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Sustainable Product Service Systems in Small and Medium Enterprises (SMEs): Opportunities in the Leather Manufacturing Industry

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Abstract: This paper presents an approach to identify opportunities to develop sustainable Product Service Systems (PSS) involving Small and Medium Enterprises (SMEs). The purpose of the research is to build understanding of how the integration of product and service design and the use of Information and Communication Technologies (ICT) can contribute to identify opportunities to develop sustainable PSS involving SMEs. In order to develop the approach, research with 16 Colombian Manufacturing SMEs was carried out. A reference model and four generic types of PSS according to the relationships between product and service design and ICT are used to analyse the data. Finally, the possibility of extending the approach into a general framework to work with other industries is discussed.

Keywords: design for sustainability; Product Service Systems; ICT; SME; design; green operations; organizational transformation

1. Introduction

Sustainable business development is a relatively new area and its implementation, especially in Small and Medium Enterprises (SMEs), is limited. Van Hemel and Cramer [1] highlight that a lack of knowledge, awareness and investment are barriers for moving towards sustainable practices and more

responsible business in SMEs. Moreover, Ciliberti *et al.* [2] include lack of infrastructure, poor communication channels between stakeholders, low savings rate and lack of mentorship as additional problems in developing economies. Therefore alternatives to support the strategic development of sustainable SMEs are needed. Product Service Systems (PSS) moving the business focus away from producing and selling physical products to offering systems of services and products to satisfy the user needs in innovative ways is one alternative approach [3]. The literature shows that if the system is designed to be sustainable benefits can arise such as dematerialization, better consumption patterns through innovative scenarios of use, new market opportunities, more efficient use of resources and cost savings [4,5]. However some of the barriers for developing sustainable operations in SMEs are also barriers to developing sustainable PSS. More efficient firms with higher innovation capacity, flexible operations and better communications skills are part of the benefits of a sustainable PSS but are also part of the competences required for PSS.

However, the rapid evolution of Information and Communications Technologies (ICT) could give SMEs the competences required to develop sustainable PSS and transform them into sustainable businesses. Though research into the relationship between ICT and sustainable development is very new, when ICT are oriented to build sustainable business there are key areas of opportunity and benefits, these include development of smart products, improved stakeholders communication, dematerialisation, increased social inclusiveness and consumer empowerment [6–9]. Despite the potential of using ICT and developing sustainable PSS little is known about the conditions needed to enable this integration. Therefore the main aim of this research is to investigate how product and service design and ICT can be integrated to create opportunities for PSS development in SMEs.

2. Theoretical Background

2.1. Product Service Systems (PSS)

According to Manzini and Vezzoli [3] a PSS is a strategic decision to move from designing and selling physical products to designing and selling systems of products and services that together can satisfy the user needs. It demands high levels of innovation and the capacity to change structural aspects of the organisation [10–12]. However a PSS can represent for the producer a better strategic position closer to customers and for clients more flexible and convenient offers. Overall PSS could bring environmental benefits related to dematerialisation, reduction of material flow and energy consumption, longer product life cycles, less waste and more efficient use of products [4,11]. Additionally, social benefits associated with the creation of collaborative networks, more diverse markets, awareness of the stakeholder's roles and access for poor people to basic services through communal systems have been identified [5,13]. Finally in economic terms the benefits are related to new market opportunities, increased competitiveness, more efficient operations and strong innovation focus [5].

Between the possible combinations of products and services and the purposes of a PSS different authors have mentioned three main types: product oriented, use oriented and result oriented [4,14,15]. Product oriented PSS where the main aspect of the offer is a product complemented with a set of services and where in general the ownership of the product remains with the customer, Use oriented

PSS where the product is the property of the producer and the customer pay for a specific use of the product and services of the system. It implies generally a use for a determined period of time or service units. Finally Result oriented PSS where the producer owns the product and there is an accorded result which the customer pays for. In this case the products and services that the producer uses to produce the result are not the main issue, the principal point is to achieve and deliver the predefined result [14].

Despite the potential benefits there are also barriers and difficulties identified to deploy these kinds of systems [4,14,15]. Mont [16] mentions for example organisational resistance, problems of balancing environmental goals with customer satisfaction, prevention of diversification, public acceptance, relationships with other stakeholders and lack of demand for these systems. Some of these barriers have to do with the balance between the change in the ownership of the offer and the level of customer satisfaction. That balance has a strong relation to how products and services are designed and integrated into the system. According to Creusen [17] one main issue for further research in PSS is the consistence and mutual support that products and service should have in a PSS. It means designing products and services that work together to satisfy the customer without producing rebound effects that erode the potential environmental and social benefits or the economical attractiveness.

These barriers mentioned by Mont [16] and the challenges presented by Creusen [17] could be part of the reason why the number of examples of PSS is still low. According to BCSD-UK [18] the concept of PSS is not totally new, but it has not achieved momentum in its development. It means that despite the benefits, the fact that service economies are stronger, technology is changing rapidly allowing more complex offers and that there is a general awareness of the environment, there is not a clear trend towards sustainable PSS development.

Additionally there are not many methodologies to develop PSS. Van Halen *et al.* [19] present MEPSS (Methodology for Product Service Systems) that, due to its structure, is more oriented to medium and large firms than to small companies. They claim the methodology is suitable to be applied in all kinds of firms but competences required such as multidisciplinary team building and the ability to engage other stakeholders make the process difficult for small businesses, especially for small business in developing economies. Ciliberti *et al.* [2] say for example that the lack of mentorship and skills transfer, the lack of support networks, poor infrastructure, low savings rate and the difficulties accessing financial capital are common weaknesses in SMEs in developing economies. Previously Van Hemel and Cramer [1] had mentioned lack of awareness of environmental legislation and social impacts derived from industrial activity as obstacles to develop sustainable business in SMEs. These weaknesses make the application of methodologies such as MEPSS difficult for SMEs. Taking into account the lack of instruction oriented to SMEs in developing economies to develop these systems, the approach explored in this paper investigates the integration of product and service design with the use of ICT as a possible path to create opportunities to develop sustainable PSS in these firms.

2.2. Design in SMEs

According to March-Chorda *et al.* [20] and Mascle and Zao [21] successful product development in time and level of innovation is a determinant factor on firm's competitiveness. Up to 80% of the costs associated with product development, manufacturing and use are established during the design stage [21]. In terms of business strategy Borja de Mozota and Kim highlight that managers should

value design skills as “rare, inimitable and non-substitutable” ([22]: p. 68). They consider design as a core competence that gives superior value to customers and is an organisational asset. Moultrie *et al.* [23] present a series of arguments why design is an important competence particularly for SMEs. They mention for example how product design can give company differentiation, can encourage innovative aptitudes, can contribute to strength commercial relationships and communicate value to customers. Despite these benefits Moultrie *et al.* [23] also highlight how product design is often undervalued in small companies and its potential benefits lost. This marginalization of design is manifested by unclear design practices, unskilled design professionals doing design tasks and managerial resistance.

Finally in relation to the development of sustainable PSS Manzini and Vezzoli summarize the role of design with the term strategic design “it is intended a design activity aiming at an integrated system of products, services and communication, based on new forms of organisation, based on the roles reconfiguration of different companies, clients and other stakeholders; a design developing a strategy linking long term goals with existing trends and based on new systems of values and new market opportunities” ([3]: p. 856). This vision is shared by Esslinger [24] who mentions the important role of designers to articulate customer needs and aspirations with technology and innovation toward sustainable solutions. In this context the challenge presented by Creusen [17] can be approached by understanding what aspects of the design process in SMEs and of the resulting products can be modified in order to contribute to develop sustainable PSS. The mechanism being considered to produce these modifications in the design process and in the resulting products in SMEs is the adoption and use of ICT.

2.3. Design and ICT in PSS

The relationship between ICT and PSS has been mentioned previously in the literature. Mont [4] highlights the potential of ICT to contribute to achieve organisational efficiency and communication skills required to develop a PSS. Roy [10] defines that relationship in terms of the possibilities that new technologies can bring to make PSS more practical and economical viable. Finally Manzini and Vezzoli [3], Tukker and Tischner [11] and Mont [25] discuss how ICT can help to build measures and performance indicators for these systems. Despite these relationships having implications for product and service design there is no existing work specifically oriented to understand in detail this integration. For these reasons as part of the theoretical background an analysis was undertaken of 36 examples of PSS aimed to explain the possible relationships between product and service design and the use of ICT in a PSS. These relationships identified were used in the analysis of the research with 16 Leather Manufacturing Colombian SMEs.

The criteria used to select these examples, some of them referenced earlier, were that the systems were developed with commercial interest, that they were currently present in the market, and that the companies or organizations who develop the PSS described the systems including environmental or social benefits or both. A representative sample of cases was not selected and the analysis was not used as a classification method. The examples came from a diverse set of industries and from small, medium and large companies (see Appendix 1). Each example was analysed looking at the description of the systems given by the developers, how the use of ICT and their product and service design were linked to each other and the main value created by the system. Four different relationships were

identified: Design Based, ICT Based, Design and ICT as Supporters, Integrated Design and ICT. These groups characterised the relationship between ICT and product and service design in a PSS and not the purpose of the PSS as in the classification by Tukker [14]. In Figure 1 examples of each relationship are presented.

Figure 1. Four types of relationships between Design and Information and Communication Technologies (ICT) in different Product Service Systems (PSS) [26–33].



Design Based: PSS where products and services are designed specifically to fulfil the purpose of the PSS. ICT play mainly a commercial role establishing relationships with customers and as a means

to deliver the offer. Products and services in this kind of PSS could demand the use of innovative materials or special production processes. Loop by the Yard [26] and Heim Housing System [27] are PSS in this group.

ICT Based: ICT articulate the system and enables its existence. In this kind of relationship ICT can be embedded in the products but demand just small modifications to the product design. Examples can be ZIPCAR [28] and Call a Bike [29].

Design and ICT as Supporters: Both product and service design and ICT are supporters of the system. The main value of the system is not directly attached to them but they are part of the offer. It means systems where products could be generic and not designed specifically for the PSS and where ICT are used generally only for commercial purposes. Pallet Renew [30] and Farm Fresh to You [31] are examples of this kind of relationship in a PSS.

Integrated Design and ICT: There is strong relationship between ICT and product and service design in the PSS. Here products are designed exclusively for the PSS and ICT articulate the system connecting customers to products. The flow of information between customers and products through using ICT is fundamental for the system. Examples of this integration could be Motiva [32] and Pay-per-Wash [33].

3. Approach Adopted in the Research

From the conclusions of the literature review the research was oriented to investigate how the integration of product and service design and the use of ICT can contribute to generate opportunities to develop sustainable PSS in SMEs. This was explored first through a scoping study with 38 Colombian SMEs using an exploratory survey, and then with detailed study involving a second group of 16 Colombian Manufacturing SMEs.

A reference model based on the literature review and the results of the scoping study was developed as a methodological tool for the research. In the next section a brief explanation of the reference model is presented illustrating how it was developed and what its main purpose was during the research.

3.1. Development of the Reference Model

Taking into account the previous considerations a reference model was built to explore the elements relevant to develop the research and to lead the investigation. The first version of the model was developed after the initial research proposal. In this first version only ICT, Design, Sustainable Business Development and PSS appeared as the main areas of interest. There were also some relationships suggested but without much detail about the interactions between the components because these interactions were to be explored during the research.

During the literature review the elements previously included in the model were enriched and the relationships between them were better defined building a more complex structure. At that point of the research the justification of the elements in the model became more evident. ICT were included due to their potential as a transforming agent and engine of organisational change [34]. Davenport and James [35] mention particularly the capacity of ICT to transform the product development process within an organization. Other authors such as Kotelnikov [36] and the OECD [34] illustrate how in the case of SMEs the adoption and use of ICT increases competitiveness, reduces transactions

cost, increases speed and reliability of operations, improves communication between stakeholders and relationships with customers. More specifically, ICT can also contribute to developing sustainable business. According to Ryan [6], Pamlin [7] and Cohen [37] smart green products, servitization, green buying, e-commerce, virtualization and energy efficiency are some of the contributions from ICT to develop sustainable business.

In terms of ICT and PSS the relationships between them were investigated in the literature. Despite some suggestions from a number of authors [3,4,10,11] a clear methodology to enable the integration of these concepts was not found. In this sense ICT and PSS were not directly connected in the model. Product and service design as a process was included to make this connection. The inclusion of the design process to enable this integration is a key contribution. It was done taking into consideration the importance of design in developing PSS [17] and the potential that design has to influence the sustainable performance of final products, services and systems.

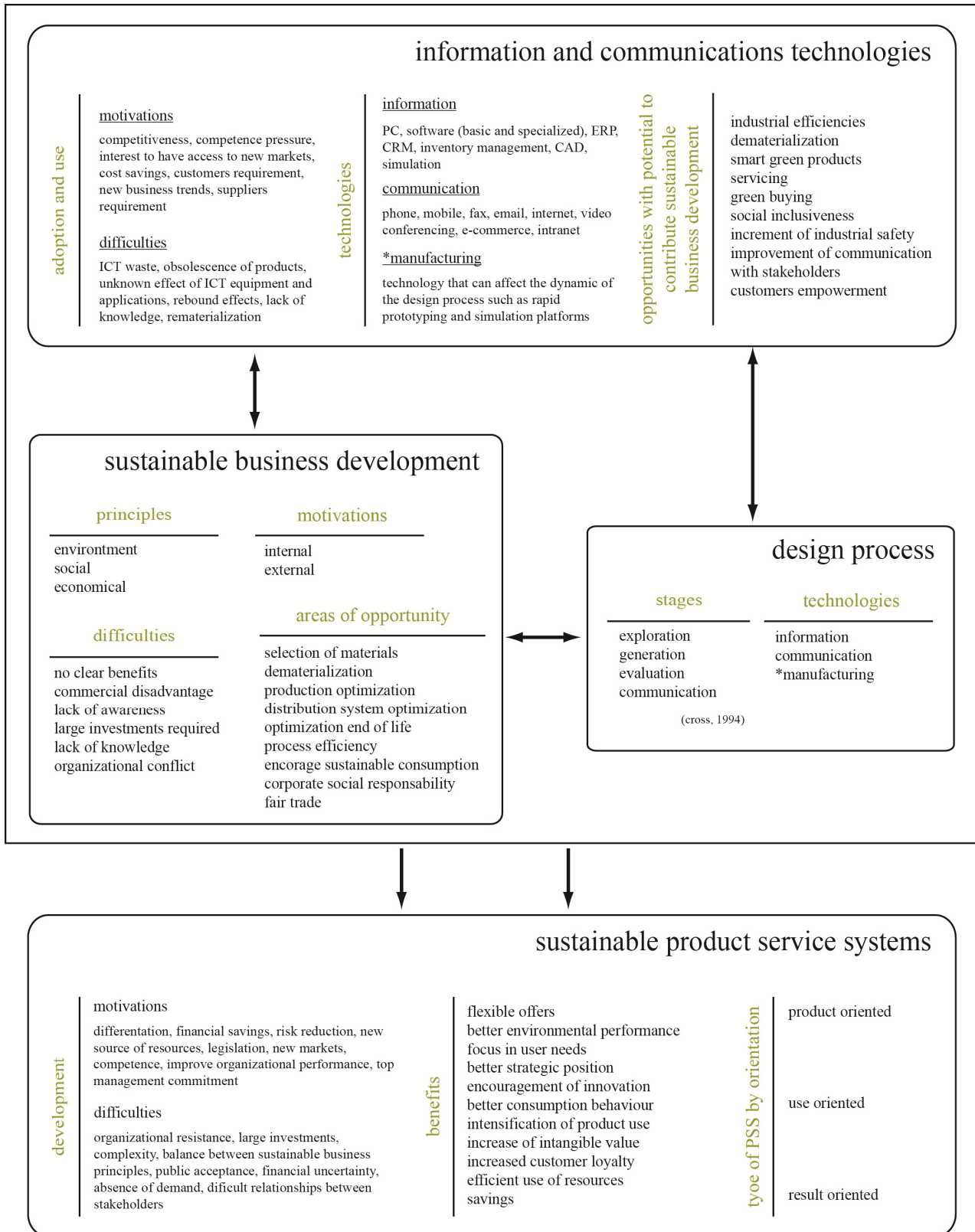
This second version of the reference model was refined as a result of a scoping study carried out with 38 SMEs from different industrial sectors. These companies were selected in cooperation with the Colombian Ministry of ICT. The study explored the perception of these firms about PSS, sustainable business development, use of ICT and the role of the design process. During the analysis of the results of this scoping study and with the literature review updated constantly a gap was found in the model. The connection between ICT and design was evident in different ways but not directly related to the development of PSS. In this sense one of the main results of the analysis was that it identified the need for a methodology to develop sustainable PSS based on the contribution of the changes that ICT can produce in the product and service design process. Finally, the reference model presented in Figure 2 and modified after the scoping study was used to lead a series of semi-structured interviews with a second group of Colombian Manufacturing SMEs all of them from the Leather Industry in the main study. This second group of SMEs was again selected in cooperation with the Colombian Ministry of ICT.

It was decided to work with Colombian SMEs for the scoping and main study because of an initial interest to develop the research with SMEs in a developing economy. The main reason was due to a lack of existing research in the field involving companies from developing economies particularly Latin-America. Additionally, and as part of the requirements to develop the research, it was necessary to work with SMEs with at least a basic knowledge of ICT. Thanks to a previously established relationship with the Colombian Ministry of ICT work with Colombian SMEs was considered to be the most suitable option.

In terms of the industry selected for the main study, three criteria were used to make the selection. First, an industry where it would be possible to have at least a group of 10 SMEs all of them previously involved in the same ICT adoption project. Second, to work with a manufacturing industry with an important representation in the national economy and, and finally an industry which strategic vision favouring areas such as design, technology and sustainability. In any case the potential to develop sustainable PSS was not part of the criteria to select the industry because one of the objectives of the research was to find if the approach used in the research was suitable to identify opportunities to develop sustainable PSS involving manufacturing SMEs. With these criteria in mind and through the cooperation scheme with the Colombian Ministry of ICT the Leather Industry was considered to be the

best option and a group of 16 SMEs agreed to participate. In the next section the main findings from this case study are presented.

Figure 2. Reference model to lead the research.



4. Main Study Colombian Leather Manufacturing SMEs

In cooperation with the Colombian Ministry of ICT SMEs from the leather industry, mainly footwear factories were contacted. Semi-structured interviews were carried out in 16 companies with the owners or general managers to explore the role of the product design process in relation to the subjects identified in the reference model. These SMEs were selected to insure they were using ICT in their daily activities as one main element in the reference model and the starting point for the research. Additionally it was important to work with firms that had been through a similar process of adoption and use of ICT. This process as an organisational experience allows comparisons to be made between the firms. In Table 1 the main features of each SME are presented.

Table 1. Main features of the Small and Medium Enterprises (SMEs) involved in the study.

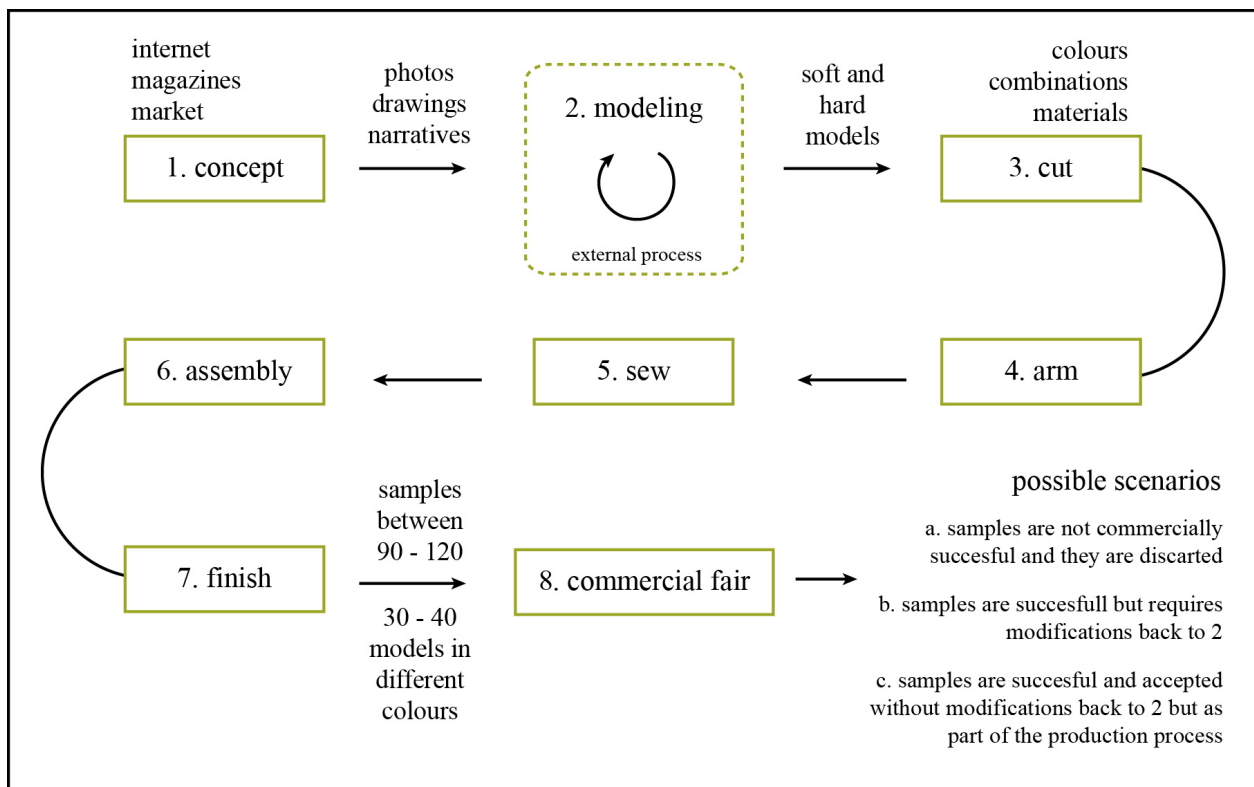
Company		Type of company		Industry	Interviews
ID	Name (Tag)	Number of employees	Classification	Main product	Person interviewed
1	Company A	15	Small	Footwear	Owner
2	Company B	30	Small	Footwear	Owner
3	Company C	20	Small	Footwear	Owner
4	Company D	25	Small	Footwear	General Manager
5	Company E	20	Small	Footwear	Owner
6	Company F	40	Small	Footwear	Owner
7	Company G	19	Small	Footwear	Owner
8	Company H	50	Small	Footwear	Owner
9	Company I	25 (average)	Small	Footwear	Manager's Assistant
10	Company J	21	Small	Footwear	General Manager
11	Company K	9	Micro	Accessories	Owner
12	Company L	20 (average)	Small	Footwear	Owner
13	Company M	<10	Micro	Clothes	Owner
14	Company N	15 (average)	Small	Footwear	Owner
15	Company O	<10	Micro	Footwear	Owner
16	Company P	15 (average)	Small	Footwear	Owner

In terms of the industry, the leather sector in Colombia is a large employer with companies located in nine departments of the country. It is estimated that this sector employs almost 19,000 people around the country [38]. In 2004 the Colombian government defined the strategic vision of this industry. This vision was based on the optimization of the activities of the sector through building supply chain collaboration, encouraging cleaner production and fulfilment of environmental legislation, supporting the internationalization of the sector offering services to complement the sales of the sector, and finally investing to improve design and quality of the final products [38]. This strategic vision was relevant in selecting the leather industry as the focus for the main study.

A large part of each interview was dedicated to understanding the product design process followed by these firms. Just a few SMEs described their product design as a process following certain logic, the majority recognised activities done to fabricate the shoes and embedded some stages of decisions about the design of their products. This attitude is aligned with the analysis presented by Moultrie *et al.* [23] where design tasks in SMEs are often executed by people who have not been trained as designers usually production engineers that usually locate design activities into the production process.

In general terms the design process followed by all the SMEs interviewed is very similar. This generic process is presented in Figure 3. The process starts by looking for ideas to design a collection, this search mainly goes on through the internet looking for products (footwear) from other companies in other countries, the ones mentioned were Italy, Brazil and the United States. Few companies mentioned complementing this search by looking for initial ideas in other means such as magazines or working with suppliers' advice and sales feedback.

Figure 3. General design process of footwear production in SMEs in Colombia.



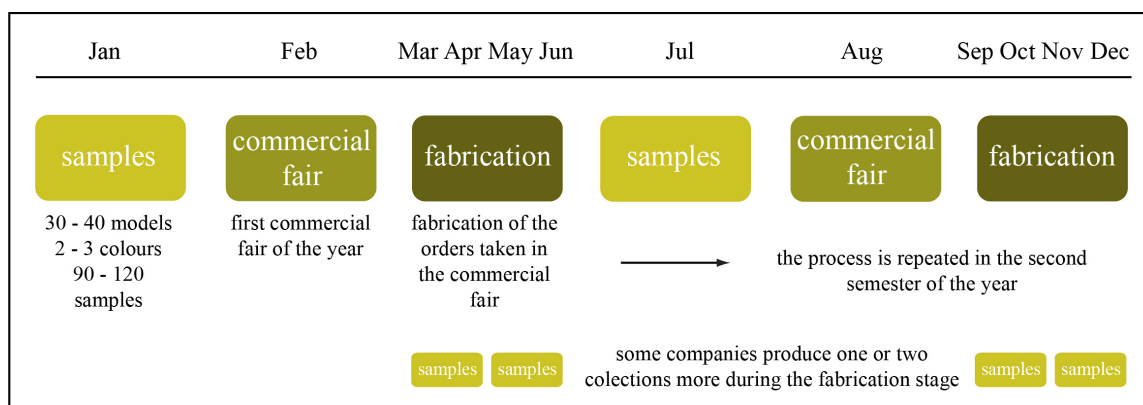
The main output of this stage of the process for the majority of the companies are photos with small modifications to accessories, clasps and heels but keeping a large proportion of the initial design. Just three companies described this first stage as doing drawings and sketches of the product design from original ideas. These photos or sketches are delivered to an external party, generally one person who creates the models. Just two firms undertook the modelling process themselves. This stage of the design process consists of translating the images of the product into a model that will be the basis of cutting and sewing the final product. This modelling is an iterative process between the person in charge of design in the SMEs and the model maker.

The output of the modelling stage is a soft model in cardboard that is then copied onto metal sheets. This activity is done within the SMEs and it is considered part of the modelling process. The hard model (metal) is then used to cut the pieces of what will be the final shoe. At this stage colours and combinations of materials are selected to produce the samples. These decisions are the last taken about the design of the product until the commercial fair where the samples are assessed by the clients and could be accepted without changes, accepted with modifications that requires the fabrication of new samples, or rejected. On average each of the SMEs interviewed designs thirty different models for each

commercial fair and using two or three different colours and combinations they present approximately 120–140 samples at the fair.

All the SMEs work with the same process and their schedule is determined by the commercial fairs in the country. The dynamic of one year of work for these SMEs is presented in Figure 4.

Figure 4. Design and production dynamic of footwear SMEs in Colombia.



4.1. Analysis of the Design Process

From the descriptions of the design activities in the SMEs the first perception was that the product design is limited to products already on the market. The owners and general managers interviewed mentioned the importance of designing and producing shoes that are consistent with the fashion trends of the country and even with the fashion trends of the cities. In this sense the majority of the firms keep the same line of design, transforming products already on the market in other countries into national trends changing colours, accessories and materials. It means following trends more than working to create new ones.

“My boss, what she does is to search for designs on the computer. Then if she likes a particular design in order to make it new she gives it a personal touch. She changes something in it, if it has three straps, then she maybe will put two and one crossed”, Explanation of the beginning of the design process. Manager Assistant Company I.

Another characteristic of the design process is that it is mainly a manual process that in some cases could even be described as a handcrafted process. Because of this the modelling stage that is done by an external model maker is considered fundamental and relies on the experience of the model maker. A couple of companies claimed to have used some design software for the modelling but this failed because of the lack of precision and inflexible results obtained. Model makers are people specialised in translating photos and sketches of finished products modified by the SMEs into patterns that allow the samples to be produced for the commercial fairs. Model makers working with a pantograph are able to reproduce the patterns and scale them to a specific shoe size in which the samples are produced.

“The designer, the model maker make the majority of it (the model) by hand, I think 80% is very manual, very handcrafted”, Explanation of the design process, Owner Company A.

The design process relies mainly on the owners of the SMEs. They search for initial ideas for the collection and then they decide colours, combinations and materials. This responsibility makes them very close to the model makers, however it appears that the modelling process is a black box and

SMEs depend largely on this external process. They even describe the relationship with the model maker in terms of time as working together and attributes such as honesty being important. The fact that the design process relies on the owners of the company makes it very closed in some companies where only a few people can intervene.

“I take the photo to the model maker that I have had for several years, then I tell him what I need, then he makes it, he designs the shoe in agreement.”, Explanation of the relationship with the model maker, Owner Company A.

In summary, the identified design process in the group of footwear SMEs in Colombia reflects a very traditional way to design and develop their products. Despite the adoption and use of ICT, these technologies have not been embedded into the design process except for the initial search for ideas through web sites from other producers. This use is not necessarily the most positive for the design process. A lack of knowledge of possible technologies to design the products was identified such as software for sketching, developing the models or producing different prototypes (colours, combinations, materials), also communication technologies to develop collaborative design between the SMEs and the model makers, or between the SMEs and clients during and after the commercial fairs. This lack of knowledge is made worse by a resistance to using technology resulting from bad experiences and the results in comparison with the traditional methods (model makers using pantograph).

The dynamic of the SMEs shows a high resource demanding industry. SMEs produce on average 120–140 samples that they present at the commercial fairs and only 10–20 of these samples are sold to be produced on a large scale. The other 100–120 samples are rejected and usually disposed of. This behaviour generates a waste of resources and unnecessary efforts.

4.2. Opportunities Identified to Develop Sustainable PSS in the Leather Industry

The next step in the main study was to identify areas of opportunity in relation to some of the elements included in the reference model. Then these opportunities were expressed in terms of sustainable PSS according to the types of relationships between product and service design and the use of ICT. Two of the systems proposed were oriented to an individual development in the SMEs and the other two were systems involving more stakeholders from the leather industry. The systems proposed were:

Design and ICT integrated system based on the virtualization of the production and evaluation of samples. SMEs could be transformed from designing and selling footwear to offering a system of design and production capacity to their current clients and to new ones. Basically SMEs could develop a system supported by the ICT to change the design and production of samples. This system could allow them to produce virtual samples encouraging clients to evaluate the models over the system and not through physical products. This type of system can enrich the evaluation process giving the opportunity to use more colours, materials and combinations without the need to produce physical samples that are waste time and resources. This system could be developed for the current market or even could open up new markets oriented to final consumers where design and production are services articulated and presented to the clients using ICT. It could be a sustainable PSS taking into account the benefits associated with the reduction of resources required to produce the samples, better

production scheduling in the SMEs, development of new markets and a different way to approach the business.

Design and ICT as system supporters based on the recovery, repair and resale of products.

This system is thought to take advantage of the knowledge, production capacity and workforce of the SMEs to offer a system of recovery, repair and resale of products after an initial life cycle. Shoes in general become waste not because of damage to the main leather part of the shoes; usually the soles and the heels wear out first. These parts of the shoes are replaceable, but many users don't bother or don't know how to repair them. Even if there are shoe repair shops the business model is traditional in the sense that the user must arrange the repair and the proportion of shoes repaired is small. The system proposed is on a larger scale and with different incentives. SMEs could offer to rebuy old shoes for part of the original price or as percentage of the price of a new pair of shoes. Customers could in this way save some money and get the benefit of a new pair of shoes consistent with the current fashion trends. On the other hand SMEs could develop new markets of second hand shoes that could be repaired and resold saving the majority of the original materials. The system could be a sustainable PSS in that the traditional business of production and sale of shoes is changed into a new and innovative scheme. The main benefits are represented by the reduction of resources used, the development of new markets, the extension of the life cycles of products and the better utilization of the production capacity.

ICT based system focused on the optimization of the production process with satellites.

Currently satellites work in a temporal basis with the SMEs and while at some times of the year there is not enough work in others there are not enough people to satisfy production demand. A system could be developed supported by ICT to generate a more efficient schedule of work for the satellites and more flexible production capacity for the SMEs. This system could help SMEs to have better control over the outsourced production tasks and manage standards of design and production with the same level of quality as large orders. The main service of the system will be the production capacity of the satellites. It could be a sustainable PSS if a reduction of resources is achieved through the system thanks to better information exchange avoiding reprocesses. It could also have social benefits creating more regular employment in the industry, avoiding informality and satisfying international markets.

Design and ICT integrated system oriented to integrate technologies in the design process into a collaborative platform between SMEs and model makers. Design can become the main service of a system that connects SMEs with model makers. In this system the objective will be to support the product and service design process by the use of ICT. There are already technological solutions for the design of footwear on the market that could help to make this relationship more efficient and robust. If both parties involved in the product design process support their work with the use of technologies they could share information and interact in a more dynamic way. For model makers this kind of system could represent a change in their business from the sale of models to sale of design as a service. For the SMEs it could represent an improvement in the traceability of the design process, more control over the process and the possibility to integrate the outputs of the product design process with other systems of information. This system could be a sustainable PSS with benefits in terms of reduction of iterations in product development, production of more flexible designs, closer cooperation between SMEs and model makers and the reduction of intermediary physical models.

5. Discussion

The main contribution of the approach developed is to enable the development of sustainable PSS through the use of design and ICT in an integrated way limiting the possibilities to four generic systems that could make the initial stage of searching for opportunities more productive and guided. The approach suggests relating the elements identified in the reference model with the four types of systems according to the relationships between product and service design and use of ICT as one way to identify opportunities to develop sustainable PSS involving SMEs. It is clear that these generic systems proposed overlap and between them there could be other possibilities. However the four types of systems are not prescriptive for SMEs but aim help them consider whether one of these combinations could be applied and adapted to their own situation making a transformation process less uncertain.

It is important to highlight that the approach is oriented to a diagnostic stage of an organizational intervention involving SMEs. The approach was developed to help organizations dedicated to supporting SMEs analyse the current situation within one or more SME in a specific industry and help them to move towards sustainable PSS as one approach to becoming sustainable and competitive. Any transformation is a process that requires time, resources and support, this approach is the first step to define the possible route, after this support organizations and SMEs have to work together to achieve the transformation and the potential benefits.

6. Conclusions

Considering the integration between product and service design and the use of ICT to develop sustainable PSS is an innovative and unexplored area of research. The analysis of the product design processes of the 16 Colombian SMEs showed a complex situation with internal and external actors involved even in these small companies. Additionally, the results show a lack of connection in strategic terms between the adoption and use of technologies with the other areas analyzed such as design and sustainability. This lack of consistency between the adoption of technologies and other areas and processes in the organization is not part of this research but it is a big concern that has to be taken into account in a future framework as part of the risk assessment of the transformation process.

The analysis of the results of the main study from a sustainable perspective and using the concept of sustainable PSS was useful to define an initial set of proposals to improve the performance of the SMEs but also to affect the general behaviour of the industry. One of the barriers identified during the development of the main study was a general lack of awareness about what a sustainable operation is. This lack of awareness is reflected in few actions taken by the SMEs in the environmental and social field. It is an industry very oriented to economic incentives and with tight financial budgets to introduce new projects in areas that are not directly related to production and that do not show savings in short term. These obstacles can be overcome if the inclusion of concepts to develop sustainable PSS is done through a third party such as Universities, Consultancies, Government Agencies or any organization with the capacity to support organizational projects in SMEs. This alternative could help to train companies in areas such as sustainability, strategy, design and technologies in a structured way following the approach described here.

Future work will be oriented towards developing a structure to link the elements in the reference model with the types of systems according to the relationships between product and service design and use of ICT to develop sustainable PSS in SMEs. The objective is that this analysis could be applied in different industries and different types of SMEs. The study of the Colombian leather industry shows the logic of the approach and the potential results, but a general framework is needed in order to use that logic in other situations.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. Van Hemel, C.; Cramer, J. Barriers and stimuli for ecodesign in SMEs. *J. Clean. Prod.* **2002**, *10*, 439–453.
2. Ciliberti, F. Pontrandolfo, P.; Scozzi, B. Investigating corporate social responsibility in supply chains: A SME perspective. *J. Clean. Prod.* **2008**, *16*, 1579–1588.
3. Manzini, E.; Vezzoli, C. A strategic approach to develop sustainable product service systems: Examples taken from the “environmentally friendly innovation” Italian prize. *J. Clean. Prod.* **2003**, *11*, 851–857.
4. Mont, O. Clarifying the concept of product-service system. *J. Clean. Prod.* **2002**, *10*, 237–245.
5. Omann, I. *A Multicriteria Tool for Evaluating the Impacts of Product Service Systems on Sustainable Development: A Multi-Criteria Evaluation for Austrian Companies*; Working paper No. 5; Sustainable Europe Research Institute (SERI): Vienna, Austria, 2007.
6. Ryan, C. *Digital Eco-Sense: Sustainability and ICT—A New Terrain for Innovation*; RMIT University: Carlton, Vic., Australia, 2004; Lab3000.
7. Pamlin, D. A Report about ICT and sustainability. In *Sustainability at the Speed of Light: Opportunities and Challenges for Tomorrow's Society*; Pamlin, D., Ed.; WWF Sweden: Stockholm, Sweden, 2002; pp. 6–11.
8. Erdmann, L.; Hilty, L.; Goodman, J.; Arnfalk, P. The Future Impact of ICTs on Environmental; Sustainability Technical Report; 2004; EUR 21384.
9. Langrock, T.; Ott, H.; Dworak, T. Environmental friendly ICT-products. In *Sustainability at the Speed of Light: Opportunities and Challenges for Tomorrow's Society*; Pamlin, D., Ed.; WWF Sweden: Stockholm, Sweden, 2002; pp. 96–109.
10. Roy, R. Sustainable product-service systems. *Futures* **2000**, *32*, 289–299.

11. Tukker, A.; Tischner, U. *New Business for Old Europe: Product-Service Development as a Means to Enhance Competitiveness and Eco-Efficiency*; Final report of SUSPRONET December 2004. Available online: http://www.suspronet.org/fs_reports.htm (accessed on 12 May 2011).
12. Maxwell, D.; van der Vorst, R. Developing sustainable products and services. *J. Clean. Prod.* **2003**, *11*, 883–895.
13. Ness, D. Sustainable Product Service Systems: Potential to deliver business and social benefits with less resource use. In *Greening the Business and Making Environment a Business Opportunity*; IGI Global: Hershey, PA, USA, 2007.
14. Tukker, A. Eight types of Product-Service System: Eight ways to sustainability? Experiences from SusProNet. *Bus. Strategy Environ.* **2004**, *13*, 246–260.
15. Cook, M. Bhamra, T.; Lemon, M. The transfer and application of Product Service Systems: From academia to UK manufacturing firms. *J. Clean. Prod.* **2006**, *14*, 1455–1465.
16. Mont, O. Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. *J. Sustain. Prod. Des.* **2002**, *2*, 89–103.
17. Creusen, M.E.H. Research opportunities related to consumer response to product design. *J. Prod. Innov. Manag.* **2011**, *28*, 405–408.
18. BCSD-UK. *Smart Business: Sustainable Solutions for Changing Times*; Report of the UK Government's Business Taskforce on Sustainable Consumption and Production; Department of Business, Enterprise and Regulatory Reform: London, UK, 2008.
19. Van Halen, C. Vezzoli, C.; Wimmer, R. *Methodology for Product Service Systems Innovation*; Koninklijke Van Gorcum: Assen, The Netherlands, 2005.
20. March-Chorda, I. Gunasekaran, A.; Lloria-Aramburo, B. Product development process in Spanish SMEs: An empirical research. *Technovation* **2002**, *22*, 301–312.
21. Mascle, C.; Zhao, H. P. Integrating environmental consciousness in product/process development based on life cycle thinking. *Int. J. Prod. Econ.* **2008**, *112*, 5–17.
22. Borja de Mozota, B.; Kim, B.Y. Managing design as a core competency: Lessons from Korea. *Des. Manag. Rev.* **2009**, *20*, 66–76.
23. Moultrie, J. Clarkson, J.; Probert, D. Development of a design audit tool for SMEs. *J. Prod. Innov. Manag.* **2007**, *24*, 335–368.
24. Esslinger, H. Sustainable design: Beyond the innovation-driven business model. *J. Prod. Innov. Manag.* **2011**, *28*, 401–404.
25. Mont, O. Product-Service Systems: Reviewing achievements and refining the research agenda. *J. Clean. Prod.* **2006**, *14*, 1451–1454.
26. MIO Company LLC Loop. Available online: <http://mioculture.com/loop-by-the-yard.html> (accessed on 12 May 2011).
27. SEKISUI CHEMICAL CO. LTD Reuse System. Available online: <http://www.sekisuicheimical.com/about/division/housing/reuse.html> (accessed on 12 May 2011).
28. Zipcar. Available online: <http://www.zipcar.com/> (accessed on 12 May 2011).
29. DB Rent GmbH Call a bike. Available online: <http://www.callabike-interaktiv.de/> (accessed on 12 May 2011).
30. Pallet Renew. Available online: <http://www.palletrenew.com/> (accessed on 12 May 2011).

31. Farm Fresh To You Farm Fresh To You. Available online: <http://www.farmfreshtoyou.com/index.php> (accessed on 10 June 2011).
32. Koninklijke Philips Electronics N.V. Motiva. Available online: http://www.healthcare.philips.com/gb_en/products/telehealth/products/motiva.wpd (accessed on 10 June 2011).
33. Electrolux New & Future Business Electrolux offers 7,000 households free washing machines. Available online: <http://group.electrolux.com/en/electrolux-offers-7000-households-free-washing-machines-1885/> (accessed on 10 June 2011).
34. OECD Promoting entrepreneurship and innovative SMEs in a global economy: Towards a more responsible and inclusive globalisation. In *2nd Organisation for Economic Co-operation and Development Conference of Ministers Responsible for Small and Medium-Sized Enterprises (SMEs)*, Istanbul, Turkey, 3–5 June 2004.
35. Davenport, T.; James, S. *The New Industrial Engineering: Information Technology and Business Process Redesign*; Massachusetts Institute of Technology Sloan School of Management: Cambridge, MA, USA, 1990.
36. Kotelnikov, V. *Small and Medium Enterprises and ICT*; UNDP Asia-Pacific Development Information Programme, e-Primers for the Information Economy, Society and Polity; UNDP: Bangkok, Thailand, 2007. Available online: <http://www.apdip.net/publications/iespprimers/epriemer-sme.pdf> (accessed on 10 June 2011)
37. Cohen, N. E-Commerce and Enviroment. In *Sustainability at the Speed of Light: Opportunities and Challenges for Tomorrow's Society*; Dennis, Ed.; WWF Sweden: Stockholm, Sweden, 2002; pp. 64–75.
38. DNP. *Documento Sectorial Cadena Cuero, Calzado y Manufacturas*; Departamento Nacional de Planeacion Colombia: Bogotá, Columbia, 2007; p. 48.

Appendix 1: Examples of PSS analysed

No.	Name	Company	Website
1	Loop By The Yard	MIO Company, LLC	http://mioculture.com/loop-by-the-yard.html
2	ZIPCAR	Zipcar UK Ltd	http://www.zipcar.com/
3	City Car Club UK	City Car Club Limited	http://www.citycarclub.co.uk/
4	Heim System Housing	Sekisui Chemical	http://www.sekisuichemical.com/about/division/housing/reuse.html
5	Tool Lending Library	Berkeley Public Library	http://berkeleypubliclibrary.org/about_the_library/neighborhood_branches/tool_lending_library/index.php
6	ReEntry® 2.0	Interface	http://www.interfaceglobal.com/Sustainability/Sustainability-in-Action/Closing-the-Loop.aspx
7	AutoShare	Car Sharing Network Inc	http://www.autoshare.com/
8	Solar Community Centers	GreenStar	http://www.greenstar.org/
9	Xerox Document Services	Xerox	http://www.xerox.co.uk/consulting/
10	Software as a Service	OpenCrowd	http://clountaxonomy.opencrowd.com/taxonomy/software-as-a-service/
11	NorLux LED Light Systems	NorLux	http://www.norluxcorp.com/
12	Sick Sensor Technology Solutions	Sick	http://www.sick.com

Appendix 1. Cont.

13	Energyextra	Energyextra	http://www.energyextra.co.uk/index.html
14	Call a bike	DB Rent GmbH	http://www.callabike-interaktiv.de/
15	Liftshare	Liftshare.com Limited	http://www.liftshare.com/uk/
16	Farm Fresh To You	Farm Fresh to You	http://www.farmfreshtoyou.com/
17	Ashland Chemical Solutions	Ashland Inc	http://www.ashland.com/
18	Metal recycling operations	Cookson Group	http://www.cooksongroup.co.uk/cookson/pages/about
19	Mannington Flooring Solutions	Mannington Mills Inc.	http://www.mannington.com/Corporate/OurCompany.aspx
20	Odin	Odin Consumentenservice	http://www.odin.nl/
21	Ceiling 2 Ceiling	Armstrong	http://www.armstrong.com/commceilingsna/article63579.html
22	Green Genie Tools	Armstrong	http://www.armstrong.com/commceilingsna/article50807.html
23	Pay-per-Wash	Electrolux	http://group.electrolux.com/en/electrolux-offers-7000-households-free-washing-machines-1885/
24	Roppe Flooring Designer	Roppe Corporation, U.S.A	http://roppe.com/FDC/index.html
25	Gispen Furniture	Gispen	http://www.gispen.nl/nl/mvo/18-milieuwinst/
26	Koppert Biological Systems	Koppert BV	http://www.koppert.nl/bedrijf-biologische-gewasbescherming-natuurlijke-bestuiving/
27	Textile and Carpet Care	MilliCare	http://www.millicare.com/Pages/our-services/carpet-care.aspx
28	Mobility Car Sharing	Mobility Cooperative	http://www.mobility.ch/en/pub/index.cfm
29	Oce Printing for Professionals	Oce / Canon Group	http://www.oce.nl/
30	Spulmobil	Dekomueller	http://www.dekomueller.de/
31	OmniDiagnost Eleva	Philips	http://www.healthcare.philips.com/de_de/products/xray/products/fluoroscopy/omnidiaagnost/
32	Pallet Renew	Pallet Renew Inc	http://www.palletrenew.com/services.html
33	Statt Auto	STATTAUTO Munich	http://www.stattauto-muenchen.de/faltblatt_grundsatzliches.shtml
34	Wilkhahn	Wilkening + Hahne GmbH+Co.KG	http://www.wilkhahn.com/loadframes.html?/0_meta/_reddot/3091.htm
35	Castrol Complete CMS	Castrol Limited	http://www.castrol.com/castrol/sectiongenericarticle.do?categoryId=9018374&contentId=7033411
36	Motiva	Philips	http://www.healthcare.philips.com/de_de/products/telehealth/Products/motiva.wpd