Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 47 (2016) 430 – 435

www.elsevier.com/locate/procedia

Product-Service Systems across Life Cycle

Lifespan extension for environmental benefits: a new concept of products with several distinct usage phases

Tom Bauer[a]*, Guillaume Mandil[a], Élise Naveaux[b], Peggy Zwolinski[a]

[a]*Université Grenoble Alpes,G-SCOP laboratory, 46 av. Félix Viallet, Grenoble 38031 cedex 1, France*
[b]*CEA-Liten, 17 rue des Martyrs,Grenoble 38054 cedex 9 France*

* Corresponding author. Tel.: +33-476-825-124. *E-mail address:* tom.bauer@g-scop.eu

Abstract

End-of-Life (EoL) strategies, and especially products' lifespan extension, are becoming key issues for more and more manufacturers. Their implementations have to be done from the design stage and may be facilitated with design methodologies and guidelines. However, if a function of the system is no longer efficient enough during its use phase, in such a way that remanufacturing and upgrading may not be considered, the system has reached its final EoL, even if it might have been used for other applications.

To address such kind of situations, the present paper investigates the concept of Design-2-Life (D2L) systems. To do so, EoL strategies will be explored to understand the key issues. Then a clear explanation of D2L concept will be proposed as well as its main characteristics. Finally we will discuss the challenges of this new approach and the advantages to develop it under a PSS framework. The case of batteries used in electric cars will be used to illustrate the concept.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
Keywords: Design 2 Life; repurposing; product life extension

1. Introduction

Products and systems are subjected to different regulations to ensure the minimization of their ecological footprint. These regulations prevent hazards all along the lifecycle of the systems. They are covering all the lifecycle stages, from the raw material extraction to the end-of-life (EoL), even if they are mainly focusing on use and EoL stages. Indeed, some regulations oblige manufacturers to care about EoL [1,2], in terms of reuse, recycling and valorisation mainly. Some are focusing on the use phase [3,4], aiming to reduce the impacts from different inputs - energy, water, etc. These regulations complement one another to ensure fewer impacts on the whole lifecycle of the systems. Another way to minimize the environmental impacts of the system, as mentioned by the European Commission, is to extend the products' lifespan [4]; in most cases, this would lead to decrease all the impacts at the same time.

At the other side of the lifecycle, designers need to integrate all these aspects to comply with regulations. The primary steps are decisive to ensure fewer impacts during the use phase of the system and when it has to be retired. To help designers all along the design stage, many methods, guidelines and norms are available today: Design for Environment, Design for Remanufacturing, Design for Recycling, Eco-design norm (NF E 01 005), Qualitative Life Cycle Assessment, Life Cycle Assessment, ISO 14062, etc. Depending on the characteristics of the products, the regulations to which they are inclined, and the internal policy of the company, designers can set up EoL strategies - e.g. reuse, remanufacturing, upgrading, etc. - to increase the lifespan of their products and so reduce their environmental impacts. In these design strategies, the Product-Service Systems (PSS) business model (BM) would be much more appropriate to manage products [5]. They are defined as "a marketable set of products and services, jointly capable of fulfilling a client's need" [6]. Thus, PSS focus shift from selling products to services, so that, providers are more

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.079

subjected to manage use and EoL phases, which would facilitate take-back and feedbacks from customers, improve the lifespan, and so the environmental and economic aspects [5].

However, those EoL strategies may not be appropriate for all products, especially when the key functions and the overall performances of the system decrease. Our research investigates how to reduce the environmental impacts of such products by increasing their lifespan through multiple applications. In this paper, the focus is to investigates this new concept of Design-2-Life (D2L) systems and understand the main differences between current EoL scenarios. To do so, Part 2 defines the main EoL strategies, their steps and characteristics. Then, Part 3 gives a clear explanation of D2L systems and to draw its main characteristics. Finally we will discuss the challenges of this new approach and the advantages to develop it under a PSS framework in Part 4. The case of Li-ion batteries used in electric vehicles (EV) will be used to illustrate the concept.

2. End-of-Life strategies from literature

In order to define the D2L strategy, different EoL scenarios will be investigated and, more particularly, the strategies that aim to extend products' lifespan.

First of all, it is considered here that the EoL of a system is reached when its user discards it, no matter the product is broken or not. Thus, the system follows an EoL strategy, which has been planned from the design stage or which depends on the product profile. Four EoL strategies are usually mentioned in the literature: reusing, remanufacturing, recycling or disposal - see Fig. 1 from [7]. As it will be exposed, other strategies may be considered as sub-levels of the four above-mentioned. Anyway, they all aim to reduce the environmental pressure of products [8].

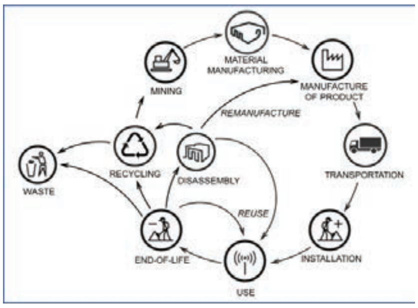

Fig. 1. Classical lifecycle of a system (From Zhang [7])

EoL strategies are influenced by many factors, coming from different perspectives; such as the product characteristics, the process and the BM [5]. In this paper, the BM includes all the surrounding elements set up to perform the EoL strategy (such as the organization, the relationships with the stakeholders, the value creation, the value chain of the offer, etc.), adapted from [9]. These characteristics are specific to each strategy However, as we focus on strategies to extend products' lifespan, it will be interesting to identify the ones that are similar and these which are different. Indeed, this will help to identify the scope of the D2L strategy and to better understand the scope of applications. The EoL characteristics will be classified regarding the 3 aforementioned spheres - i.e. product, process, BM - and a rough estimation of their importance regarding the strategy will be made. Furthermore, EoL scenarios usually follow different steps along their life cycle. These steps may be proper to each or shared between some of them - e.g. cleaning, repairing. On the contrary, one strategy as a whole might be included in another. In this second part, the principal EoL scenarios are defined and described in terms of steps and characteristics.

2.1. Reuse

Reusing products consists of collecting them from the waste stream, controlling damages and reusing them for an identical purpose [10,11]. Reuse is mainly possible when the lifespan of some parts of the system are wider than their effective usage [12]. Thus, when manufacturers are reusing a product, they have to worry about its performances: the reused system needs to have the same characteristics and performances than a new one to achieve the same function, no matter the user [10]. In general, these products and components are used as second-hand products or to repair systems - e.g. cars, copiers, etc. - [11] or they are part of another EoL strategy - e.g. remanufacturing - [10]. Consequently, no design methodology has clearly been defined in mechanical literature yet. Nevertheless, some guidelines highlight key criteria to ensure better reuse potential [11]. To facilitate reuse, PSS BM can be used [10]. Thus, different elements would be integrated from design, such as the EoL management.

The reuse strategy is often preferred because its theoretical impacts on the environment are lower than any other strategies [11–15]. Indeed, it doesn't imply any manufacturing activities, such as repair or reconditioning, but only reverse logistic (RL) management. The lifespan of products or components is then extended and environmental as well as financial costs are minimized – in comparison with other EoL scenarios [5]. However, even if it seems to be the easiest way to reduce environmental burdens, it is important to prove that, environmentally speaking, a reused product is better than a new, efficient one [16]. One other important characteristic for reuse is the reliability [13] – e.g. cores of cartridges, furniture for offices, etc. However, as mentioned, this has to be temper by efficiency gains due to technology improvement [17]. Another characteristic of reused products would be the cost of such option compared to others. Indeed, the reuse tends to postpone the final EoL of the product and thus avoid manufacturing and disposal stages at least once [11,12]. Then, a system may be characterized by the ease of supply– e.g. to take-back products – [12,18] and the easiness of reusing the product [14]. Last but not least, users' profiles would mainly influence the performances of the system at the end of the first use and be determinant for a potential reuse [13].

The above-mentioned characteristics of a reused system are summed up in Table 1. They have been categorised according to the 3 dimensions related to the product, the process or the BM. As stated before, and regarding the EoL strategy, an evaluation of the importance of each characteristic has been done from the authors' opinion.