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THE PRODUCT DEVELOPMENT PROCESS ROADBLOCK THAT IS RESTRICTING THE WIDESPREAD ADOPTION OF DESIGN FOR SUSTAINABILITY.

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ABSTRACT
There is now growing pressure on manufacturers from all sectors, and of all sizes, to adopt Design for Sustainability (DfS). The aim of DfS is ensure that both the environmental impact, and any wider social concerns, of new a product or service are considered from a life cycle perspective, and appropriate decisions taken early in the design and development process. The past decade has also seen considerable research into developing effective tools, techniques and practices aimed at enabling DfS (including ecodesign) to be conducted more effectively, in all sizes of business**.** However, despite the increasing pressure on companies, and the research, there has been a distinct lack of progress to date in establishing environmental and social consideration as a part of mainstream product design in the majority of companies. This paper reviews some of the documented obstacles, but then proposes an alternative root cause for this lack of DfS integration. It then outlines an ongoing study of manufacturers, within the North West UK, which is being undertaken to examine this alternative, and includes the preliminary findings from the first part of this study.

Keywords: Design for Sustainability, Product Development, Design Management

1. INTRODUCTION
There is now wide acceptance that manufacturers from all sectors increasingly need to consider the environmental, and social, impact of the products that they develop and produce. The drivers of this requirement include the growing environmental awareness of customers and consumers, which is creating demand for products that use and waste less resources and are more socially acceptable [1,2]. Product focused environmental regulations are also impacting on more businesses. In addition, there has been an increase in companies taking a proactive approach to sustainable development. This is highlighted through the number of organizations that produce reports that, despite their different names, attempt to account for their social and environmental impacts, and those that are adopting the 'triple bottom line' as a measure of corporate 'sustainability performance' [3,4,5]. Further, while not always clear or strong, the potential financial advantages and market opportunities of considering environmental issues are becoming recognized [2,6,7].
Initially, the focus of environmental attention within companies, in part due to the adoption of environmental management systems such as ISO 14001, was towards improving the manufacturing 'end-of- pipe' performance, in terms of reducing waste and emissions [1,8]. However, this focus has changed. This is due to the realization that it is the key decisions made during product design, as regards material choice, usage options, manufacturing processes and disposal, etc, that determine the vast majority of all product-related environmental impacts [9]. As a result, there is acceptance that while attention to manufacturing remains important, the most effective way to gain significant overall reductions in the environmental and social impact of a technology, product or service is to consider its whole life cycle, and make appropriate decisions early in the design and development process [2,8,9].
Critically, this attention to undertaking environmental, and social, considerations during design is not just an issue for the major product developers. Collectively, the sheer number of Small to Medium Sized Enterprises (SMEs) within industry that innovate and develop new products, either as part of a supply chain or for direct sale to consumers, means that their environment and social impact can be substantial [10]. It has been reported that SMEs contribute 70% of global environmental pollution, with the majority coming from the manufacturing sector [11,12].

As regards establishing environmental, and sustainable, decision making within the product design and development processes, the past decade has seen considerable research into developing tools, techniques and practices for enabling this to be conducted – and in all sizes of business**.** Research has looked at methods and support tools, specific products, certain life cycle phases, along with the integration of emerging tools and techniques into environmental management systems and product development systems [1,2,6,13,14].

Undoubtedly, the initial focus for both researchers and industry has primarily been environmental concerns, and enabling the practice of tackling the greatest environmental impacts across a product's life cycle (eco-design). But, the need to consider both environmental and any wider social issues is increasing being explored. In addition, there is 'renewed' recognition of the importance of ensuring that the wants and requirements of the customer and a company's economic needs (its economic sustainability) are not forgotten in the attempt to make the product more sustainable. Hence the broader concept of sustainable design or Design for Sustainability (DfS) has now emerged [1,2,6]. However, despite all the increasing pressure on manufacturers and the considerable research effort, there has been a distinct lack of progress to date in establishing environmental and social consideration as a part of the mainstream product development activity in the majority of companies. It would appear that few businesses have actually adapted their product development process to emphasize the integration of eco-design tools [15]. Equally, while there are various case examples of the application of DfS and eco-design, these typically illustrate practice by a few leading companies, or are pilot or niche products [6,16]. Most companies are simply still doing the minimum to meet required legislation, and as a result, not only is the actual application of DfS or eco-design by industry not common, sustainable design knowledge is still limited even in companies with a 'green image [16].

The aim of this paper is to cover the work carried out during the early stages of a PhD research project that is investigating this lack of progress. This includes the initial literature research into the documented internal obstacles facing DfS integration into product design. It also introduces the subsequent hypothesis development – primarily, at present, from a UK perspective – of an alternative product development process issue that could be a major root cause of DfS not becoming 'mainstream'. This suggests that perhaps the real roadblock is that many product development 'environments', especially within SMEs, are simply still not yet capable of incorporating the thinking, tools and practices required for DfS. They retain a culture, rigidity of approach, and a lack of structured 'good' practice, that will always frustrate and significantly hinder the integration of DfS. Finally, the paper outlines the ongoing research being undertaken to examine this hypothesis. This includes the instigating of a study of manufacturers, within the North West UK. This is intended to examine the understanding of DfS within these companies, along with their actual product development approaches and product specification development practices. The paper includes the preliminary findings from a questionnaire, which is the first part of this study, and these seem to suggest that in line with the hypothesis, product development practice in many companies does not provide an environment conducive to DfS integration.

2. LIMITATIONS OF DESIGN TOOLS

In undertaking a literature research into the possible 'internal' obstacles to DfS integration, the first step assessed one of the most common issues; the tools and techniques (mostly eco-design) that have been developed for use by environmental specialists, engineers and designers. The research highlighted that there are undoubtedly plenty of tools, and more being continually being developed, which can be used to introduce and examine environmental and sustainable considerations during the design process. For instance, the Ecodesign Navigator lists over 50 tools, from Life Cycle Analysis packages, which can cost thousands of pounds, to handbooks, guidelines and checklist, many of which are free [17].

There have also been a number of methodologies created to help take companies, step by step, through a 'more environmentally focused' product development process. One example of this is the lifecycle assessment tools and evaluation process that have been developed and used to guide companies towards achieving McDonough Braungart Design Chemistry's Cradle to Cradle certification [18]. Another is Sustainable Product and Service Development (SPSD) [19]. This uses a qualitative, pragmatic approach that is customized to a company's existing business and product strategy, and which introduces, where relevant, suitable quantitative tools. The goal of SPSD is to produce products and/or services that are sustainable and achieve their required functionality, meet customer

requirements and are cost effective. One key difference with this method is the shift of design focus away from producing products to providing a function and determining whether the function can be provided by a service, a product or some combination of a Product Service System.
However, many of the tools, techniques and methodologies can suffer from major adoption drawbacks, some real and some perceived. A typical anecdotal complaint – especially by smaller companies – is that many require just too much specialist knowledge and too much time. Life Cycle Assessment (LCA) is a case in point. This can be a powerful tool to determine environmental impacts derived from products and systems, and to calculate resource consumption. But, the complexity of LCA, in particular the time/expertise/data needed if the assessment is to be thorough, poses restrictions to its use, while earlier limitations have clouded the image of the tool in some minds, irrespective of developments [17, 20]. A range of abridged LCA tools have also been developed, which are essentially simplified and cheaper versions. Although these tools can save a substantial amount of time and money, a certain level of background knowledge is still necessary and results are not as trustworthy as those provided by a full LCA [17].
Another observed drawback with many of the (eco-design) tools, is that they are purely focused on environmental issues and so do not sit well within a design process [21]. They encourage designers and development teams, either by design or by the default of requiring so much time and effort, to focus primarily on environmental issues, and fail to link these with other essential design requirements such as functionality, performance, customer requirement, cost, etc [22]. The response to this has been recognition of the need for balancing requirements, and research that has resulted in tools such as the Eco Functional Matrix [21]. One of the objectives behind this tool is to highlight the importance of balancing functional requirements and environmental impacts, presenting both the advantages and disadvantages of the product. The basic idea is to account for user and societal preferences as well as environmental impact when assessing alternative product concepts at early design stages [21].
One of the biggest obstacles reported in respect to the wider usage of many of the available support tools, and life cycle assessment in general, is what has been termed the design paradox [21]. This relates the way that the design degree of freedom reduces as the knowledge about design increases, with the way that many environmental design tools only become feasible when a certain level of knowledge about the design is attained. Hence, the worst case situation being that environmental analysis is often only carried out at a stage when the design is almost complete, because the quality of data for analysis is better. But at this point, the design has progressed to a stage whereby it is too late to make any significant changes to the design, irrespective of the results of the analysis [23]. The slightly better case, often associated with tools such as Design for Disassembly, is that it is not quite to late to influence the design, but it still means requiring designers, often under extreme time pressures, to revisit design decisions. Either situation can prove extremely frustrating for designers, and enough to persuade many not to bother the next time.
Against this background of identified problems, it is not surprising that despite the wide range of eco-design and DfS tools and techniques available, research suggests that few are being integrated into product development practices [24], especially within SMEs [25].
However, it is also clear that not only is there considerable research looking into developing new tools that are easier to use [25], and focused on fitting within actual design practices [26], but that the failings of existing tools and techniques are far from the only observed internal obstacles to the adoption of DfS within companies [26].

3. THE IMPORTANCE OF PROCESS

Of the wide range of additional internal obstacles, a number are related to the importance of wider business involvement. DfS is not just an issue for engineers and designers, or even environmental specialists, and the solution to its wider adoption must involve more than just trying to find better tools to drop into the design process. For instance, while engineers and designers can play a part, they should not be expected to the only driver of DfS [6]. Senior managers have to deliver more support [29]. Not only does this support need to be in terms of resources, but also in providing the vision, commitment and involvement (not just authorizing funds) needed to create internal 'top-down' pressure. This type of commitment is essential [29]. Equally, functions outside of design and engineering can have a pivotal role in DfS. In particular it has been found that without marketing commitment, it becomes extremely difficult for designers to give any priority to considering, and/or reducing a product's environmental or social impact [30]. Unfortunately, engaging functions such as

marketing can be extremely difficult, as their awareness and understanding of the 'what and how' of DfS in practice is even more limited than many engineers [6].
Similarly, DfS is clearly not just a design activity. More specifically, it has been fundamentally shown that the critical stage for encouraging environmental and social consideration, and so DfS, is the formulation of the product specification - the task clarification stage of product development. [30,31]. It is at this point that engineers and designers, along with marketing and management, should initially investigate and agree all key design requirements, including those related to reducing environmental and social impact. Yet, most companies struggle to make this happen, and it has been noted that is often due to this lack of environmentally and socially oriented requirements within the specification that design teams only achieve minor improvements [30]. It has also been observed that this same lack of sustainability focus within specifications is also a major reason why many of the tools that have been developed in order to help designers achieve environmental objectives are seldom used [32].
As a result of these observations, there are some suggestions that what are needed are DfS tools that are developed or adapted to better fit the specification activity, and some research is following this route [32].
However, a different conclusion that can be drawn is that the problem is far more deep routed, and that the reason for the lack of 'front-end' DfS consideration is more to do with the failings of many company's existing product development process, and practice, rather than the need for a new environmentally and socially focused tool.

4. MISSING GOOD PRACTICE

Based on this conclusion, further literature research has examined product development in general, again primarily from a UK and SME perspective. The aim of this has been to investigate if process and practice problems still exist, which could relate to the lack of progress with the adoption of DfS.
Looking first at senior management support, which, as has been noted, is recognized as vital for DfS, it has been suggested that this also remains a major issue for product development in general within UK SMEs. A particular aspect of this is the reported lack of understanding among senior management ranks about product development, and the role they need to play to support it [33,34].
Another clearly important issue for DfS adoption is the development process itself. The assumption likely to be made by those developing eco-design and DfS tools and practices is that companies are likely to have formalized and structured processes, such as stage and gate [35]. These tools can then be introduced into the development process at the appropriate stage. But, this becomes far more difficult when companies do not have structured approaches. And, it appears that such a lack of formal documented procedures, and the poor management of development activities, still appears to be common, as reported in a number of studies of UK companies [34, 36]. Similar situations have also been witnessed outside of the UK [37].
However perhaps the most interesting observations concern what typical does, or does not happen in terms of front-end product design planning and specification activity within UK SMEs. The importance of this activity to the adoption of DfS has already been noted. But, it has also been recognized for many years that the 'front-end' work, which should involve various functional groups clarifying and committing to a product design specification prior to concept generation, is something that is vital to the subsequent effectiveness of any product development project [38,39,40]. Its importance is highlighted within the Total Design process [41]; "From a statement of the need – often called the brief – a product design specification (PDS) must be formulated – the specification of the product to be designed. Once it is established, it acts as the mantle or cloak that envelops all the subsequent stages in the design core. The PDS thus acts as a control for the total design activity because it places the boundaries on the subsequent designs" [41].
Yet, it appears that this again is an area of product development that many UK companies still fail to manage well. The failure to undertake this work effectively continues to be reported as one of the main reasons for product development problems. Observations show that companies still rely on informal practices, often only involving management and/or marketing, to roughly sketch out the specification and pass it on to the engineers and designers [33,34,42]. As a result, it could be suggested that one reason why (UK) companies struggle to introduce DfS within this front end activity, is simply because there is no recognizable front end stage in which to do undertake it.
Overall, this literature research appears to show that changing the culture and practice of product development within many UK companies has proven extremely difficult. Therefore, despite the

growing importance of the need to improve and accelerate product development efforts and take on board new approaches, such as DfS, it can be concluded that many of the issues that have been generally recognized as product development problems for many years still continue to exist.
Based on this conclusion, and combined with the findings from the initial obstacles to DfS adoption work, the following hypothesis has been developed;
'A major roadblock to DfS integration is that many product development 'environments', especially within UK SMEs, are simply still not yet capable (in terms of following proven good practice) of incorporating the thinking, tools and practices required for DfS. This is irrespective of how good existing or improved tools are, or how enthusiastic for DfS or well trained individual engineers and designers are. Essentially, the culture and rigidity inherent within existing product development approaches, combined with the lack of structured design practices and development processes, especially in terms of front-end Product Design Specification activity, will continue - unless changed - to frustrate and significantly hinder the adoption of DfS within many companies'.

5 RESEARCH BACKGROUND

In order to research this hypothesis more extensively, a research project has now been instigated, in conjunction with the Manchester, UK, based The Manufacturing Institute. This involves direct contact with a range of manufacturing companies in the North West of the UK, and has two fundamental objectives.
The first is to assess the general current state of product development processes and practice within a range of North West manufacturers, with some focus on SMEs. A particular aspect of this assessment will be the 'front-end' specification development activities employed by these companies.
The second objective is to assess level of understanding of Design for Sustainability within these manufacturers, and establish which, if any, associated practices are being applied within these companies. The research will also test the model and definition of DfS developed as part of the theory development.
It was determined that the study should involve the following key stages;

1. An initial questionnaire to be sent out to as many companies as possible with the local area.
2. A more detailed telephone interview to be conducted with a determined number of the companies who agree, as part of their response to the initial questionnaire, to be contacted as part of ongoing research
3. To identify a small number of companies (6-12) from the telephone interviews who would be willing to take part in more in-depth face to face interviewing on specific issues.

Due to the lack of direct manufacturing contacts available via the University of Liverpool, and with the researcher's existing relationship with the Manufacturing Institute, the decision was made to undertake a joint project. This provided the project with a number of advantages, not least access to the Manufacturing Institute's extensive network of manufacturing contacts and its CRM system that enabled the first part of the project to become a quick and inexpensive e-questionnaire.
During late December 2008 a total of 2615 e-mails were sent out to individuals from various functions, including all medium and senior management ranks within operations, marketing and engineering, etc. and a range of manufacturing and engineering companies inviting them to complete the 'on-line' questionnaire.
With both product development and DfS clearly involving more that just engineers, it was decided that for this initial survey it was worth getting as wide a range of opinions as possible. In terms of company size, the data set comprised of 140 micro, 784 small, 847 medium and 844 large companies. Of the invites sent 452 (17%) were opened, but of those respondents who opened the invitation, 90 (20%) have completed the questionnaire, at present. Of these 90 respondents, 66 said their company undertook product development, as per the following definition; 'Product Development involves developing products that are either new to the world or new to the company, and this includes major product modifications along with new products that are an extension of an existing product family. It does NOT include minor product changes and modifications'.

6 PRELIMINARY RESEARCH RESULTS

Due to the timing of the first stage of the research, and the ongoing development and undertaking of the telephone interviews, a complete analysis of the questionnaire replies has yet to be concluded. However, some of the very early and preliminary findings are extremely interesting in the context of

the proposed hypothesis. Therefore, a selected set of questions and answers from the initial questionnaire have been included and detailed in this section of this paper, which is then followed by a discussion of the potential significance of the results.

6.1 How Product Development is Managed

The respondents were asked how product development is managed within their company;

- 27 (41%) agreed that their company operates a formalized and structured product development process (such as a stage and gate or phase and review process)
- 8 (12%) agreed that their company has a formalized product development process that follows recognized key development steps and activities, such as those outlined in BS7373
- 24 (36%) agreed that their company has an informal but understood product development process
- 7 (11%) agreed that their company does not have a recognizable product development process

6.2 The Main Barriers to Effective Product Development

The respondents were asked to indicate the three biggest barriers to the performance of their product development process. This elicited the following responses;

- 17 (9%) Lack of a structured and understood NPD process
- 35 (18%) Constantly Changing Requirements
- 13 (7%) Poor Cross Functional Teamwork
- 8 (4%) Poor Understanding of Customer Needs
- 24 (13%) Technology Uncertainty
- 22 (12%) No early Definition of Product Requirements
- 14 (7%) Poor Project Management
- 17 (9%) Shortage of Design and Engineering Skills and/or Resource
- 7 (4%) Lack of Senior Management Support
- 34 (18%) Too many projects being undertaken at same time

6.3 The Product Design Specification

The respondents were given the following definition; 'A Product Design Specification (PDS) establishes an up-front understanding of the customers and the market for a new product, and an unambiguous definition of the product's requirements. This specification can be used to drive the subsequent development activities'.

Based on this definition they asked if their company typically produces a Product Design specification (PDS), or equivalent for its product development projects. The responses were;

- Yes 39 (59%)
- No 27 (41%)

6.4 How the PDS is Created

Those respondents who answered yes to the previous question, were asked furthers question aimed at gaining more details on the how, who and when of their company's PDS development approach. The responses were as follows;

How

- 19 (49%)agreed that the PDS, or equivalent, is created through a structured and understood process
- 20 (51%) agreed that their PDS, or equivalent, is not created through a structured and understood process, but is undertaken informally.

Who

- 26 (67%) agreed that their PDS, or equivalent, is created by a team that includes engineers and designers
- 13 (33%) agreed that their PDS, or equivalent, is created by a team that just includes management and marketing and is then passed to the engineers and designers

When

- 24 (62%) agreed that their PDS, or equivalent, is formally documented and agreed before design work begins
- 15 (38%) agreed that their PDS is not formally documented and is presented informally to

designers and engineers

6.5 Communicating Requirements Without a PDS

Those respondents who said that their company did not create a PDS were also asked further questions on the how, who, and when of collating and communicating the product requirements within their company.

How

- 25 (93%) agreed that their product requirements are collated and developed informally during early project meetings
- 2 (7%) agreed that no specific activity is undertaken in terms of collating the information and developing requirements

Who

- 11 (41%) agreed that the product requirements are drawn up by a cross functional group, including designers and engineers
- 14 (52%) agreed that the product requirements are presented to the designers and engineers

When

- 17 (63%) agreed that the key product requirements are drawn up and agreed before design work begins
- 9 (33%) agreed that their product requirements are determined by the designers and engineers working on the project as it progresses.

6.6 Design for Sustainability and Ecodesign

The respondents were given the following definition, which had been developed for this questionnaire. 'Design for Sustainability (DfS) is the practice of understanding the customer and economic requirements for a product, along with the need to improve both its environmental and social impact, and then considering and balancing all these factors during its development'.

They were then asked if DfS (as per the definition) was practiced by their company. This question elicited the following answers;

- Yes 35 (53%)
- No 31 (47%)

They were also asked if an Eco-Design approach (i.e. primarily focusing on the environmental impact of a product during design) was practiced in their company. The responses were;

- Yes 23 (35%)
- No 42 (65%)

They were further asked if DfS should be part of the product development process at their company. The responses were;

- Yes 57 (86%)
- No 9 (14%)

7 RESEARCH DISCUSSION

A number of interesting (preliminary) findings, which could support the proposed hypothesis, were presented by the answers to the questions on the product development process and specification development.

For instance, despite the long recognized importance of having a structured and formalized process in order to aid the management of product development [35] (and the introduction of DfS tools and practices), the results show that 47% of the respondent's companies do not have such a process. While only 41% of these companies appear to have adopted what is regarded as best practice.

The importance of this issue is highlighted by the finding that the lack of a structured process, combined with poor process management (as indicated by too many ongoing projects), are regarded by the respondents themselves as important barriers to the performance of their company's development process.

However, it appears that specification issues are clearly as big a problem, if not greater, for most respondents, with constantly changing requirements, and no early definition of requirements being selected as two of the main barriers to effective product development. This seems to be confirmed by the answers to the specific questions on the use and development of a Product Design Specification

(PDS). While 59% of respondents said their company created a PDS, over half (51%) of these agreed that this PDS was created informally, 33% agreed that its production did not involve engineers and designers, and 38% agreed that it is not formally documented. Suggesting for many that they produce a PDS in name only, and do not actually follow accepted best practice. The apparent shortcomings with the front end activity for many companies are further illustrated when the results from those respondents who accept that their company does not produce a PDS, are added. Combining the answers, it would appear that only 29% of respondents use a formalized process for front end specification activity. Equally, by taking the two responses that relate to 'who', it appears that in 41% of the companies taking part in the study, designers and engineers are not even involved in creating the product requirements or specification.

It seems clear, admittedly from early results, that for many of these companies, their development practice, and in particular their specification development activity, does not really constitute practice that would easily allow DfS issues to be fully considered at this stage. For example, educating and providing designers with the tools to consider DfS from early development stages will be pointless as it very often the marketing and management who seem to decide on key product requirements, including its sustainability.

The results from the questions on DfS and ecodesign are interesting, but from an entirely different perspective. The number of respondents who say their company practice DfS seems to be much higher than expected given the results of the literature research. However, it is partly contradicted by the results of the question on eco-design practice. How can companies be effectively practicing DfS if they do not at some point employ eco-design? In addition, other answers suggest that far fewer responding companies actually consider the environmental and social impact of products during early product development activities. All this could indicate the level of confusion that may exist among managers and marketing, which were represented among the respondents, as to what DfS actually entails, especially the need for whole life cycle consideration and assessment from early in the development process. In particular, it could possible be due to many respondents seeing little differentiation between DfS and simply ensuring environmental regulations and sustainable policies are complied with. Alternatively, it could be that the Manufacturing Institute's database includes a large proportion of more forward looking companies. Although, the overall findings on product development practice do not seem to suggest this. This is obviously another key issue that will require further investigation, which will be possible as 17 respondents have agreed to take part in the next phase of the research.

Interestingly, some of the questionnaire finding also relate to the often noted external obstacles to the integration of DfS that also exist. For instance, is there a demand for, and are customers willing to pay for, products that have reduced environmental and social impact? Without demand, or more specifically, without the potential for DfS to improve business performance, why should companies consider adopting it? While the study does not directly look at this issue, it is clear that the vast majority of respondents think they should adopt, some form of, DfS. This suggests that respondents do accept that reducing environmental and social impact could potentially help to improve product acceptance either tangibly (financially) or intangible (product perception) and hence improve business performance. For the majority of respondents, there appears to be a clear customer demand, or a response to competitor (along with regulation), driving the move towards the adoption of DfS. Although for a significant number of others, the lack of customer demand was reported as a major hindrance to adopting DfS. However, the biggest reported hindrance to adopting DfS was the difficulty in justifying the anticipated additional expense involved. Overall this seems to suggest a partial catch 22 situation. Companies want to adopt DfS, to meet some form of demand, but are as yet unable to easily quantify the benefits that meeting this demand will generate, and so are probably reluctant to move forward (beyond the minimum of meeting legislation).

In looking for a solution, and in relation to this study, the questions that need to be further investigated are; could the potential cost burden of adopting DfS, and the resources needed for the anticipated 'extra' work, be reduced or eliminated by improved design practice? Could the introduction, as some suggest, of regular DfS thinking in pre-specification work lead to more innovative solutions that are better, more sustainable and cheaper products?

Therefore, if the ongoing study (and any additional work undertaken) does bear out the overall hypothesis, it is anticipated that further work will focus on two specific areas;

- Creating a 'viable' definition for DfS that has resonance and meaning with practicing engineers

and managers.

- Creating guidelines and principles for integrating DfS principles – and sustainability decision making - into a structured (cross organizational) Product Design Specification activity. This could include stipulated criteria in the form of a checklist.

Based on these two areas, any subsequent work could investigate the potential for the creation of a 'specification workshop' that could be developed and trialed – possibly within companies that take part in the initial study - for implementation within and by companies, that will;

- Improve the product design specification process within companies
- Enable companies to introduce DfS thinking and principles at the product design specification phase.
- Enhance the ability and desire of companies to adopt and employ appropriate DfS and Eco-design tools.

8 CONCLUSION

The lack of widespread adoption of DfS as a part of mainstream product design is clearly due to a wide range of obstacles. However, while there is important work to be done on issues such as the tools available and the education of engineers and designers, it does appear that in many companies the main roadblock could well be the product development 'environment' itself. In particular, there is recognition that the front-end product specification activity is key to enabling environmental and social issues to be considered, and decisions made, at the stage where they will have most impact. Yet, most companies seem unable to introduce DfS thinking this early in their product development process.

While this situation could be seen as the result of failings associated with the practice of DfS or the tools and techniques available, this paper suggests the hypothesis that the real fault often lies with the 'outdated' product development culture and practices (or lack of) that still exist within many companies. Therefore, enabling the wider adoption of DfS is likely to require tackling the problem not from a specific DfS perspective, but from that of improving the management of product design and development. More specifically, rather than the ongoing frustration of trying to force DfS tools and thinking into an unwilling environment, the need is to establish how to make the environment more accepting of DfS, and the suggestion is the focus must be on existing specification development practices. This hypothesis is now being tested through direct investigation of company's product development capabilities, with encouraging preliminary results. Over the long term the research could lead to a 'workshop' that would encourage good development practice, including DfS consideration.

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