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SUPPLY CHAIN ECO-INFORMATION SHARING IN THE PRODUCT DEVELOPMENT PROCESS THROUGH COMPUTER AIDED DESIGN SOFTWARE

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ABSTRACT
As decisions made during the design of a product have a significant impact on environmental performance, it is imperative that environmental considerations become an integral part of the design process. The integrated software platform for Green ENgineering dESIgn and product sustainability (G.EN.ESI) project aims to develop a software platform, for use with CAD/PLM software, which simplifies the process of integrating environmental and economic requirements the design process. A key component, paramount to the success of the platform, is its ability to obtain eco-information directly from the supply chain through the use of a web based supply chain portal. This paper details the considerations and work undertaken in the early stages of the portal's development. Based on analysis of past and existing portals and data collected through a survey and a case study, possible architectures of the web portal, and their associated characteristics, were derived using scenario planning. Moving on, the next steps involve surveying more companies and using the insights gained, a detailed design brief for the portal which covers both technical and functional requirements will be created.

Keywords: eco design, integrated product development, new product development, collaborative design, 3DCE

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1 INTRODUCTION

With organisations experiencing increased social and regulatory demands to behave in an environmentally conscious manner on a global scale, environmental impact is fast becoming a factor considered on par with cost, functionality and value during the product development process. However, these new requirements are often viewed as mandates or burdens that slow development while ramping up cost, detracting from the main business of the company. As a result, environmental aspects are often considered an afterthought, resulting in delays and added costs as changes are made after the late addition of environmental requirements into the development process (Handfield *et al.*, 2001; Sousa and Wallace, 2006). (Ellram *et al.*) 2008 suggest that utilising the three-dimensional concurrent engineering (3DCE) approach holds great promise for early integration of environmental considerations into the product development process. With its roots in concurrent engineering, 3DCE is the notion that the simultaneous design of product, process and supply chain, through links between internal functions and participation with external partners, leads to improved operating performance (Fine, 1998).

As firms sought to attain sustainable growth and profitability through the rapid introduction of new products and against the backdrop of increased global competitiveness, the product development process, an inherently collaborative activity between internal groups (such as engineering, marketing, manufacturing, sales and service), increased in complexity due to the addition of external partners (such as subcontractors, customers, technology suppliers and co-development partners). This decrease in vertical integration, combined with increasing globalisation and outsourcing, resulted in the growth of supply chain management (SCM) which places great emphasis on the management of relationships within the supply chain, viewing the supply chain as more than just a logistic network comprising of interrelated companies built around delivering a specific product or service to the customer (Saeed *et al.*, 2005). Through cooperation and information sharing, SCM coordinates different parties within the network and establishes business partnerships with the aim of achieving overall and long-term benefits for all involved parties.

1.1 Importance of Inter-Organisational Information Sharing during the Product Development Process

Typically, information sharing within the supply chain is associated with maximising responsiveness and efficiency while minimising cost, with the relationships formed handled by the procurement and/or logistics department; while information sharing within the product development chain is allied with the acquisition of resources and capabilities to improve product offerings, with the collaborative relationships formed more likely to have a research and development focus. On the one hand, there is Kanter's notion of collaboration advantage, defined as " *a significant leg up in a global economy due to a firm's well developed ability to create and sustain fruitful collaborations*" (Kanter, 1994), which is associated with the development chain and on the other there is the resource-based theory view that one source of differential performance between firms is the way in which they organise exchange activity (Conner and Prahalad, 1996), which is related to the supply chain. Therefore, it would seem logical to then deduce that the amalgamation of the two forms of information sharing would result in advantages gained through the unified use of the formed relationships, enriching the depth and quality of information shared via both design and supply chains. With particular focus on design chains and collaborative design, utilising supply chain information sharing relationships and methods within the product development process would offer a means of augmenting the match between product and process, which most companies accomplish through concurrent engineering, with an additional consideration of supply chain configuration.

1.2 Embedding Eco-Information into the Product Development Process

Set within the context of the household appliance industry and through the adoption of the 3DCE approach, the integrated software platform for Green ENgineering dESIgn and product sustainability (G.EN.ESI) project is a European Union Seventh Framework project that aims to achieve a 30% reduction in lifecycle energy use and a 50% reduction in industrial waste in household appliances produced, based on the choices made through its software platform and eco-design methodology. For the successful integration of the G.EN.ESI platform into CAD/PLM software, it is paramount to ensure that there is an accurate and reliable flow of information from various supply chain partners,

including suppliers, product dismantlers and distributors, to the software. This vital flow of information from the supply chain into the design process via the G.EN.ESI platform will be realised through a unique web-based supply chain portal.
Since internet communication technologies gained popularity as a means of simplifying business to business (B2B) communications and were seen to have an impact on logistics process performance, purchase process efficiency and supplier relationships (Baglieri *et al.*, 2007); supplier portals have been found to promote information sharing and coordination of operational flows (McIvor and McHugh, 2000), support supplier management and create a sense of community among buyers and suppliers; all the while increasing the stability of relationships and suppliers' loyalty to their customers (Roberts, 1999). It is this collaborative potential within supplier web portals that the G.EN.ESI project is looking to harness. The web portal required to support the G.EN.ESI platform can be seen as an evolution of supplier portals from their traditional role as an e-procurement tool; it is the development of this new portal that is the main focus of the work presented in this paper.

2 THE G.EN.ESI PROJECT

Through the development of a software design tool (G.EN.ESI platform) and supporting eco-design methodology (G.EN.ESI methodology), the G.EN.ESI project aims to address the lack of easy to use and robust tools for environmental evaluation at the engineering design stage. Currently available tools are either too qualitative/subjective to be used by designers with limited experience, or too quantitative, costly and time consuming and for use during the early stages of the product development process (Sakao, 2007; Boks, 2006). Moreover; these tools are usually stand alone and do not allow for easy integration with traditional design tools. The shortcomings of current eco-design procedures and tools mean they fail to offer practical solutions for day-to-day use in design and engineering departments as they only achieve limited industry penetration (Lofthouse, 2006). The main objective of the project is to supply a platform that can be completely integrated with other main design tools, such as CAD and PLM, which helps designers make ecological design choices without losing sight of cost and typical practicalities of industry.
The G.EN.ESI platform architecture will be based on the integration of various tools into the same structure, with the tools communicating to support the entire product design process. Each tool within the platform will examine design choices from a specific point of view while simultaneously possessing the ability to provide information to the designer on environmental issues. This connection between the tools will allow for an immediate check of the congruence of the choices with other key design parameters. Additionally, environmental decisions made by the designer will be supported by a case-based reasoning tool which will utilise knowledge stored from previously successful cases to suggest possible environmental improvements.

2.1 How the Supply Chain Portal Supports the G.EN.ESI Platform

A reliable input of accurate data and information is central to the success of the software platform; the platform will manage data through relational databases structured such that they align with the most common databases which support software tools used by the companies. The G.EN.ESI databases will not only inherit data from local company software tools (CAD/PLM) but will also collate data from various members of the supply chain through the use of a web-based portal. Using eco-information that the supply base inputs into the portal, the platform tools assesses the environmental impacts and cost of various options, allowing the designer to select the most convenient in terms of environmental aspects. The use of the web portal will encourage sustainability competitiveness within industry, while stimulating eco-efficiency throughout the whole supply network.
Figure 1 shows the structure of the web portal proposed by the project and how the portal interacts with the software platform. An example of how the portal and platform interact when used by a designer is as follows: a member of the supply chain uploads information into the portal regarding a component they supply, including weight of component, geographical location of the production plant and transport used to ship it. When the designer selects this component during the design process, the 0km tool within the platform automatically downloads all the information regarding the transport scenario from the portal. The 0km tool collates transport information relating to all the chosen components within the design, it is this information that is used as part of the environmental impact (S-LCA) and cost (S-LCC) calculation along with calculations made from other tools such as DFEE and LeanDFD. It is the results of these calculations that are then present to the designer.

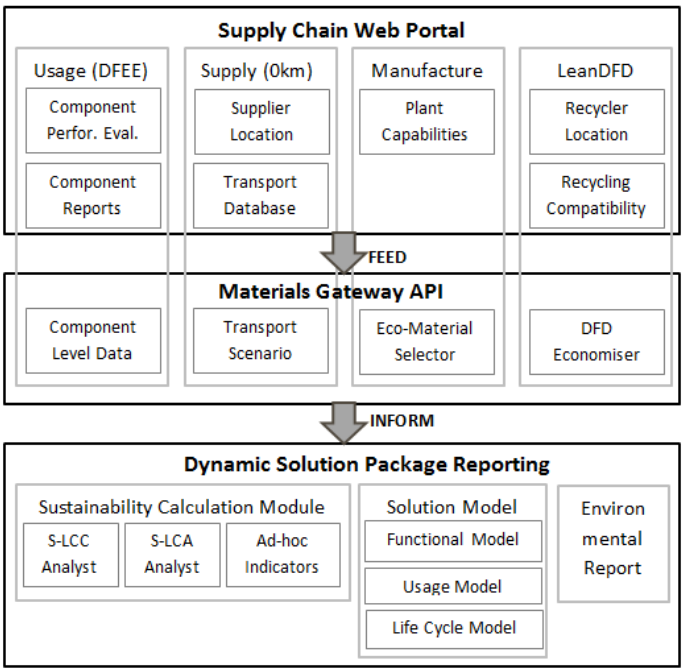

Figure 1. Structure of the G.EN.ESI platform's web portal

3 SUPPLY CHAIN PORTAL DEVELOPMENT OBJECTIVES

As opposed to its more traditional use as an e-procurement or purchasing tool, the G.EN.ESI project is proposing the development of a supply chain web portal that facilitates the sharing of eco-information within the supply chain; this information would be input directly into the product development process via the G.EN.ESI platform, an add-on for CAD/PLM software, simplifying the process of designing products with increased environmental performance and sustainability and improving supply chain visibility. While sitting at a desk and with minimal effort, the designer is able to see, in real time, the impact that decisions made regarding the use components, processes and services provided by external firms have on the environmental performance of the product being designed.

To ensure effective deployment of the supply chain portal, it is essential at this early stage in its development to answer the following four critical questions: 1) what information to share, 2) whom to share with 3) how to share it and 4) when to share. This need resulted in the construction of the following aims for this paper:

1. To explore possible portal architectures – this will allow for a better understanding of how the design and use of the portal supports the supply strategies of a firm and how it can impact performance outcomes associated with supply chain relationships.
2. To understand the impact that the characteristics of eco-information have on the use of the portal.
3. To understand the impact that the distinction between firms that initiate the system (called initiators) and those that participate in the system (called participants) would have on the use and success of the portal. As research indicates that initiators tend to be are the primary beneficiaries as they tailor the portal to their benefit and exert control over participants (Riggins and Mukhopadhyay, 1999); it is important to construct the portal such that win-win situations are created.
4. To understand the impact that any associated competitive conditions, real or perceived, would have portal use.

For the successful creation of the web portal, it is important to understand that there is a distinction between the two different types of collaboration that are required with supply chain partners. The first is collaboration on the development of the portal itself, it is essential that the portal be constructed with input from both participants and initiators; while the second is the long term collaboration through information sharing which is key to the success of the G.EN.ESI platform.

4 RESEARCH METHODOLOGY AND RESULTS

Due to this dual nature of the collaboration requirements and to ensure that both options are sufficiently researched, a two-phase data collection process was formulated and executed. Firstly, data was collected through an online administered survey aimed at understanding the nature of supplier collaboration in new product development (SCNPD) with particular focus on the perspective of suppliers; the survey garnered 76 responses from individuals involved in SCNPD projects across a number of engineering industries. The second phase, whose aim was to acquire a better understanding of the acceptability of the portal's proposed role, the climate under with it would be used and the profile of a typical platform user, involved an in-depth case study of a G.EN.ESI project industrial partner through a site visit and interviews with various departments including design, production, sales and procurement. Table 1 summarises some key results from the two phases of data collection.

Table 1. Key results from data collection phase

Online Survey	Case Study
Most cited factors/qualities to consider when selecting a partner: 1) Trust and reliability 2) Openness and mutual support 3) Congruence of goals (win win) 4) Relationship with buyer.	Biggest concern with portal is the security of the information that is shared. "*I don't know if I can trust sharing information over the internet, how can you be sure that only the people you want to can see the information you upload?*"
When asked which was more important, trust or contracts, 50% of the respondents said trust and the other 50% said they were both equally important.	Cited that the fear that information would get abused, used for anything that has not been agreed upon, is a concern. "*It is not like if you are not happy with what they are doing with the information you can take it back*".
Average success rate of SCNPD projects = 70%	As environmental awareness has spread through the company, people are starting to view eco-design as more than just an imposed burden.
Most frequently faced challenges when collaborating: 1) Relationship management 2) Aligning goals and objectives 3) Financial burden.	As environmental design is still in its infancy within the industry, it offers a chance to attain an advantage from something that is sure to become required of all firms.
Most difficult challenges faced when collaborating: 1) Dealing with failed relationships 2) Relationship management 3) Aligning goals and objective	"*It is hard enough as it is to get information from their suppliers, even information that they possess; they usually refer us to a data sheet on the website."*
Effects of project failure: 1) Relationship breakdown 2) End of collaboration projects.	"*If the people we supply to asked us for the information that we would likely have to ask for from our suppliers, we would not be able to provide it*."
Most projects only exchange information and knowledge that is essential to the success of the project.	Increasingly, their customers are requesting eco-information regarding the products that they are purchasing.

5 DEVELOPMENT OF THE G.EN.ESI SUPPLY CHAIN PORTAL ARCHITECTURE

As with Ferrari who were able to align the functional requirements of their supplier portal with their strategic goals (Baglieri *et al.,* 2007), it is important to ensure that the G.EN.ESI web portal's functional requirements align with the strategic implications it would have on firms using it. Defining the strategic goals of the portal is important as it has a strong and direct impact on the success of the portal's implementation. Through the provision of strong support and maintenance by top management during the implementation phase, supplier involvement can be encouraged, aiding in the attainment of any supplier relationship building and management strategic goals. To determine various strategic scenarios of use concurring to the supply chain web portal, the technique of scenario planning was used. Scenario planning is a futures technique that is used to generate different scenarios that represent possible futures associated with different trends and events to help develop policies and strategies that are robust, resilient, flexible and innovative (Schoemaker, 1995).

In this case, scenario planning was undertaken to determine the following: 1) the best way to structure the supplier portal, 2) strategic implications its structure would have on buyers (firms using the G.EN.ESI platform) and suppliers (supply chain firms that upload information into the portal) and 3) how the way the portal is used varies depending on the strategy implemented. During the scenario planning, it was essential to assign equal weighting to the supplier and buyer perspectives as they are complementary and focusing on both offers a holistic and more realistic view of the portal allowing for the creation of a more robust portal.

The key question, central to the scenario planning, was as follows: "*what is the best and most viable way of structuring a web based supply chain portal to facilitate eco-information sharing between firms that use the G.NE.ESI platform and members of their supply chain*?" Through the analysis of past and present web portals and insights gained from the data collection, the drivers and deterrents listed in Table 2 were generated and used as the basis of the scenario generation.

The two axis method, based on one of the approaches employed by Shell (Foresight, 2009), was then used to generate four contrasting scenarios that are related to the use of web portals by placing a major factor influencing the future of the issue on each of two axes that cross to form four quadrants. It was identified that the major factors influencing the use of the portals were related to the number of companies that would use a single portal; these are described in more detail in Table 3. A four scenarios diagram, with each scenario represented in a single quadrant as a series of potential gains and barriers, was then developed; a simplified version is shown in Figure 2.

Table 2. Drivers and deterrents influencing the adoption of web portals

Drivers and Polarities	
Impact on eco-product development process.	Alignment with strategic focus.
Impact on reputation.	Pressure from other external stakeholders.
Availability of required eco information.	Buyer power vs. supplier power.
Ease of data input into portal.	Top management support and buy-in.
Impact on other business processes.	Cost of use.
Impact on financial performance.	Current buyer-supplier interactions.
Cost savings from reduced environmental impacts.	Impact on buyer-supplier relationship.
Advancements in software technology resulting in heightened web portal security mechanisms.	Nature and sensitivity of information shared.
Availability of resources and capability required to implement and use web portal.	Cost of integrating the web portal with existing practices.
Consequences of non-conformance.	Increase in work load.
Increasing eco-legislation and regulations.	Level of commitment required.
Who else is using the G.EN.ESI tools and platform?	Ease of retrieving data from portal.
Increasing customer demand for eco products.	

Table 3. Description of major factors influencing the use of portals

Axis	Description
Multiple Suppliers ↔ Single Supplier	Number of suppliers that interact and input eco-information into a single web portal. At one end, the web portal is set up such that it receives information input from a single supplier; while on the opposing end, multiple suppliers can interact with the portal.
Multiple Buyers ↔ Single Buyer	Number of buyers that interact with and access information that has been uploaded into a single web portal. Much like the 'supplier axis', on one end, a single platform user can access information that has been uploaded into the portal and at the other end, multiple platform users can access the information.

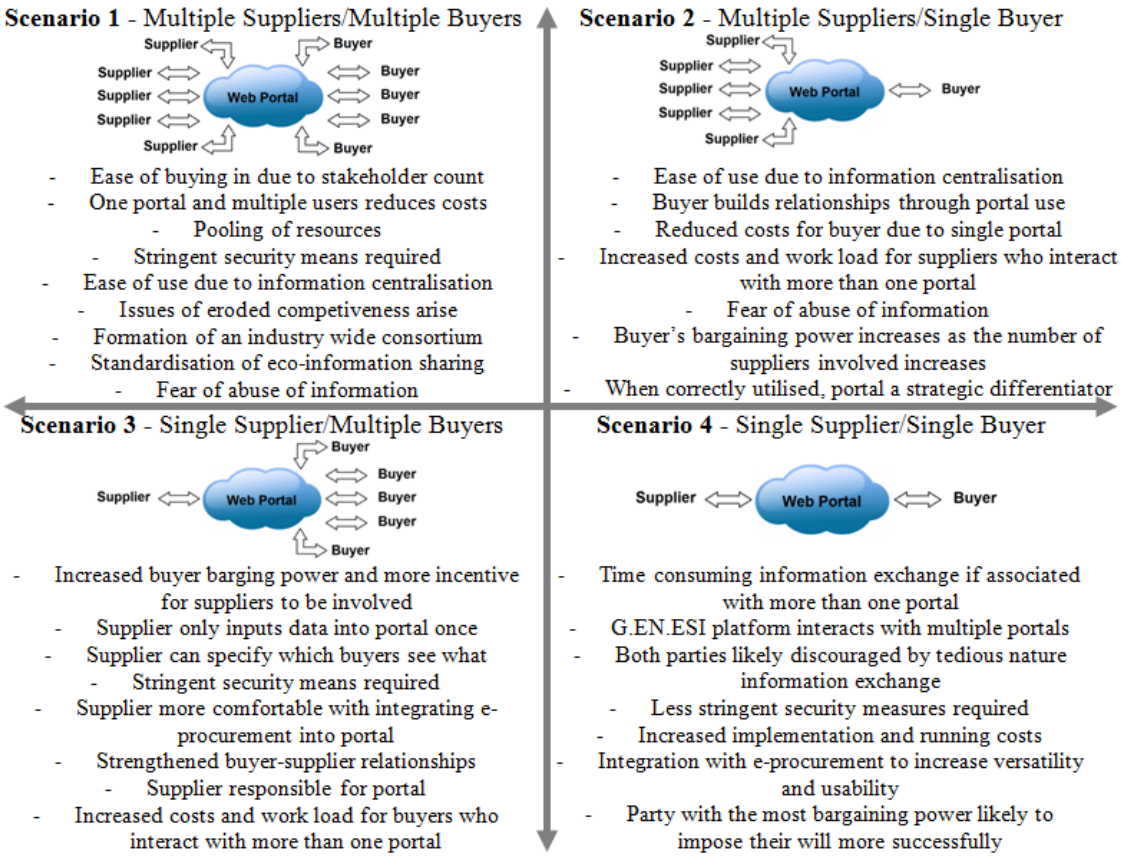

Figure 2. Simplified four scenarios diagram

Following the development of the scenarios, the main actions that could be taken to manage the risks inherent in each scenario were identified. With so many firms involved with a single portal in Scenario 1, the development of robust ownership rights is a must; this will ensure that portal is well maintained and monitored for misuse. In Scenario 2, as the buyer has access to collated information regarding a number of suppliers, there is scope for misuse. As a result, it is essential to ensure that the buyer does not have sole responsibility of the portal and that suppliers have a way of checking that the portal is not being abused. The portal should also allow suppliers to export information across multiple portals if they have multiple buyers using the G.EN.ESI platform. Scenario 3 requires a function that allows buyers to assign multiple portals to a single software platform and due to the scale of their responsibilities it is paramount to ensure supplier commitment. As they have a bigger role, suppliers are likely to feel more comfortable with the extension of its functionality to include communication of information relating to production and deliveries. The main action with Scenario 4 is to ensure that both parties are fully committed and aware of the work involved if they end up associated with multiple portals; additionally, buyers should be able to assign multiple portals to a single platform and suppliers should be able to share information across multiple portals of their choosing.

Critical 'must-do' issues to be addressed that are common across the various scenarios were also identified. Regardless of the scenario, it is essential to have commitment from both suppliers and buyers by framing it around business benefits for both parties and to guarantee the security of information that is being shared through the use of heightened security measures. The portal should be designed such that the effort required to input data is minimal and that the possibility of entering information in the wrong format is eliminated. In addition to the design of the portal, a robust implementation strategy is also essential to ensure that no one is exposed to unnecessary cost.

6 SUPPLIER COLLABORATION IN NEW PRODUCT DEVELOPMENT THROUGH THE WEB PORTAL

Guided by the rules of integration (Teddlie and Tashakkori, 2009), inferences where made from the collected data and, combined with the process of observer impression (Punch, 2005), used to develop an deeper understanding of the nature of and conditions surrounding the long term collaboration forged between supply chain partners after the implementation of the web portal.

6.1 Impact of Eco-Information Characteristics on Supply Chain Information Sharing for New Product Development

The supplier collaboration that is the driving force behind the G.EN.ESI platform and the web portal is based on eco-information sharing. Although asymmetric information, which refers to various members of the supply chain having differing states of information relating to cost, resources, performance status and market conditions, exists within todays supply chains, firms are continuously working to fill in existing gaps to avoid misunderstandings, opportunism and making sub-optimal decisions. It is too early in the platform's development to explicitly outline the type and format of eco-information that will be required; however, the fact that it requires information that is not traditionally exchanged will result in incomplete information being supplied to the portal as not all members of the supply chain will have all the required information pertaining to the products and services they provide. As an example, a component manufacturer likely would be able to supply information regarding the materials and manufacturing processes related to aspects of the component that they have designed in-house; however, without requesting it from their own suppliers they would not be able to provide the same information for parts that they buy in. It is expected that with time, as the supply chain becomes more familiar with eco-information requests, its flow into the portal will increase, along with its completeness. Information suppliers will be required to make necessary investments on their end in order to attain any missing eco-information relating to the products and services they supply; however, as the world becomes more environmentally conscious, it is not presumptuous to say that these will be investments that firms have to make to remain competitive. The magnitude of challenges presented by the type of information to be shared over the portal means that the presence of a "champion", whose role is to guide the process along and ensure that communication channels are in place in case conflict or challenges arise, would be paramount and very likely the key to its success.

6.2 Initiators vs. Practitioners and the Competitive Conditions Associated with Supply Chain Portal Use

With the platform being utilised in buying firms, it is more likely than not that buyers will be the initiators of the web portal. This makes it important to understand if, in the presence if perfect eco-information regarding their products, suppliers would be comfortable sharing it with their buyers. This applies two fold; are supply chain members satisfied with the security of the portal and are they also willing to share information about their products which they might consider sensitive, especially if it leaves them at a disadvantage when compared to their competitors or if it has the potential to compromise their competitive advantage? Based on the survey results, this fear is augmented by the fact that in 62% of SCNPD projects the authority lies solely with the buyer; if the same is applied to the web portal, suppliers' reluctance to be involved due to the fear being overexposed is not unfounded. It is important that the portal architecture is designed in such a way that it allows buyers to acquire the information they require while at the same time instilling confidence in suppliers regarding the information they are sharing. Not only is it important that the portal be designed to minimise abuse, but it is also important to ensure that once the buyers have the information, they do not misuse it. When asked in the survey which was more important, trust or contracts, 50% of the respondents said trust and the other 50% said they were both equally important. This suggests that trust is an essential component in the success of the portal in terms of long term use.

Developing the portal with input from both participants and initiators ensures that the architecture of the portal allows for win-win situations for all involved. For example, if both the buyer and the supplier are happy with the portal, the supplier will upload information into the portal that they are comfortable sharing and will actively ensure that the information is regularly updated; on the other hand, the buyer will be able to confidently use the information in the portal without having to double check with the supplier to see if it is still relevant. Through this process, the relationship and trust between the two is strengthened, leading to the supplier providing information that they previously would not have been comfortable sharing; the act of providing eco-information to the buyer will result in the supplier becoming more aware of the environmental impact their products have. Initially, it is expected that partners with long term trust based relationships will be most forthcoming in terms of sharing eco-information; with the practice filtering through the whole supply network as each member requests eco-information from members of their own supply chain. In addition to trust, it is also important to ensure that there are contracts in place that outline the terms and conditions surrounding the use of the portal; terms and conditions that create win-win scenarios for all participants. As more

and more firms within an industry adopt the G.EN.ESI platform, it could provide a consistent method of sharing eco-information resulting in the formation of an industry wide eco-information sharing standard.

7 CONCLUSIONS AND MOVING FORWARD

During this early stage in the project, the main aim was to gain a deep understanding of the scenarios in which the portal would be used, to ensure that the portal design would fit as best as possible with the strategies implemented by the users, as well as to understand any other issues surrounding the use of the portal from the perspective of both initiators and participators. However, moving forward, it is important to take into consideration, and not to underestimate, the technology required to create true buyer-supplier collaboration because compared to more traditional EDI and XML information exchanges, portals require a significant investment from the perspective of the supplier (Keifer, 2009). The main costs encountered by suppliers include supporting technology and infrastructure, and increased work load relating to acquisition and distribution of eco-information; while buyers would be faced with the cost of implementing and possibly maintaining the web portal. Therefore, the option of software as a service, whereby applications are hosted by vendors, needs to be explored as it offers an option where the need to invest in elaborate in-house systems and install updates is eliminated, making it easier for companies to adjust to any changes.

Expanding and moving on from the work carried out so far, and with the gained insight, future research will be conducted to support the formulation of an appropriate detailed design brief for the portal that covers both technical and functional requirements. This will be done by:

- Conducting a survey across a range of industries to gain a better understanding of the issues surrounding eco-information sharing and to test the concept of the G.EN.ESI platform and portal in industry outside of the G.EN.ESI project industrial partners.
- Carrying out more case studies on the G.EN.ESI project industrial partners and use the information gained to select the most suitable scenario for the portal to be built around.
- Using the extra insight gained, create a detailed brief for the portal that covers both technical and functional requirements. It is this brief that will be used in the construction of a detailed specification that will underpin portal that will be constructed.

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