A model for integrating services and product EOL management in sustainable product service system (S-PSS)

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Abstract Sustainable product service system (S-PSS) regarded as an evolution of existing product development approaches which incorporates services as well as products for achieving sustainable development. Therefore, several IT manufacturers around the world have developed plans for fulfilling consumer’s needs by providing a combination of product and services and also management of product at the end of its life (EOL). Hence, it is essential to develop an analytical model that can help manufacturers to analyze their S-PSS plans. We model both optimization of environmental and economical impacts of the product during consumption and end of life phase from point of view of the consumer and manufacturer. A multi-objective genetic algorithm has been applied to simultaneously optimize service period and product EOL decisions. Finally, a case study of a notebook market is provided to show the applications of the model.

Keywords Sustainable product service system · Warranty · End of life · Genetic algorithm

Introduction

Manufacturers have to improve their outcomes to meet the ever-changing customers’ demands in order to develop their competitiveness continuously. Along with the shift from industrial market to customized market, Product Service System (PSS) turns out to be the key means to solicit customers (Gao et al. 2011; Leitão et al. 2011). This approach is a function-oriented business model that moves away from traditional product concepts, and inherently focuses on the product function that needs to be fulfilled by a combination of products and services (Tukker 2004; Baines et al. 2007).

In recent decade, due to the severe environmental legislations, consumer awareness and extended producer responsibility (EPR), sustainable product service system (S-PSS) is regarded as an evolution of existing PSS approaches which incorporates services as well as products that contribute to better environmental performance. Sustainability is about fulfilling needs with minimal material use and emissions. The sustainability of PSSs depends on whether a PSS as such is less material intensive, and whether actors in the chain feel incentives to lower material intensity even more (Tukker 2004).

The main objectives of S-PSS are:

1. To minimize the total waste generated by the product during consumption and EOL phases. So by increasing the product life cycle through maintenance and recovery at EOL phase, one of the main objectives of S-PSS is achieved and hence waste generation is minimized. Therefore, the negative impacts on main environmental indicators, namely: human health, ecosystem and consumption of resources are reduced (Roy 2000).

2. Also social elements (including consumer satisfaction, product safety, etc. (Halme et al. 2006)) will be increased due to providing services and fulfilling consumer needs. The concept of S-PSS is shown in Fig. 1.

As shown in Fig. 1, S-PSS creates an optimum balance of environmental protection, economical and social benefits by providing product and services during usage and recovery including repair, reuse and recycling at the EOL phase (Maxwell and VanderVorst 2003; Roy 2000). In other words,
Minimization of total cost: (during warranty, post warranty and EOL)

Minimization of environmental effects (human health, ecosystem and resource consumption)

Achieving social benefits (safety, consumer satisfaction, etc.)

Sustainable Product Service System (S-PSS)

Table 1  Examples of successful S-PSS application in PC manufacturing industry

<table>
<thead>
<tr>
<th>Organization</th>
<th>Description of S-PSS plan</th>
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<tr>
<td>IBM (2012)</td>
<td>Introduced an environmental solution in which the equipment can easily be repaired or upgraded in order to extend its useful life and it can be taken back to manufacturer at EOL phase</td>
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<tr>
<td>Toshiba (2012)</td>
<td>With Toshiba financial services, consumer can purchase a product with different warranty agreements. They also provide product take back programs</td>
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<tr>
<td>Dell (2012)</td>
<td>Dell developed the product-life extension plan to increase the useful life of their products through maintenance, repair, reuse and recycling. Therefore, the amount of energy and resources required to provide a given function are reduced</td>
</tr>
<tr>
<td>Sony (2012)</td>
<td>Sony developed products with consideration for their upgradeability. At the EOL phase, products are taken back to manufacturer by global take back centers</td>
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According to consumer tendency, many consumers tend to acquisition of their products (Michelini and Razzoli 2004; Cooper and Mayers 2000). In these circumstances, by selling the product, manufacturers have not any information about their product during consumption period and only can bring technical services with warranty agreement for fulfilling customers’ requirements. At the EOL phase product taken-back by the manufacturer for EOL decisions and the manufacturer responsibly for this phase. However, manufacturer should pay a certain cost to provide maintenance services and product EOL management. In addition, consumer decisions during the use phase of a product on whether to repair, pass on or throw away product due to post-warranty maintenance costs and product functionality are among the factors that affects product life span and therefore the rate of waste generation.

Although S-PSS have been applied by several industries, its application in developing countries is still a relatively unexplored area and they are faced with the challenge of balancing rapid economic growth with social and environmental considerations (Nnorom and Osibanjo 2008; Ness and Wagner 2007). Also, many developing countries are consumers of high tech products imported from other countries. Therefore, only the consumption and the EOL phases occur in these countries. In this circumstance, the manufacturers and their representations are interested in introducing an efficient S-PSS schemes to manage usage and EOL phases.

This paper addresses this problem through developing a mathematical model that helps manufacturers consider the impacts of both service decisions (maintenance, warranty and post warranty periods) and EOL options on the S-PSS.

**Literature review**

In this section we provide a brief literature review on the modeling of maintenance and EOL management in S-PSS context. The main reason of our literature review is to realize the major specifications of previous researches in order to clearly differentiate our work from those studies.