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Applying design for sustainability in an ICT company

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Abstract: Environmental awareness has been raised up globally, and as a consequence sustainability is increasingly under focus. Due to increased demand from end-users, and tightened legislation, companies have to seriously take sustainability into account. The nature of business in the information and communications technology sector (ICT) is moving from pure product business to more service oriented approaches. Best results can be obtained through combining sustainability requirements directly to product development. This paper analyses how a significant ICT company combines sustainability and product development with design for excellence practices. The results include a description of practical realisation of design for sustainability together with its main challenges.

Keywords: design for excellence; sustainability; ICT; product development; environment; reliability; service.

1 Introduction

Environmental concerns have been raised up globally, and as a consequence sustainability is increasingly under focus. Due to the increased awareness of end-users, and tightened legislation, companies have a motivation to seriously take these issues into account, both at the strategic and operational level. (e.g. Johansson, 2008; Johansson and Brodin, 2008; Platcheck et al., 2008; Seliger et al., 2008; Herrmann et al., 2008; Charter and Clark, 2008; Smith, 2008).

Typically, sustainability, and environmental aspects are approached through considering recycling and disposal (Gehin et al., 2008). However, sustainability should not be seen as a separate issue after product delivery, but rather be integrated into all company processes. Integrating environmental aspects into product development is seen to lead to synergies with other business interests, such as improving company image, creating new market opportunities and even cost reductions (Byggeth and Hochschorner, 2006). The ability to influence the success of product development (PD) is the greatest at the start of the project (Yang et al. 2007; Harkonen et al., 2009; Lau et al., 2007). According to Mascle, and Zhao (2008), as much as 80 % of the costs of product development, manufacture and use are determined during the initial design stages. The share of product development over the total life-cycle costs is relatively small in relation to its impact (Sroufe et al., 2000). Product and process life-cycles have become increasingly important considerations while the importance of sustainability has been amplified (Yi et al., 2008; Kloepffer, 2008).

Design for eXcellence (DfX) is an organised way to systematically address the early involvement and functional integration (e.g. Bralla, 1996). Design for environment (DfE), which is a sub-discipline for DfX, is seen among the most effective for addressing sustainability (Kurk and Eagan, 2007), even though other methods exist, such as life-cycle assessment (e.g. Boks and Stevels, 2007; Hunkeler and Rebitzer, 2003).

This study addresses sustainability in the information and communications technology (ICT) sector through analysing the practices of a significant actor with a good environmental image. DfX practices of the case company are studied in order to obtain an understanding over how sustainability is included. The above mentioned can be condensed into the following research questions:

RQ1 How can the sustainability viewpoint be connected to product development?
RQ2 What are the main challenges of integrating sustainability in a large ICT company?

The first research question is addressed, both theoretically and by analysing a large ICT company. The second research question is addressed through a qualitative interview study.

2 Literature review

Design for eXcellence is an integrated approach for designing products, and processes, for cost-effective, high quality operations addressing the entire product life-cycle (e.g. (Xu et al., 2007; Jablokow and Booth, 2006; Gehin et al., 2008; Rungtusanatham and Forza, 2005; Jose and Tollenaere, 2005; Barton et al., 2001; Haque and James-Moore, 2004; Tseng, and Jiao, 1998; Kuo et al., 2001). DfX is seen to reduce time-to-market, lower cost, and increase product quality (e.g. Maltzman et al. 2005; Gungor, and Gupta, 1999; Prasad, 1997; Prasad, 2000). Reusability viewpoint is also emphasised (Zuidwijk and Krikke, 2008).

The first attempts to address the needs of internal customers consist of manufacturing considerations including assembly (e.g. Lai, and Gershenson, 2008; Huang, 1996; Bralla, 1996; Boothroyd & Dewhurst, 1983; Huang et al., 2001). DfX was later broadened into design for manufacturing (DfM) to include a broader set of manufacturing aspects (e.g. Chang et al., 2005; Stoll, 1988; Chang et al., 2007). Since the early 90s DfX methodology has expanded into new areas, such as design for testability, design for usability, design for safety, design for serviceability, design for packaging and design for supply chain. The DfX concept now covers the entire product life-cycle. (Sheu and Chen, 2007; Jiao et al., 2007; Bralla, 1996; Charter and Gray, 2008; Huang et al., 2001; Gatenby and Foo, 1990; Tichem, 1997; Cowan et al., 2000; Kumar and Fullenkamp, 2005).

Also, the important area of environment has been included to the DfX concept (Kurk, and Eagan, 2008; Graedel, 2008; Ehrenfeld, and Lenox, 1997; Coulter and Bras, 1997; Bras, 1997; Tichem, 1997). The goal of design for environment (DfE) is to minimise the overall environmental impact when producing goods and providing services (e.g. Gungor, and Gupta, 1999; Dowie, 1994). Nowadays, companies are seen to concentrate on fulfilling the requirements set by legislation, however, combination of business considerations and green legislation is not simultaneously optimised (e.g. Boks and Stevels, 2007; O'Hare et al., 2007). Fitzgerald et al., (2007) present a comprehensive list for DfE: comply with legislation, avoid liability, satisfy customer demand, participate in eco-labelling programmes, enhance profitability, and behave ethically. Following this type of guidelines enables companies to combine economic and environmental aspects.

Design for environment has, obviously, been recognised as one of the means for addressing sustainability (e.g. Mascle, and Zhao, 2008; Bridges, and Wilhelm, 2008; Kurk, and Eagan, 2008; Choi et al., 2008). Adding social and economic issues expands DfE to design for sustainability (Kurk & Eagan, 2007; Finster et al., 2002). Additionally, the overall supply chain performance is seen to become a critical competitive focus for addressing sustainability (e.g. Seuring et al., 2008; Carter and Rogers, 2008; Seuring and Müller, 2008). In order to address sustainability businesses must move from traditional product-oriented approach to a new, product-service oriented business (e.g. Manzini, 1999).

Good product reliability reduces the need for new products, need for maintenance, need for unnecessary service visits, and other activities that burden the environment. Adequate reliability thus increases customer satisfaction. Companies that reach good reliability find it more lucrative to provide all-inclusive service contracts (e.g. Jackson and Pascual, 2008; Rittgen, 2007; Gupta et al., 2008). Customers expect customised products with documented reliability, maintainability, maintenance, and support characteristics, together with minimum environmental impacts (Lad and Kulkarni, 2008). In the future, the share of service business increases in the expense of pure product business. Consequently, sustainability does not necessarily mean selling of continuously increasing number of 'green' products (e.g. Rao and Holt, 2005; Pickett-Baker and Ozaki, 2008).

3 Research process

The research process is described in Figure 1. Sustainable development and design for excellence were first studied by using existing literature as the key source. The chosen case company was then analysed in order to obtain an understanding of the company's practices. Weekly workshops were organised during the period of five months to discuss the practical realisation of DfX in the case company. Interview questions were

formulated based on the obtained understanding, see Appendix A. Deeper industrial interviews were carried out in the case company, including different sites. Results were analysed by reflecting them against the literature. The results of the analysis are presented in the section 4 Results and analysis.

Figure 1. The research process

The study consisted of 20 interviews, comprising multiple sites and countries. The study included the relevant DfX managers and responsible managers for vital internal processes. The interviews were conducted informally, in a qualitative manner, allowing the interviewees to explain and clarify the cases and topics as entities. As a result, these interviews represent the DfX activities in the case company in a versatile manner.

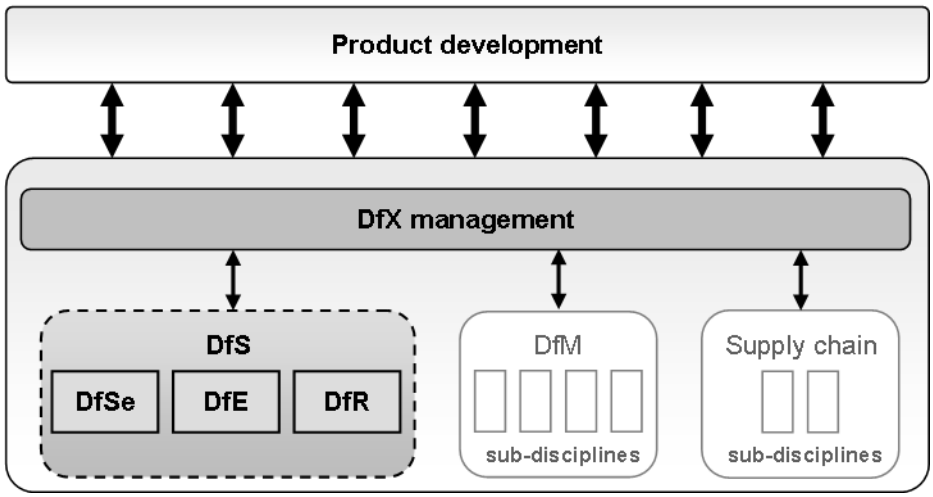
4 Results and analysis

4.1 Design for sustainability in the studied company

Sustainability aspects are integral aspects of DfX activities in the studied company. DfX in the studied company covers both, addressing internal customers, such as manufacturing, and external aspects, such as service, environment, and reliability. The case company has separate DfXs for all the above mentioned aspects. External aspects are vital after the product has been delivered, but must be designed in already during product development.

In the studied company, the role of DfX is to ensure that the needs of manufacturing, supply chain, and after-sales service are taken into account during product development. Important aspects for sustainability include, service, environment, and reliability. The studied company has a common DfX management organisation, which coordinates different DfXs and communicates their needs into product development. Each DfX has a named responsible manager. Figure 2 describes the DfX system of the studied company.

Figure 2. The DfX system of the studied company.



Design for sustainability (DfS) can be seen to include design for service (DfSe), design for environment (DfE), and design for reliability (DfR). Currently, however, DfSe, DfE, and DfR are managed as separate disciplines in the case company. Other separate DfXs include, design for manufacturing (DfM), covering its sub-disciplines design for board assembly, design for final assembly, design for testing, and design for packaging, and supply chain aspects that have been sub-divided into design for supply chain covering the structure of the chain, and design for supply chain capability.

Each DfX sub-discipline communicates its requirements into product development projects through DfX management organisation. This communication is supported by organising training sessions for product development personnel. Product development projects have named specialists for each DfX sub-discipline, enabling direct feedback.

Each sub-discipline of DfS is described in more detail below. The descriptions include input (where each DfS obtains requirements from, and what type they are), output, and practical realisation.

4.1.1 Design for environment (DfE)

Input: Higher level DfE requirements are seen to include legislation, such as market area and national laws, and EU directives, e.g. RoHS (Restrictions of Hazardous Substances in Electronics), and its Chinese equivalent. The case company has made some strategic choices in its environmental policy and DfE has to comply. In practice, the actions are the same for both, legal and company policy based requirements. DfE also receives green requirements from customers. In addition, DfE takes into account the requirements set by environmental organisations, such as World Wide Fund for Nature (WWF) and Greenpeace. Environmental requirements are seen to change over time, the pace varies depending on the issues. DfE follows the development of these general environmental requirements.

Output: Environmental issues are seen to be visible throughout the product life-cycle including disposal. DfE sets generic minimum requirements for all products, and all company units. However, business units and product development projects can set more stringent environmental requirements for themselves. DfE sets both, product and process requirements, for example in the form of recyclability target percentages. DfE requires product development to reflect environmental issues clearly in product specifications. It is seen vitally important for product development and business level to comprehend the

environmental requirements. DfE clarifies the meaning of environmental requirements with designers. DfE requirements are hierarchically divided into mandatory and optional. In some cases exceptions are granted for environmental requirements, such as lead-free soldering.

Practical realisation: Prioritisation of requirements starts from legislation, followed by cost aspects. Additional nice-to-have requirements are prioritised based on company business and environmental strategies. Design review process in the case company, states that there should be an environment representative in all product development projects. This representative is not necessarily part of the DfE organisation. In the design review process checklists and environmental impact analyses are utilised to address environmental aspects. DfE has prepared tools and document templates for product development projects. Design engineers are expected to analyse and solve problems themselves, and contact DfE only when needed. Agreement templates for suppliers include forms covering environmental aspects. DfE utilises the DOORS® tool, and balanced score card based on spreadsheets, for managing environmental requirements. DfE is responsible for ensuring that documents for environmental issues are included in the product data.

Environmental requirements have been collected into a document, covering the essential aspects: energy consumption, hazardous substances, recyclability, marking of plastics, and references to standards. This document has been included in company processes, both electronically and on paper. DfE operates actively in cooperation with substance and legal experts. A separate expert teams have been formed for energy consumption, and for material requirements, including a list for banned substances. DfE is responsible for combining the requirements set by these teams. Training and communication are an important part of DfE activities, including self-study material on environmental issues.

4.1.2 Design for reliability (DfR)

Input: Higher level requirements are seen to include legislation, standards and different EU norms, such as environmental issues. The company has been proactive, aiming to fulfil these requirements, before they are mandatory. In addition, energy saving is a new viewpoint that has been addressed. The company strategy and business targets set the second level of requirements, leading to demands for DfR in issues, such as, availability, reliability and repairability. As an example of practical challenges DfR is having to address, is the scepticism in the USA considering the reliability of lead-free soldering, which on the other hand is promoted on environmental grounds in the other parts of the world.

Typically, customer requirements do not enter DfR directly, but are provided by the marketing/sales function or in some cases by product development projects. The marketing people have opened doors for DfR and provided access to customers. DfR also interviews customers to understand their viewpoint. Internal customers include project management teams, DfX management, and different DfXs.

Output: DfR is seen to set requirements for product development regarding product requirements, and for internal business processes (reliability process, product development process, and customer loyalty). Requirements are provided, especially for new products. Company standard, which is based on fault frequency of components, is used for reliability calculations.

DfR gathers customer feedback and communicates it inside the company. Annual customer loyalty process includes customer interviews for which DfR gives input from the reliability viewpoint. DfR also communicates service and maintenance related issues, for example in relation to speeding up software updates.

In addition, DfR arranges internal training sessions on reliability and customer aspects. An important part of the operation is to provide formal and informal networking for persons interested on quality and reliability.

Practical realisation: One of the main benefits of DfX is seen to enable personnel to understand the big picture, even though they have their functional home silos. Vital for prioritising reliability requirements is to understand both, the company's, and customers' businesses. Systems sold to customers, should be understood as a hierarchical entity, where the highest level is absolutely crucial, and the lower levels are less critical. In other words, prioritisation actions must be based on the reliability seen by the customer. In addition, customer documentation should be seen as a vital part of the product. When prioritising requirements from the business viewpoint, life-cycle cost thinking is seen to be the starting point. Interviewees note that price competition is fierce, resulting in cost control being in focus.

4.1.3 Design for Service (DfSe)

Input: The starting point for requirements definition, and evaluation, is the overall business. Customer requirements are seen not to enter DfSe directly, but are provided by business units, which are regarded as internal customers. Service product managers of each business unit are responsible over service portfolios and service concepts.

Service business units prioritise requirements and generate requirements lists for DfSe. The prioritisation of requirements is seen not to be always based on careful quantitative analysis, but gut feeling of business managers is involved. DfSe is a support function for both, hardware dominated business, and for a pure service environment, and must therefore understand their needs.

Output: While requirements are distilled out of the service concepts, the emphasis is on generic requirements relevant for all products. The requirements vary from very small and simple to wide issues to be provided to the product development. However, DfSe tries to avoid proposing product development any technical solutions. The requirements are seen important to be written down together with the relevant metrics. This is to allow later discussion with PD over the effective implementation. DfSe also gives recommendations, in the form of features, for product development. PD analyses and prioritises the requirements to be implemented in different releases. In addition, DfSe assures that installation guides are created and that the product features can be found in the company data system.

Practical realisation: DfSe is seen to focus on business, covering both, existing and new products, rather than concentrating on product development projects only. Other DfXs are seen to focus more on product development. DfSe calculates potentials for future service business, and aims to improve quality of service. DfSe collects service requirements into a catalogue consisting of detailed requirements. Cost calculations are seen as the deciding factor for prioritising requirements. The data system utilised by DfSe is more management oriented (Focal Point™), opposed to other DfXs that utilise DOORS®, which is more engineering oriented.

DfSe, together with DfX management, participate in installability reviews which typically identify new product specific requirements. Product volumes are seen to strongly influence the prioritisation of requirements. DfSe recommends which requirements will be taken into account in different product generations.

Prioritising requirements includes DfSe conducting their own internal analysis, considering whether it is necessary to hand particular requirements over to PD. DfSe tries to minimise product development's work-load. Even though PD makes its own prioritisation, it is also seen to be in the interest of PD that DfSe has a proposal on what should be implemented. Time-to-market, customer satisfaction, and satisfaction of the

operational units are the main arguments for prioritisation, including both hard facts and expert opinions.

4.2 Analysis of DfS in the case company

Company strategy has been to be proactive in its sustainability efforts. Design for environment has experience over a decade and is relatively well established. Design for reliability, on the other hand, is a fairly new discipline and its practices have only partially stabilised. Design for service differs from the two above mentioned in the sense of service also being a business itself. This results in service activities being organised in a different manner.

DfSe does not see itself as being closely connected to other DfX disciplines. Typically, in other DfX disciplines, local knowledge is collected from manufacturing sites, and supply chain in order to feed it to the global research and development (R&D). It is seen very difficult for the DfSe to balance the needs of local services to global R&D.

4.2.1 Challenges of DfS in the case company

Describing requirements in a suitable format, and to a reasonable degree of detail, for product designers is seen as a challenge. All sustainability requirements are not always relevant to all products and processes, and it is a challenge to formulate minimum requirements so that they are valid for all the company products.

Prioritisation of requirements is challenging, while there is no sufficient commensurability. The prioritisation is attempted through utilising cost calculations based on both, customers' and company's own businesses. However, expenses on disposal and recycling are seen not to be properly included in calculations. In addition, DfSe views that the ease of installation and serviceability are not adequately addressed in these calculations. Cost calculations are also seen to address short term aspect better than the long term aspects, which are typical to the sustainability viewpoint.

Environmental requirements are typically legislation based, and tend to change over time. These changing requirements are a challenge as changes can be fairly rapid. For example, should a substance be banned within a timeframe of six months, this would result in excessive burden to quickly check all the relevant products and documents. Interpretation of legislation varies leaving room for arguing whether company products comply with the existing laws. Ideally requirements would be unambiguous, however, in practice this is not possible as situations change. In addition, customers may prioritise requirements differently than the company itself.

In a large organisation, with multiple sites and cultures, communication is always a challenge. Requirements are often optimised for a single organisational unit, and this does not fully support business. Requirements and metrics can also be understood in different ways in different parts of organisations. For example, production personnel talk about PPM (parts per million) and reliability people about MTBF (mean time between failures). In addition, different product lines may understand requirements differently.

Product development is seen not to understand business and customer viewpoints adequately. This insufficient understanding leads to sub-optimal products, and related documentation. Business is handled globally, yet services should be handled locally. As a result, it is a challenge for DfSe to gather the local knowledge and understanding from factories and logistics, and to bring it to product development.

The company strives for global solutions in order to minimise costs. Even within the EU, there are twenty seven national legislations, all of which the company should follow.

It is a challenge to avoid sales from promising something that cannot be realised in global terms.

Table 1 summarises the key challenges faced by design for sustainability

Table 1 Key challenges faced by design for sustainability

	Challenges
Describing requirements	Agreeing on suitable format Adequate level of detail Relevance for all products
Prioritisation	Commensurability Cost calculations Inclusion of sustainability viewpoint Short term vs. long term Customers may prioritise differently
Changing requirements	Rapid pace of change Varying interpretation of legislation
Communication	Multi-project/ multi-site/ multi-cultural environment Complex organisation Varying vocabulary
Global solutions	High number of national legislations Complicated product portfolio Combining global business targets with local service needs

5 Conclusions

Environmental concerns have been highlighted globally, and as a consequence sustainability is increasingly under focus. Best results can be obtained when sustainability is addressed already during product development, not only after product realisation. This paper analyses how a significant ICT company combines sustainability and product development.

Design for eXcellence can be utilised to systematically incorporate different issues directly to product development. DfX seems to be an effective means for addressing environmental and sustainability and their requirements already during early PD. The case company does not have a separate DfX discipline for sustainability, but these issues are managed in three independent sub-disciplines: design for environment, design for reliability, and design for service. The literature seems to support sustainability consisting of these three elements, even though they are not typically described as an entity.

Currently there are many challenges in the realisation of design for sustainability. Large and complex organisation, together with multi-project, multi-site, multi-national, and multi-cultural environment results in communication being demanding. Prioritising requirements is a significant bottleneck in this complicated environment with a large product portfolio. Prioritisation of requirements is experienced to be most effective through cost calculations. However, the current calculation formulas are seen to insufficiently include the post-installation impact, important for the sustainability viewpoint in the case company. In addition, the challenges are accumulated by different

national legislations and service typically being a local function, hindering global, cost effective solutions.

In the case company, design for service differs significantly from the other DfX sub-disciplines through its stronger business orientation. Even though this is strength for the discipline, this study indicates that DfSe ought to also go deeper into practicalities.

Company strategy has been to be proactive in environmental issues. However, there is room for improvement during the post delivery phases to enhance sustainability viewpoint. Highlighting sustainability and combining the relevant sub-disciplines to support this might prove beneficial for the case company. A potential way to better address sustainability might be to learn from the example of DfM, where internal manufacturing aspects are combined effectively. Nevertheless, learning only covers combining different elements, and special characteristics of DfS must be separately addressed.

This study describes one of the top companies in its field. Concentrating on a single company enabled a more thorough analysis, and concrete descriptions on how sustainability is connected to product development in practice. The interviews covered all the key persons involved in DfX, providing a comprehensive view. The obtained results could vary to some degree, should a wider set of companies be included in the study. Design for sustainability is a relatively new topic and there is need to clarify its content and relevant elements.

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Appendix A

Questionnaire

Name
Title
Organisational unit

1. Please describe what you understand with requirements management and requirements? (Specifications, needs, constraints, etc.)
    - How do requirements relate to your area of responsibility

2. Where does your organisation unit get its requirements?
    - What type of requirements – please give examples

3. To which organisational units, within the company, do you set requirements?
    - What type of requirements – please give examples

4. How are requirements prioritised?
    - How would you develop the prioritisation of requirements

5. What are the main challenges relating to requirements management form your organisational unit's perspective – How would you attempt to rectify these issues?

6. How do you view DfX (Design for Excellence)?

7. How does the view over requirements vary – in your opinion – in different parts of the company (for example different sites, different functions: product development, production etc.)?

8. How have the changes in the company organisation influenced requirements management?