January 01, 2010

System dynamics approach in inventory management of end-of-life products in a disassembly line

Badr O. Johar

Surendra M. Gupta
Northeastern University

Bibliographic Information

Johar, B. O. and Gupta, S. M., "System Dynamics Approach in Inventory Management of End-Of-Life Products in a Disassembly Line", ***Proceedings of the 2010 Northeast Decision Sciences Institute Conference***, Alexandria, Virginia, pp. 445-449, March 26-28, 2010.

Copyright Information

Contact Information

Dr. Surendra M. Gupta, P.E.
Professor of Mechanical and Industrial Engineering and
Director of Laboratory for Responsible Manufacturing
334 SN, Department of MIE
Northeastern University
360 Huntington Avenue
Boston, MA 02115, U.S.A.

(617)-373-4846 ***Phone***
(617)-373-2921 ***Fax***
gupta@neu.edu ***e-mail address***

http://www.coe.neu.edu/~smgupta/ ***Home Page***

SYSTEM DYNAMICS APPROACH IN INVENTORY MANAGEMENT OF EOL PRODUCTS IN A DISASSEMBLY LINE

Badr O. Johar, Northeastern University, (617) 373-7635, johar.b@neu.edu
Surendra M. Gupta, Northeastern University, (617) 373-4846, gupta@neu.edu

ABSTRACT

A major challenge original equipment manufacturers (OEMs) currently face is how to implement an effective reverse supply chain network that is both cost effective and efficient. The rapid increase in the end-of-life (EOL) products returns from end customers back to origin for recovery or proper disposal can be said one of the main reasons behind this interest. Thus, the purpose of this paper is to examine the relationship between all elements of inventory management in the disassembly context using the system dynamic modeling approach to analyze the inventory of disassembled parts. Analysis of different market scenarios is conducted. The system dynamic tool can be used as an experimental tool which can be used to forecast the system's behavior under different conditions.

Keywords: Reverse supply chain, Disassembly, System dynamic, End-of-life, Inventory management

INTRODUCTION

Recent years have witnessed Reverse Supply Chain (RSC) become the center of attention for researchers and Original Equipment Manufacturers (OEM's). “Reverse supply chain is the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it” [1]. The fast depletion of virgin resources and the rapid increase of product returns from end customers to original manufacturers for maintenance, repair or to be disposed of can be said to be one of the main reasons behind this interest. Electronics manufacturers have introduced state-of-the-art technologies in quick succession. As a result of this, the end-of-life (EOL) products returned by customers have grown significantly in volume. But often these end-of-life (EOL) products are found to be in excellent working conditions (functional). Customers return them because of the various marketing programs or favorable incentives offered by service providers or manufacturers that create a “must have” sense in the minds of customers to acquire upgraded products. Of course, there are times when the products are worn out or do not function properly anymore. In the past two decades environmental concern has focused on production processes, and environmental regulation has concentrated on pollution from industry. However, there is growing awareness that this may not be sufficient and it is increasingly recognized that the use and disposal phases, as well as the production phase of the product life cycle, are important. Environmentalists have always demanded that the manufacturing companies should take these EOL products back and manage them in an environmentally conscious manner. EOL products can be remanufactured, reused, recycled, or disposed of [2], [3]. However, planners did not invest or engage themselves in such initiatives because of the uncertainty in quantity and quality of items taken back.

BACKGROUND IN DISASSEMBLY

Environmental regulations and consumer pressure are forcing manufacturers to become more responsible for the safe disposal and recycling of used products. This requires a new approach to product design, one which results in a product designed for all the stages of its life-cycle. Many corporations have understood the economic and environmental benefits of minimizing the use of virgin resources. Also, due to strict environmental legislations, they have started to comprehend the importance of the recovery process and are taking serious steps in restructuring their supply chain processes to meet the new regulations. Examples of such regulations include limitations on waste disposal and recycling requirements. The idea behind the change is to use materials and parts more than once before they are finally discarded. Thus, effective supply chain management is vital in gaining a competitive edge over other corporations. Supply chain management, by definition, “involves functions such as production, purchasing, material management, warehousing, inventory control, distribution, shipping, and transport logistics” [4]. Supply Chain Management is a consequence of the increased necessity for holistic considerations in between and across companies' business activities and resources in and between marketing channels, in order to improve the overall performance towards the ultimate consumer in the marketplace [5].

However, the take-back process is more environment friendly than the traditional supply chain process as it “closes the loop” of the supply chain process and transforms the end-of-life (EOL) products into new serviceable products. This new portion of the supply chain is known as Reverse Supply Chain (RSC). It has been found that the original supplier is in the best position to control the return process. The basic reverse supply chain logistics model operates independently of the forward supply chain that delivered the original product. When a firm controls the full process of forward and backward shipment the result is called a Closed Loop Supply Chain [6], [7].

Closed-Loop Supply Chain Management may be defined as the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time [1]. In comparison to regular supply chain management, the management of reverse supply chain is more challenging because it is more reactive and less visible. Such challenges may include, changing demand rates, multiple demand sources, variety of products and logistical complications. Yet another challenge is inventory control and value management of end-of-life (EOL) products. Due to the disparity between demand for parts and materials and their yields, the planner faces economical as well as physical constraints when trying to take a decision on how many products to take back and when to take those back. Economical constraints may include holding and transaction cost of excess inventory whereas physical constraints may include capacity and space limitations. The objective of this research is to develop and examine an inventory control policy of an On-Hand Inventory (OHI) of returned items and disassembled parts using system dynamic (SD) approach that works as a simulation tool to examine the behavior of the inventory pile up along the disassembly line and the effect of different changes in supply/demand trends on the overall inventory cost.

SYSTEM DYANMIC: METHODOLOGY AND APPROACH

In this paper, system dynamics approach is presented in an attempt to solve the inventory control problem in context of disassembly. The model assumes a stochastic formulation that takes into consideration the uncertainty in demand and line yields. Generally, system dynamics approach is applied to macro-systems such as production-inventory system, national economies, and macroeconomic systems. The philosophy behind it is founded on the concept that the system state changes based on the changes in the rates of inflow and outflow, and characterized by the feedback loop that triggers the corrective action, and thus, the model can be developed using Euler's first order differential equations. This study provides knowledge that helps understanding the challenges and opportunities associated with inventory control in disassembly line context. Disassembly Line faces a serious inventory problem because of the disparity between the demand and the disassembly line yields. Workstation along the line tend to experience different accumulation rates and depletion rates depending on how demanded these parts are. This fluctuation between inventory and demand will create uncertainty in inventory levels.

Methodology

The problem statement clearly indicates that it is extremely difficult to solve this problem without making a number of generalizations. Simulation appears to be the most appropriate solution procedure. However the accuracy of simulation warrants precise and voluminous real life data which is very difficult to obtain.

Hence the author feels that two alternative techniques could be employed:

1) System Dynamics simulation modeling
2) Markov chain analysis

This paper will address the System Dynamic (SD) approach only.

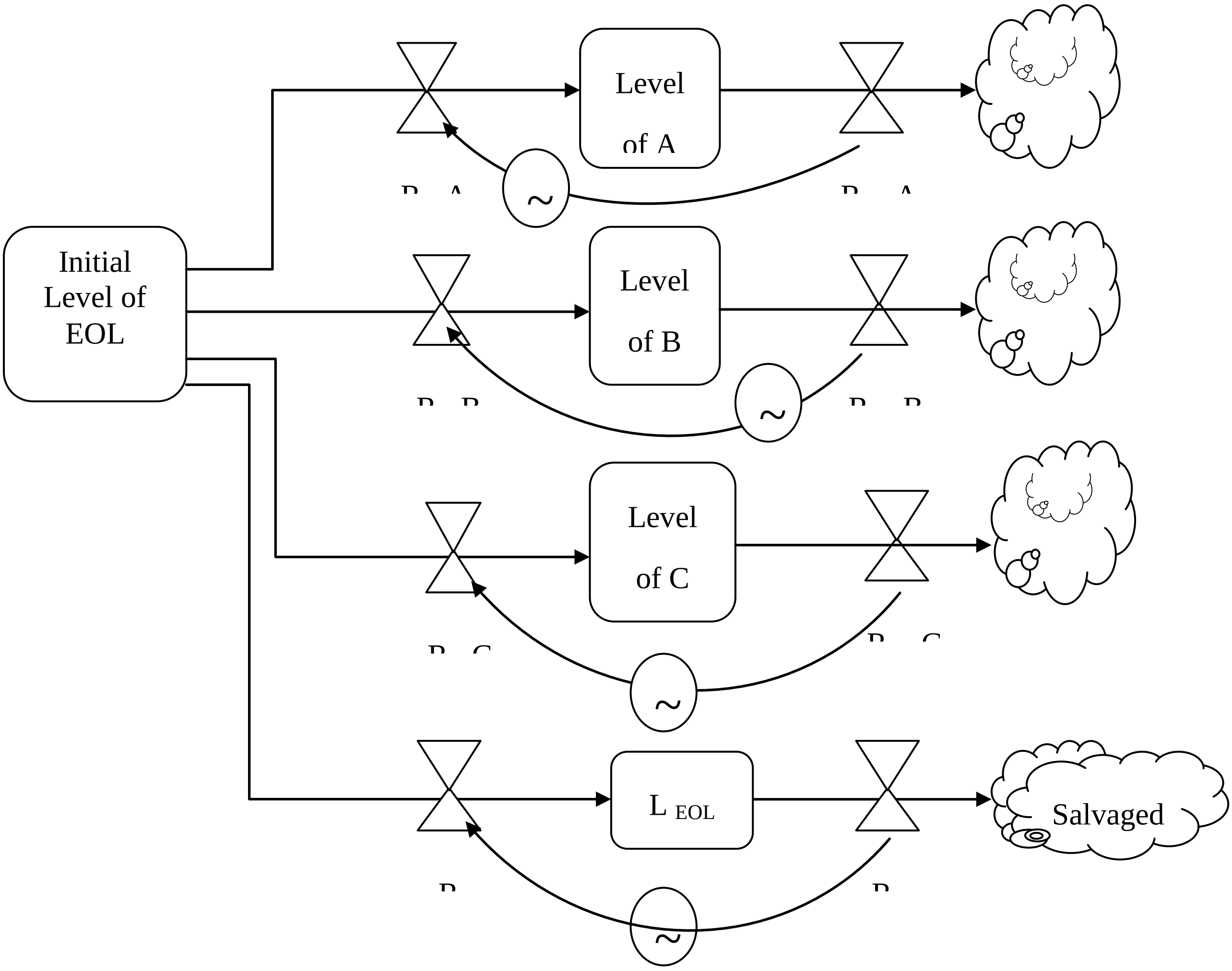
Approach

System Dynamics (SD) approach is generally applied to macro-systems such as production-inventory systems, macroeconomic systems, demographic transformations, national economies and so on. Growth models for national economies have been successfully developed by many researchers. Production-inventory systems were elaborately discussed by Forrester J.W in his ‘Industrial Dynamics’.

The philosophy behind SD simulation is founded on the concept that industrial systems are like input-output systems. The system state changes according to the changes in the rates of inflow and outflow. The steady state condition is achieved when the input rate is equal to the output rate. Thus any system can be viewed as an input-output system with input and output rates. The system is characterized by the feedback loop that triggers the corrective (control) action.

Based on these assumptions the system model can be developed using Euler’s first order difference equations. The model is as shown in figure 1 below:

Figure (1) System Dynamic in Disassembly Line



Notation

L_{EOL} Level of end-of-life (EOL) inventory of core products

L_j Level of disassembled part type *j*, where $j = \{A, B, C\}$

$L_{EOL(t-1)}$ Level of end-of-life (EOL) inventory of core products at time $t-1$

$R_{in}EOL$ Rate of incoming end-of-life (EOL) products, known as input rate

$R_{out}EOL$ Rate of demand of end-of-life (EOL) products, known as output rate

Δt Incremental time or time step

$L_j(t)$ Inventory level of disassembled part *A* at time t

$L_j(t+\Delta t)$ Inventory Level of disassembled part *j*, at time $t+\Delta t$

Model

If the rates of inflow and outflow are precisely known which may depend upon the demand distribution of each product A, B or C, it would be easier to solve the problem. It is also important that the unit costs of each product C_A, C_B, and C_C also known. Similarly an additional complexity that emerges in the modeling is the life period of products A, B or C. Since all these products are supposed to have reached their life period, reusability depends on further deterioration or decay. If an exponential deterioration is assumed the model has to be incorporated with these terms. Here the author intends to solve the problem assuming that deterioration doesn't make any problem in salvaging the product. The author wishes to use SD software ARENA for simulating this system. The problem can be modeled as follow

$$EOL\_INV\_Level = L_{EOL} = L_A + L_B + L_C = L_{EOL(t-1)} + (R_{out}EOL - R_{in}EOL)\Delta t \quad (1)$$

Similarly,

$$L_A\_a\_t + \Delta t = L_A(t+\Delta t) = L_A t + (R_{out}A - R_{in}A)\Delta A \quad (2)$$

$$L_B\_a\_t + \Delta t = L_B(t+\Delta t) = L_B t + (R_{out}B - R_{in}B)\Delta t \quad (3)$$

$$L_C\_a\_t + \Delta t = L_C(t+\Delta t) = L_C t + (R_{out}C - R_{in}C)\Delta t \quad (4)$$

CONCLUSIONS

In this paper, a brief description of the inventory control problem in disassembly line is given. The probabilistic nature of the problem is assumed to provide more accurate results compared to deterministic models, hence systems dynamic (SD) approach is developed for a hypothetical product *ABC*. Problem methodology and model is presented in this paper, and simulation model using commercial software ARENA will be developed to simulate the buildup of inventory and steady state of the system.

REFERENCES

[1] Guide, V. Daniel R. Jr. and van Wassenhove, L. N., "The Evolution of Closed-Loop Supply Chain Research", *Operations Research*, Vol. 57, No. 1, 10-18, 2009.

[2] Gungor, A. and Gupta, S. M., "Issues in Environmentally Conscious Manufacturing and Product Recovery: A Survey", *Computers and Industrial Engineering*, Vol. 36, No. 4, 811-853, 1999.

[3] Ilgin, M. A. and Gupta, S. M., "Environmentally Conscious Manufacturing and Product Recovery (ECMPRO): A Review of the State of the Art", *Journal of Environmental Management*, Vol. 91, No. 3, 563-591, 2010.

[4] Jaber, M. Y., Rosen, M. A., "The Economic Order Quantity Repair and Waste Disposal Model with Entropy Cost", *European Journal of Operational Research*, Vol. 188, No. 1, 109-120, 2008.

[5] Svensson, G., "The Theoretical Foundation of Supply Chain Management: A Functionalist Theory of Marketing", *International Journal of Physical Distribution and Logistics Management*, Vol. 32, No. 9, 734-754, 2002.

[6] Kumar, S., Yamoka, T., "System Dynamics Study of the Japanese Automotive Industry Closed Loop Supply Chain", *Journal of Manufacturing Technology Management*, Vol. 18, No. 2, 115-138, 2007.

[7] Pochampally, K. K., Nukala, S. and Gupta, S. M., *Strategic Planning Models for Reverse and Closed-Loop Supply Chains*, CRC Press, Boca Raton, Florida, ISBN: 9781420054781, 2009.