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SUPPORTING ECO-DESIGN IMPLEMENTATION WITHIN SMALL AND LARGE COMPANIES

M. Buckingham, D. C. A. Pigosso, E. A. Dekoninck and T. C. McAloone

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1. Introduction

As the theory of eco-design matures, increasing attention is being paid to its application (or lack thereof) within industry [Argument et al. 1998], [Lofthouse 2006], [Le Pochat et al. 2007], [Stevels 2007], [Short et al. 2012]. While academically developed tools and methods for eco-design are now numerous [Navarro et al. 2005], their industrial application remains low. Authors have found that these tools often struggle in industry because they focus on technical elements without addressing the wider industrial context [Dewulf and Duflou 2004], [Lofthouse 2006], [Le Pochat et al. 2007]. Similarly, industrial experience has shown that technical product alterations can struggle to achieve approval from product development systems that are unprepared for change [Stevels 2007], [Buckingham et al. 2013]. In light of this, the need for a strategic and systematic approach to eco-design implementation is being increasingly discussed [Pigosso 2012], [Short et al. 2012], [Hallstedt et al. 2013], [de Medeiros et al. 2014].

The research detailed in this paper provides empirical evidence of this need, helping to contextualise the debate. The paper describes the work of two researchers from methodologically and contextually distinct backgrounds. Researcher A (the first author of this paper) conducted a product-development-focused, eco-design implementation project (Project A) within a SME (Company A) and used this experience to develop an eco-design management tool suited to this industrial context. Researcher B (the second author of this paper) conducted a project (Project B) within a large multi-national organisation (Company B) which focused on the improvement of eco-design integration into the product development and related processes (such as procurement and manufacturing), in a systematic and consistent way. The methodology used in Project B was defined by the Eco-design Maturity Model (EcoM2) [Pigosso et al. 2013], developed by the second author in collaboration with experts on eco-design and multinational companies. By bringing these two case studies together, this paper is able to examine the impact of the organisational context and chosen eco-design implementation methodology. As well as providing empirical evidence of the opportunities and challenges faced in these two industrial contexts, the paper also highlights some important generalities and differences. The learning outcomes of this exercise are relevant to researchers and industry managers who are supporting or actively engaging in eco-design implementation.

2. Methodology

Two data gathering processes were used to document and review the projects. Project A was conducted by Researcher A, who then retrospectively reviewed it in a recent publication [Buckingham

et al. 2013]. The company perspective was then obtained through a set of semi-structured interviews with the Managing and Technical Directors. These interviews took place two years after the project's completion. To prevent the data being too heavily weighted by its retrospective nature, these findings where then cross checked against real time project documentation, including meeting minutes and internal reports.
Project B was conducted by Researcher B. The observations of Researcher B and Company B, were gathered via two email questionnaires, containing the same open ended questions used in the interviews with Company A. As primary author, Researcher A then conducted a further semi-structured interview with Researcher B, to ensure a full and in-depth understanding. As Project B is ongoing no real time documentation was needed.

3. The Project Descriptions and Eco-design Management Tools

3.1 Project A

3.1.1 The Goals and Activities of Project A

Project A was a two-year, product-development-focused Knowledge Transfer Partnership (KTP). The Knowledge Transfer Partnership scheme brings together a research partner (in this case University A) and a SME (Company A), with the aim of conducting a commercially beneficial research and development (R&D) project. The main goals of the KTP were agreed collaboratively by the University and Company. The project plan was then developed by the University and signed off by the Company. The agreed goals were to:

a) *"conduct a strategic review of [the product] design against environmental impact, carbon footprint, complex changing market and developing legislation issues."*
b) *"design [the product] family for 2012 onwards."* (Project Plan, Project A)

To meet these objectives a product development project was defined. The project consisted of traditional product development activities [Pugh 1991], with the addition of a streamlined Life Cycle Assessment (sLCA) [Guinée et al. 2002] at the outset, to identify environmental hotspots and define key product development areas. To complete the project University A employed an environmental designer (Researcher A) who worked at the company full time. Researcher A was based in the design office and had close contact with the company's managing director, technical director and production staff throughout. A summary of the key activities conducted during Project A are shown in Table 1.

Table 1. The Activities Conducted during Project A

Project A
1.1 Streamlined Life Cycle Assessment conducted on representative, mid-range product.
1.2 Conducted a widespread customer questionnaire focused on the product's use phase.
1.3 Defined improvement goals based on outcomes of sLCA.
1.4 Conducted research and development activities addressing each of the improvement goals.
1.5 Developed product concepts and prototype.
1.6 Conducted product testing and refined concepts.
1.7 Presented concepts to product development team and refined design direction.
1.8 Detailed design and prepared Computer-Aided-Design (CAD) model.
1.9 Supported first production run and refine design.
1.10 Supported product launch and media outreach.

3.1.2 Company A

The company involved in Project A are a UK-based, family-run, design and manufacturing SME, who have been in operation for over sixty years. The company employs approximately 250 people, the majority of whom work on the production line. The small management team are highly hierarchical and the managing director (MD) exercises control over all elements of the business.
The market within which Company A operates is small, competitive and very conservative. Despite these challenges the company have developed an innovative reputation that has been fostered through a longstanding relationship with University A. In the absence of any formal R&D department, this

relationship has enabled the company to develop knowledge in target areas and conduct R&D activities beyond their internal capabilities. When the KTP began, the company were enjoying a particular boost to their innovative reputation, due to the recent completion of a two year product development project, the outcome of which was being marketed as *"the most significant development in [the product's] production technology for over thirty years."*
Company A's interest in environmental design is largely driven by legislation, which they view as a target to be reached. The company produces a product that is towed behind a vehicle and despite there being no direct environmental legislation on Company A's products, tow vehicle legislation is making weight reduction so important that it is viewed as a major threat to future operations, as revealed 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." (Company A)

Environmental knowledge throughout the business, supply chain and market, was minimal when the project began. Previous environmental improvements had been ad hoc, and had tended to focus on internal measures such as an onsite recycling scheme and factory insulation. The company had no quantitative understanding of their environmental impacts and had never addressed the impacts of the products themselves.

3.1.3 The Outcomes of Project A

The primary goal of Project A was the development of an environmentally improved product prototype, upon which 2012's *'product family'* could be based. The tangible and intangible outcomes achieved by the end of the two-year project are shown in Table 2.

Table 2. The Tangible and Intangible Outcomes of Project A

Outcomes of Project A	
Tangible Outcomes	Intangible
− A streamlined LCA of the product. − Reports detailing potential improvement areas and how to tackle them. − Environmentally improved design concepts. − A market tested, low specification, low weight design.	− Introduction to lifecycle thinking and the product's environmental impacts. − An understanding of eco-design in this industrial context. − Identification of the design's environmental 'hotspots'. − Introduction of environmental issues throughout the value chain.

3.1.4 Review of Project A

Project A took a product development approach to eco-design implementation. As shown in Table 2, this approach resulted in some significant achievements; raising environmental awareness and allowing the company to market test a low impact, albeit low specification, model.
As the primary decision maker at the company, the MD's close involvement was vital. The retrospective interviews revealed just how important that was and how easily this new knowledge was being used to shape future design focus.

"it comes from all the different areas that you looked at in terms of material, material procurement, what we do here as an operation in terms of are energy usage, assembly, and then also the weight and towing characteristics in order to get a smaller tow vehicle, to get more MPG, less CO_2 emissions when towing." (MD, Company A)
"we changed the shape on the front and we put the curve onto the rear" (Technical Director)
"the next [KTP] we are looking at is aerodynamics" (MD, Company A)

However the retrospective interview also revealed that the product had failed in the market place due to a lack of awareness, knowledge and understanding outside the product development function.

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

"[The dealers] didn't understand the product, the eco-ness, the environmental issues. The dealers didn't see that."
"[Further weight reduction] comes down to the education of the consumers, you are getting to the stage of what they want in terms of specification."

What is clear is that the early stage knowledge development activities had been significantly more beneficial to the company than the latter stage product development activities. By focussing on eco-design tool application and product development, the project had failed to appreciate the knowledge development and capability building required for long term eco-design implementation. Case study A provides empirical evidence of why, even within SME's, a systematic approach to eco-design implementation in beneficial.

3.1.5 The Company Characterisation Process (CCP)

To help SME's adopt a systematic approach, the Company Characterisation Process (CCP) was developed. The CCP is particularly targeted at those who are externally supporting eco-design efforts within smaller firms. The tool introduces a four stage, continuous improvement process that begins with a Company Characterisation. The Company Characterisation involves mapping the company's current capabilities in seven key business context areas. The business context areas of importance to eco-design implementation have been speculatively identified from the analysis of this case study and then crossed checked against existing literature. Once the Characterisation has been completed, the capability map is then used to plan eco-design implementation activities that are tailored to the current needs of the company. An updated characterisation is completed at the end of each product development cycle to ensure that recently acquired capabilities are accounted for. The CCP is shown in Table 3.

Table 3. The Company Characterization Process for Eco-design Implementation within SME's

1. Company Characterisation	
Internal Business Context Features − Define management structure and hierarchy − Define existing design process and new product development timeline − Identify environmental knowledge throughout the business − State strategic intentions for project	External Business Context Features − Identify business drivers for environmental focus − Map product value chain and roles within it − Establish environmental knowledge throughout value chain
2. Develop Tailored Project Plan	
3. Conduct Project	
4. Update Company Characterisation to Kick off Next Project	

The CCP provides an intentionally loose framework for eco-design management. The tool was developed to guide activities whilst minimising that time spent on strategic planning, allowing the company to focus on core value adding activities. These criteria reflect the experience of Researcher A when working with this company and are supported by those who examine eco-design and change management in SME's [McAdam and Reid 2001], [Tukker et al. 2000].

3.2 Project B

The scenario around Project B is very different to that of Project A. Where Project A resulted in the development of a methodology to support eco-design implementation (the CCP), Project B began with a methodology (EcoM2) and applied it within an industrial context. The description of Project B, therefore begins with an introduction to the EcoM2 methodology, and follows with a description of the case study.

3.2.1 The Eco-design Maturity Model

The methodology applied in Project B was the Eco-design Maturity Model (EcoM2). The EcoM2 resulted from a full scale research project conducted by the second author of this paper, in close

collaboration with three large multinational organisations [Pigosso 2012]. It is defined as *"a management framework, with a step-by-step approach, aiming to support companies in carrying out eco-design implementation"* [Pigosso et al. 2013].
The model consists of a six-stage, continuous improvement process as shown in Figure 1. The first stage is to define the company's current eco-design maturity profile. A company's eco-design maturity is judged by assessing their performance against areas of known managerial best practice. The maturity profile can then be used to identify the company's strengths and weaknesses for eco-design implementation. Improvement projects are then planned with the aim of developing the organisations eco-design capabilities. These projects are then implemented and reviewed allowing an improved maturity profile to be assessed. Completing all six stages is referred to as one improvement cycle. A single company can apply as many improvement cycles as needed to maintain development towards higher and higher maturity profiles.
As can be seen the EcoM2 adopts a long term, systematic approach that puts the management of eco-design implementation at the centre of activities. The focus on embedding change within an organisation, rather than conducting change at an organisation, is a combined top down/bottom up approach that differs greatly to the product development approach detailed in Project A.

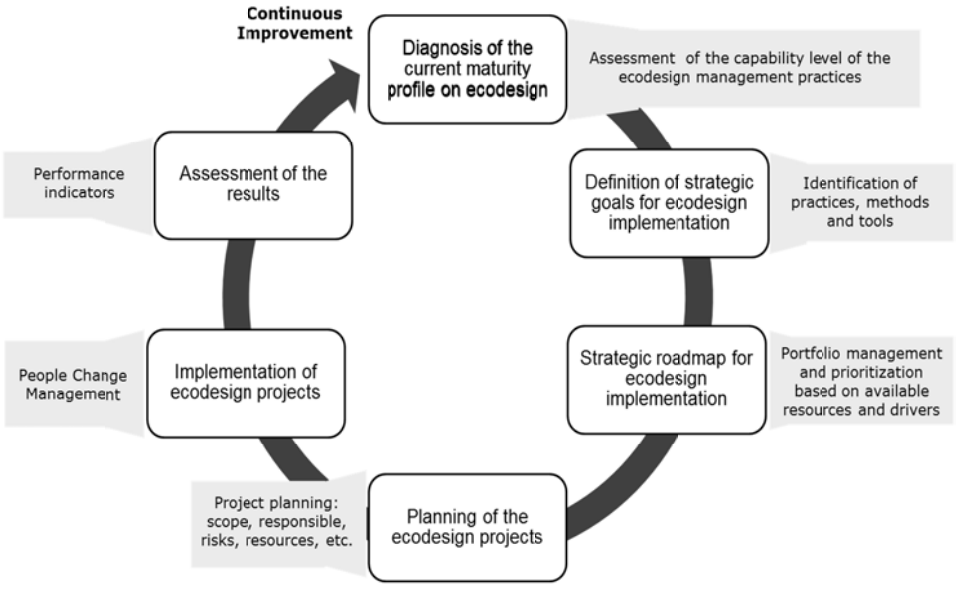

Figure 1. Application method of the EcoM2 [Pigosso et al. 2013]

In the following case study (Project B) we examine the application of this model within a large multi-national organisation. The paper then goes on to compare Project's A and B, revealing important similarities and differences. The outcome of this comparison helps identify important nuances about eco-design implementation and its relationship with the industrial context.

3.2.2 The Goals and Activities of Project B

Project B is an ongoing project that is utilising the EcoM2 management framework to support eco-design implementation. The project is a collaborative effort between Researcher B and a large multinational corporation. The primary goal of the project, as defined by the company, was the:

a) "implementation of sustainability [strategy] into product development" (Company B)

The original plan for Project B, was to complete Stages 1 and 2 of the EcoM2 approach, enabling the University to *"evaluate the current maturity profile of the company on eco-design implementation and management"* and *"identify strengths and opportunities in order to define and prioritise project for eco-design implementation."* Completion of these first two stages was proposed by the University and conducted by them free of charge.

Upon completion of Stages 1 and 2, the Company then invited the University to continue supporting them as they worked through the subsequent four stages of the model. To support this continued collaboration, a two year project proposal was developed by the University and agreed by the Company, who are funding the whole project. The project is now eleven months into this two year plan, during which time Researcher B has been working in the product development department for 50% of their time. To help the reader understand the activities of Project B a to-date-summary is given in Table 4.

Table 4. The Activities Conducted to Date during Project B

Project B
Part One – EcoM2 Stages 1 and 2
1.1 Evaluate the current maturity profile, through documental analysis and company interviews.
1.2 Define improvement project goals, activities and tools for eco-design implementation.
Part Two – EcoM2 Stage 3-6
2.1 Strategic review and prioritisation of improvement projects, definition of a five year roadmap for eco-design implementation, based on the Sustainability Strategy.
2.2 Definition of the organisational set up and decision board for project.
2.3 Development of a toolbox to support eco-design and life cycle thinking implementation into the product development and related processes.
2.4 Completion of plans to support legislative compliance efforts
2.5 Development of training set-up and communication plan

3.2.3 Company B

The Company involved in Project B are a global design and manufacturing firm, who have been in operation for over forty years. The company employs approximately 19,000 people worldwide and operates four large development facilities in Europe, America and Asia. The company have a flat hierarchy and the management style is open and collaborative.

The company have had a historical interest in sustainability and have worked with University B for the past two decades on various topics of business sustainability and environmental development. The company have a Sustainability department, who have developed a companywide Sustainability Strategy, and an Environmental Management department, who focus on environmental issues relating to manufacturing.

The drivers for eco-design within this organisation are varied. The primary driver is legislative and the company are aware that legislation is continuing to get tighter. As such, the company have taken a proactive approach with the hope of influencing future legislative direction. Their proactive stance is further promoted by the increasing number of environmental requests they are receiving from customers.

Previous eco-design efforts at the company have been largely ad hoc and there has been no historic link between the environmental departments mentioned above and the product development functions. To address this, the company have now tasked one Manager within Product Development with deployment of the Sustainability Strategy into this business function. Project B can be seen as part of these deployment activities.

3.2.4 The Outcomes of Project B

The primary goal of Project B is to support the company in deploying their sustainability strategy within product development. The list of outcomes for this project have been collated from the researcher and company questionnaires. Part 2 of the project is still ongoing so the outcomes listed in Table 5 are to date.

Table 5. The Tangible and Intangible Outcomes Achieved by Project B

Outcomes of Project B	
Part 1	
Tangible	Intangible
− Current eco-design maturity profile, based	− A common understanding of the company's

on the organisations application of the eco-design management practices. − A presentation and detailed report that identifies and describes the improvement needed to increase the company's eco-design maturity profile.	current strengths and weaknesses for eco-design − A common understanding of the need for a systematic approach to eco-design implementation − Agreement of the next steps for eco-design development
Part 2	
− A five year roadmap for eco-design implementation at the company. − Definition of the improvement projects to be implemented during the first improvement cycle. − Development of a toolbox to support the integration of eco-design and life cycle thinking into product development and related processes − Development of a training and communication concept for increased eco-design awareness and knowledge dissemination.	− Increase credibility of the eco-design related activities and important steps against resistance in the company. − Common understanding of the long-term process to be followed for eco-design implementation and management in the company. − Comprehension of the need to involve people from different departments and business units. − Commitment from people outside of the product development department.

3.2.5 Review of Project B

In contrast to Company A, Company B adopted a strategic and systematic approach to sustainability and eco-design implementation, developing a sustainability strategy prior to product development activities; an approach that can been seen as characteristic of larger organisations [Short et al. 2012].
The questionnaires conducted with the researcher and company, revealed that Project B was being viewed as a success by both. The company stated that Part 1 had exceeded their expectations, because it *"showed where [they] were and gave suggestions on what to do next"* (Company B).
The efforts made in stages 1-4 had created an environment that was supportive of change. The maturity profile created a tangible review of the company's existing status, helping them to understand eco-design as a systematic process and motivating them to improve their performance.

"[The company] had huge motivation to go to the highest possible maturity profile, as soon as possible. I think that the model gave them the motivation to do that, because when they saw where they were and they saw that it was not as good as they wanted it to be, then the motivation came automatically." (Researcher B)

The development of a road map of detailed eco-design implementation projects, then helped to ensure vision and manage expectations further. Finally the structured approach introduced a clear framework within which progress could be made.

"[The EcoM2 application] helps us frame improvements…it is a tangible way to look [at] product design in a different way. Now our approach is much more structured…we are gradually moving forward." (Company B)

Project B is however still ongoing and despite the success of the preparatory activities, change is still yet to be made. Although only eleven months into the two-year project, both the researcher and company representative commented on the resistance to change already experienced.

"There is not a sense of urgency for eco-design in the company, but managers and employees are recognising the need for sustainability considerations within product development (though it is a slow process)." (Company B)
"Due to the unexpected speed of organisational changes, the goals of the project will need to be adjusted from two improvement cycles in the period to one improvement cycle." (Researcher B)

During the follow up interview, Researcher B listed a number of reasons this change of goals:

"We can talk about the speed for change in the organisation, we can talk about resistance from the different stakeholders, we can talk about available resource to develop the projects, we can talk about

the difficulty of changing the processes at the organisation, which is significant. The size of the organisation is also a challenge; how we communicate and how we transfer the knowledge to all of the people that must be involved. And well I am only there 50% of the time, this is a challenge as well".

4. Comparing Project's A and B

The case studies detailed in this paper adopted very different approaches to eco-design implementation and resulted in very different outcomes. While Project A took a product development approach within a SME who were in the very early stages of eco-design implementation, Project B took a systematic approach within a large organisation that had developed a wider sustainability strategy. Continuing the empirical nature of this study, Table 6 and Table 7 detail the organisational opportunities and barriers experienced in each.

Table 6. Opportunities and Barriers to Eco-design Implementation within Case Study A

Opportunities and Barriers to Eco-design experienced within Case Study A	
Opportunities	Barriers
− Small number of decision makers simplified knowledge transfer process − Small number of decision makers made change fast and dynamic − Trial and error approach to product development - if it worked the company were happy to incorporate it.	− Focus on traditional value adding activities with limited strategic planning, resulting in a misplaced focus for eco-design activities. − Small number of decision makers, made individuals very powerful (if MD did not agree, it did not happen) − Limited environmental knowledge throughout the business and supply chain and low influence over most suppliers − Limited data or knowledge management, making environmental data difficult to incorporate within decision making. − Trial-and-error approach relied on currently viable options with no long term storage of 'pipeline' technologies or materials. − Low resources demanded a very clear business case for environmental improvements.

Table 7. The Opportunities and Barriers to Eco-design experienced within Case Study B

Opportunities and Barriers to Eco-design experienced within Case Study B	
Opportunities	Barriers
− Sustainability strategy drives a long term planning for eco-design implementation in the organisation. − Eco-design implementation is seen as a comprehensive long-term program, with several different complementary projects running in parallel. − Possibility to obtain specialised support from different internal stakeholders, which can enhance eco-design implementation. − Changes in the formalised processes and procedures usually leads to change in the behaviour of employees.	− Large numbers of decision makers, making it difficult and time consuming to reach a consensus. − Highly formalised process, making it difficult to introduce new activities related to eco-design and slowing the pace of product and procedural change. − Size of the organisation makes it difficult to obtain a clear view of the current processes and responsibilities. − Size of the organisation demands formal knowledge development and dissemination. Training is a huge and time consuming task. − Limited knowledge of eco-design and its benefits, resulting in low budgets being assigned to its implementation and demanding a very clear business case.

Table 6 reveals how the SME's hierarchical and flexible design process helped ensure that key decision makers were informed and design decisions were taken quickly. These characteristics support [Short et al. 2012] who proposed that "it might be easier to implement DfS/E in small companies where a Senior Manager is perhaps more autocratic and more easily able to implement changes", and that "with a less structured design process…the "system", such as it is, could be more flexible to incorporate new methods." However, despite change happening quickly, an efficient and effective focus for change was not always achieved. The limited strategic thinking and formal systems encouraged the company to prioritise product development (clear value adding) activities over more systematic development. As previously noted, a focus on value adding activities as opposed to strategic planning, is characteristic of SME's [McAdam and Reid 2001], [Oxborrow and Brindley 2013].

Table 7 shows that although a structured product development process is known to promote successful eco-design implementation [Johansson 2002], [Plouffe et al. 2011], a high level of formalisation can also poses significant challenges. In order to reach higher success rates in large companies, the implementation of a systematic and step-by-step approach, as adopted in Case Study B, has been identified as a key success factor, as often cited by other researchers [Shelton 1995], [McAloone 1998], [Stevels 2007], [Pigosso et al. 2013]. Furthermore, the existence of a strategic focus towards eco-design implementation with clear management commitment has shown crucial for effective eco-design implementation [Maxwell and Vorst 2003], [Hallstedt et al. 2013], as competence development and motivation. Finally, it could be concluded that large companies often require significant change management efforts for eco-design integration into its business processes [Verhulst 2007].

5. Conclusions

Legislative and market drivers for eco-design continue to put increasing pressure on companies to address environmental issues. During this time of increased eco-design requirements, the focus of research has been viewed as being distinct to that of industry [Stevels 2007]. To help address this gap, this paper bought together the work of two eco-design researchers who operate with an industrial focus. Two complementary, yet methodologically and contextually different, eco-design implementation projects have been described to give a broad overview of the industrial context.

Project A took a predominantly product-improvement perspective when implementing eco-design within an SME, resulting in a conceptual implementation model (CCP), Project B focused on a design process-improvement perspective for eco-design implementation in a large manufacturing company, based on a previously developed management framework (EcoM2).

The theoretical and methodological similarities between the CCP and EcoM2 tools highlight some important generalities about the case studies. Both promote a systematic approach to eco-design implementation, achieved by developing an understanding of the company's current capabilities and integrating this understanding within the planning of eco-design activities. The assessment of current capabilities and the subsequent definition of improvement opportunities are also embedded within a wider continuous improvement process. Defining eco-design implementation as a process of continuous improvement encourages a long term view that both manages expectations, and promotes achievable project goals.

Where these case studies differ is in the mechanism by which this systematic approach is implemented. Comparing the opportunities and barriers experienced in the two case studies (Tables 6 and 7), we are able to see how the size of the organisation impacted the cultural approach towards change. Within the SME, it was neither practical nor necessary to adopt a highly formalised and explicit approach to eco-design implementation and would have greatly contrasted their traditional way of working. Within the global organisation the numbers of people involved in change require formal and explicit change management. In practical terms this alters the management practices against which a company's 'eco-design maturity' should be judged. The comparative degree of formalisation and structure within the CCP and EcoM2 tools further reflect these characteristics.

The results presented in this paper provide insights that help the understanding of the industrial context within which eco-design is taking place, while the implementation models promote and support a systematic approach to eco-design implementation in any organisation. Having identified

empirically supported opportunities and barriers in each context it would be interesting to examine to what extent the benefits of each context could be mimicked in the other; developing more flexibility in larger organisations or promoting more strategic thinking in small companies. To this end the application of the CCP within a large manufacturing company and the EcoM2 within a SME, would provide interesting insights and help promote an even deeper understanding of the relationship between organisational context and effective eco-design implementation.

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Molly Buckingham, Research Assistant
University of Bath, Department of Mechanical Engineering
Claverton, Bath, BA2 7AY - 01225 384049 United Kingdom
Email: m.buckingham@bath.ac.uk