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MINIMIZING UNCERTAINTY INVOLVED IN DESIGNING THE CLOSED-LOOP SUPPLY NETWORK FOR MULTIPLE-LIFECYCLE OF PRODUCTS

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Abstract: *To ensure multiple-lifecycle of products through remanufacturing intervention requires a well-functioning closed-loop supply network. Generally, the unpredictability of quantity, timing and quality (physical/functional) of the returned products and demand fluctuation of the remanufactured products are the main sources of uncertainty of closed-loop supply network. To some extent, efficient recollection strategies and separate distribution channels for remanufactured products can minimize the uncertainty. Nevertheless, efficient recollection does not necessarily close the loop if the recovered products do not enter into the main stream of the supply network. Beside, products that are distributed through separate channels create an open loop. Thus, the problem of uncertainty remains unsolved. The aim of this paper is to propose solutions to minimize the uncertainty involved in designing a well-functioning closed-loop supply network using the system dynamics principle and tool.*
Key words: *Closed-loop supply network, multiple-lifecycle, remanufacturing, system dynamics, end-of-life product*

1. INTRODUCTION

Few examples of research work done in the area of closed-loop supply network can be found in the articles of (Guide Jr. & Harrison, 2003), (Gungor & Gupta, 1999), (Toffel 2004) and (Östlin *et al.*, 2008). All these researchers have pointed out that quantity and quality of the returned products, the timing of return of products and the demand fluctuation of the remanufactured products are the main sources of uncertainty. Recollection strategies such as, buying old products back at the end-of-life, leasing products instead on selling, returning old products when purchasing new products etc. have been stemmed out as the solution to minimize the uncertainty. Moreover, (Östlin *et al.*, 2008) have suggested to establish different types of relationship between manufactures and users for efficient recollection. These solutions definitely bring some predictability in the quantity and timing of the returned products but do not solve the quality issue. Sometimes the quality level of the returned products is rather low that they are not recoverable as whole or as material. Moreover, in most of the cases, the collectors do not have the product information which makes quality assessment of the returned products quite resource intensive and expensive. Similarly, distributing remanufactured products through separate channels are not the part of the closed-loop supply network. Even though it is addressed as closed-loop supply network, in many cases the supply loop is open. The multiple-lifecycle is a proposed concept that allows the products to be used for more than one life by means of remanufacturing (Asif *et al.*, 2010). A well-functioning closed-loop supply network is necessary to allow products, parts or materials to re-enter into the supply network in the multiple-lifecycle approach. By identifying all the sources of uncertainty involved in designing closed-loop supply network, the work presented in this paper attempted to propose solutions to minimize it.

2. SOURCES OF UNCERTAINTY

A system dynamics model has been created and identified that quality (addressed as reliability in the model) is the main source of uncertainty involved in closed-loop supply network. During the simulation it is assumed that a batch of returned products contain products with variable quality level. Depending on the quality level, the products are remanufactured, recycled or landfilled. If the products cannot be remanufactured the demand is met by manufacturing new products. Moreover, if the cost to perform remanufacturing is more than manufacturing, the model suggests to manufacture a new product as the alternative. An example is shown in the table 1, an 8 years old product has 21 % reliability and to remanufacture, it costs $1.9 more than manufacture a new product. So the model suggests to manufacture a new product to meet the demand and suggests to recycle the old product. Similarly, a product used for 3 years has 58% reliability and it cost $3.6 less to remanufacture the product compared with manufacture a new product. Finally, a product which was used for 5 years and costs $0.3 less to remanufacture is still recommended to be recycled because it does to meet required reliability level which is set to 50%.

In all these three cases the supply network is behaving as closed-loop and the demand is always met either by manufacturing or by remanufacturing. The Figure 1 confirms that the model behaves as a closed-loop supply network i.e., the supply of products and end-of-life products (waste) is steady during the span of the simulation. Of course, some products are

Age	Quality (Reliability) %	Cost of Remanufacture $	Cost of Manufacture $	Remanuf.?	Manuf.?	Recycle?
8	0.21	21.9	20	no	yes	yes
3	0.58	16.4	20	Yes	no	-
5	0.37	19.7	20	no	yes	yes

Tab.1.Comparison of quality, cost of manufacturing vs. remanufacturing for decision making

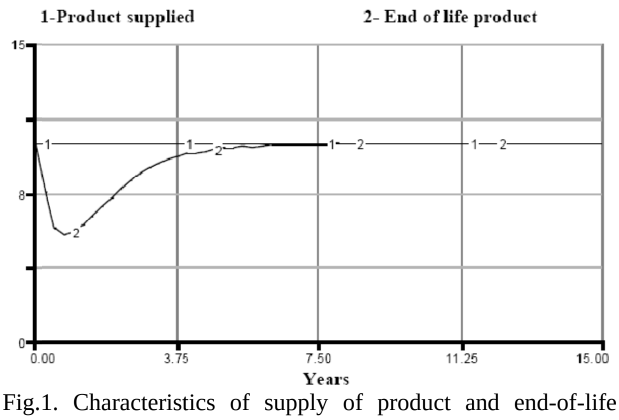

Fig.1. Characteristics of supply of product and end-of-life product in the closed-loop supply network

landfilled as they cannot be remanufactured or recycled and that is considered as an open loop in the model.

Energy consumption, environmental impact, raw material consumption, legislation etc. are few of the important aspects that also influence the decision making. These aspects have not been considered in the model because they are out of focus of the research at this level.

It can be concluded that, if the age (assuming that in a certain age all products have similar quality level) of the returned products are known and if they are collected in a certain time the uncertainty of the closed-loop supply network can be minimized.

3. SOLUTIONS TO MINIMIZE UNCERTAINTY

It is evident from the above discussion that if the quality level of the returned products is known the supply network will face less uncertainty. In the proposed multiple-lifecycle approach the appropriate time for remanufacturing, recycling or landfilling and the number of lives each product may serve is determined by the manufacturers at the product design phase. The time is mainly set based on parameters that are responsible for quality deterioration of the products, the economical and the environmental aspects etcetera. For example, it is expected that products operated in the same user conditions and user locations will have more or less similar quality level at a cretin point in time. If the products carry information such as, actual age, operation age, user locations, user conditions, service information etc., the quality level of the product can be assessed throughout its life. The product information can easily be embedded and communicated with the Radio Frequency Identification (RFID) technique (Parlikad & McFarlane, 2007). This approach will not only provide information about quality level of products at collection but also reduce the cost of quality assessment.

It is usually believed that remanufactured products are less accepted by users compared with new products. Due to this belief most of the remanufacturers use separate distribution channels to market remanufactured products. Eventually, it results in mismatch between the supply and the demand of the remanufactured products. In principle, the remanufacturing process is capable of ensuring same level of quality, safety and performance in the remanufactured products as the newly manufactured products. In addition, recent environmental concern among people has revealed that, to most of the users, eco friendly solutions are more acceptable. Therefore, it is not necessary to set up separate distribution channels for the manufactured and the remanufactured products. In the anticipated multiple-lifecycle approach, same channel will be shared by both manufactured and remanufactured products. The mix of manufactured and remanufactured products in a batch will depend on the availability of the returned products. If used products are not available at a point in time the demand will be met by manufacturing.

4. SUMMARY AND CONCLUSIONS

As discussed in the paper, supply network that includes product or material recovery does not always create a closed-loop. Even if the supply network is closed in some cases, the timing, quantity and quality of the returned products and the demand fluctuation of the remanufactured products causes uncertainty.

On the other hand in the multiple-lifecycle approach the supply network faces less uncertainty. The quality level of the returned products is deterministic to some extent. The reverse flows of the returned products are predictable and manageable. The supply of products is steady and demand is always met. Thus, the supply network is almost always closed and well-functioning.

It is worth mentioning the two main limitations of the work presented in this paper. Firstly, in the multiple-lifecycle approach the loop of recycled material is always close. But, to simply the model the loop of recycled material is considered to be open. Secondly, the data used to run the simulation is mostly based on assumptions but the logic used to define the relations and interactions of parameters in the simulation are based on scientific facts.

Due to the limitation of space only the summary of the outcomes of the simulation model has been discussed. The authors will be glad to provide further detail to any interested reader.

5. FUTURE WORK

The sources of uncertainty in a closed-loop supply network are not limited to what is covered in the paper. There are other sources within and outside the business domain. For example, the legislation and the consumers view about remanufacturing products plays an important role in designing a well-functioning closed-loop supply network. The future work will focus on finding all possible sources of uncertainty and include them in the model. The intended network will face less uncertainty in the dynamic environment. In future, the model will include social, economical, environmental and legislative factors to capture the dynamicity of the closed-loop supply network.

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7. REFERNCES

Asif, F. M. A.; Semere, D. T.; Nicolescu, C. M. & Haumann, M., (2010). Methods Analysis of Remanufacturing Options for Repeated Lifecycle of Starters and Alternators. *The Proceeding of the 7th International DAAAM Baltic Conference ,"Industrial Engineering"*, Kyttner, B (Ed)., *pp* 340-345, ISBN-978-9985-59-982-2, 22-25 April 2010, Tallinn, Tallinn University of Technology, Estonia

Guide Jr., V. Daniel R. & Harrison, Terry P. (2003). The challenges of Closed-Loop Supply Chains. *Interface*, vol. 33, no. 6, November-December 2003, pp. 3-6, ISSN: 0092-2102

Gungor, A. & Gupta, Surendra M. (1999). Issue in environmentally conscious manufacturing and product recovery: a survey. *Computers & Industrial Engineering, Elsevier,* vol. 36, no. 4, September 1999, pp. 811-853, ISSN: 0360-8352

Parlikad, A. K., & McFarlane, D. (2007). RFID-based product information in end-of-life decision making. *Control Engineering Practice , Special Issue on Manufacturing Plant Control: Challenges and Issues - INCOM 2004, 11th IFAC INCOM'04 Symposium on Information Control Problems in Manufacturing,* vol 15, no. 11, November 2007, pp. 1348-1363, ISSN 0967-0661

Toffel, M. W. (2004). Strategic Management of Product Recovery. *Californian Management Review*, Vol. 46, no. 2, winter 2004, pp. 120-141

Östlin, J.; Sundin, E &Björkman, M. (2008). Importance of Closed-loop supply chain relationship for product remanufacturing. *International Journal of Production Economics, Elsevier*, vol. 115, no. 2, October 2008, pages 336-348, ISSN: 0925-5273