LCA and CCP process, focussing on the in-use phase, eco-awareness, eco-requirements) 5. Aggregate context features, LCA and market study results and develop project plan and Gantt. Identify key development areas within the business. 6. Conduct a careful breakdown of the key product weight contributions 7. Conduct knowledge gathering and product development plan to support weight reduction. 8. Develop detailed knowledge development plans for each of key development areas and conduct knowledge gathering exercises. 9. Using the information gathered in stages 1-8 produce a business-wide eco-design manual for the company's managing director. Include short and long term plans for ongoing eco-design implementation.

Figure 3: Revised Eco-design Implementation Activities for Case Study Project

Activities 1-4 are designed to help the company understand their current situation and identify the environmental and market drivers for eco-improvements. First the results of Step 1 of the CCP are used to develop a project plan, informed by the business context. All the key decision makers (identified by the CCP) are involved in this activity to encourage awareness throughout the company. A streamlined LCA and full market study are then used to identify environmental and market priorities. Activity 5 aggregates the information generated during activities 1-4, allowing key business areas to be identified. This ensures that the project plan addresses all the new information gathered. Activity 5 should again be conducted by the company's key decision makers to ensure varied perspectives are addressed. Activity 6 involves the completion of a weight analysis and identification of the most important components for weight reduction, aligning the project with the company's current, primary eco-driver. Activities 7 and 8 involve the development

of project plans that address the key areas identified in Activity 5. These plans can be seen as decision support tools that help to define next steps. These plans detail the resource, personnel, cost and time needed to tackle each area. For this case study the first of these plans would focus on weight reduction, the second would document the lower priority areas.
The results of Activities 1-8 are collated to produce an Eco-design Manual. This is primarily aimed the primary strategic decision maker, in this case the managing director, but is shared with all the key decision makers who were involved in Activity 2. By collating and presenting the environmental, market and business perspectives of eco-design, and providing resource plans to address key environmental areas, this document acts as a powerful business planning tool that can be referred to repeatedly throughout company development.
Activities 1-9 require 12 months to complete. At this stage the project could be signed off. The company may decide that the information included within the Eco-design Manual, adequately addresses their current needs. The option of a 1 or 2 year project could be provided at the beginning, allowing the company to make a strategic decision about resource investment and knowledge development. If the company were keen to go beyond the identification of the key issues, the project plans developed in Activities 7 and 8 would be acted on.

5.3 A Project Plan that Reflects the Business Context Features

The revised project plan reflects key business context features at the company. All planning activities involve the key decision makers, particularly the managing director, reflecting the hierarchical management structure and ensuring that project activities are managed in the usual way. Step's 1 and 2 of the CCP also give the company a clear view of their current capabilities and provide a long term view of eco-design implementation, helping to manage expectations. The project plan is flexible allowing strategic decisions to be made throughout the duration of the project as new information becomes available. The flexibility reflects the novelty of environmental issues throughout the value chain and the potential for unexpected requirements as the project progresses. Due to this low knowledge base and the company's current resource restraints, the focus of the activities was also shifted towards knowledge creation and its implementation into targeted product development activities that address key strategic drivers.

6. Conclusions

The case study presented in this paper provides empirical evidence of the need for a more considered approach to the management of eco-design activities. Neither current environmental management nor eco-design tools adequately address this area. The paper presents the Company Characterisation Process, an eco-design management tool, developed as a result of the case study analysis documented. The tool maps the seven business context features found to have greatest impact on effectiveness and efficiency of eco-design activities; the management structure and hierarchy, the existing design process and timeline, the environmental knowledge throughout the business and value chain, the strategic intensions for the project, the business drivers for eco-design and the value chain itself.

An application of the CCP was then provided to show the reader how the tool would reshape the eco-design project activities and goals. Finally, a revised project plan was developed to exemplify how an understanding of the business context can be used to tailor eco-design projects.
The research provides the hypothesis that incorporating the CCP within the planning process of design activities, will improve outcomes. To test this hypothesis, the first author is now in the process of completing a widespread literature review to cross check the conclusions of this paper. The improved CCP will then be used within action research at a different manufacturing firm.

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