SYSTEM DYNAMCS MODEL FOR REMANUFACTUIRNG SYSTEM

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This thesis is dedicated to my parents, and my sister who have supported me all the way since the beginning of my study.

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ABSTRACT

Remanufacturing is a process where the used products or cores are restored to look like as good as new products. Remanufactured products have high profitability and sustainability in comparison whit the recycled materials, because it can be retain as value added. The remanufacturing system is more complex that traditional manufacturing. The relationship between the parameters of this system and analyzing their influence on the behavior of the system is more complex, for this "System Dynamics" methodology is used. The aim of this thesis is to improve a system dynamics simulation model for remanufacturing system, by focusing "customer behavior, service agreement whit customer, company reputation and recollection effort" and their influence on the dynamic behavior of the system and analyses these factors effect on the total profit, total cost and collection rate. The objective is to maximize total profit, minimize total cost, and maximize collection rate. For this, 80 different combinations of simulation scenarios are simulated, and the data form this simulation runs is analyzed by using design of experiment approach. Based on these analyses, it can be concluded that all four factors are significant, but company reputation is most significant factor to get the optimized scenario for total profit, cost and collection rate to satisfy the objective of this thesis.

ABSTRAK

Pembuatan semula merupakan proses di mana sesuatu produk terpakai telah dibaikpulih semula dan masih boleh berfungsi seperti produk yang baru. Produk yang telah dibuat semula ini mampu memberikan keuntungan yang lebih baik dan lebih lestari berbanding dengan produk yang dikitar semula. Ini kerana produk tersebut masih mempunyai nilai tambah. Sistem pembuatan semula ini lebih kompleks berbanding system pembuatan konvensional. Hubungan antara parameter yang berkaitan serta analisa terhadap pengaruh kepada sistem ini adalah lebih kompleks. Oleh yang demikian kaedah sistem dinamik telah digunakan bagi menganalisa hubungan tersebut. Objektif kajian ini ialah untuk memperbaiki model simulasi sistem pembuatan semula dengan menggunakan kaedah sistem dinamik. Model ini memfokuskan kepada faktor tingkahlaku pelanggan, perjanjian perkhidmatan dengan pelanggan, reputasi syarikat dan usaha pengumpulan semula. Pengaruh faktor-faktor tersebut terhadap kelakuan dinamik juga dikaji bagi menentukan kesan kepada jumlah keuntungan, jumlah kos dan kadar kutipan.80 kombinasi senario yang berlainan telah digunakan untuk tujuan simulasi dan hasil datanya telah dianalisa dengan menggunakan kaedah rekabentuk eksperimen. Berdasarkan kepada analisa tersebut kesemua empat faktor yang digunakan didapati signifikan dan faktor reputasi syarikat memainkan peranan yang paling penting bagi mencapai objektif kajian

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LIST OF ABREVIATIONS / SYMBOLS

SD	_	System Dynamics
CLD	_	Casual Loop Diagram
SFD	_	Stock and Flow Diagram
ANOVA	_	Analysis of Variance
RC	_	Remanufacturing Capacity
RR	_	Remanufacturing Rate
SI	_	Serviceable Inventory
DI	_	Distributors Inventory
TC	_	Total Cost
T Rev	_	Total Revenue
SC	_	Sale Cost
Rem C	_	Remanufacturing Cost
SIC	_	Serviceable Inventory Cost
DIC	_	Distributors Inventory Cost
Col C	_	Collection Cost
Pr C	_	Production Cost
Ship C	_	Shipment Cost
Rm C	_	Raw Material Cost
Op C	_	Operation Cost
CFUC	_	Cost for Unit Collected
CFU Ship	_	Cost for Unit Shipped
DITC	_	Distributors Inventory Transportation Cost
CFU Rem	_	Cost for Unit Remanufactured
CFUSI	_	Cost for Unit Serviceable Inventory
CFUDI	_	Cost for Unit Distributors Inventory
CFU Pr	_	Cost for Unit Produced
CFU Rm	_	Cost for Unit Raw material
Inv C	_	Investment Cost
Rem CEC	_	Remanufacturing Capacity Expansion Cost

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Product waste is becoming a big problem in our life. Almost all kind of products that people used in their daily life has expire time. The studies show that the product waste was increased during last decades. For using the resources efficiently and reducing the waste the used or end-of-life products can be remanufactured, also non usable part of used products can be recycled to achieve better sustainability. Remanufactured products have high profitability and sustainability in comparison whit the recycled materials, because it can be retain as value added. Now days the companies does not practice remanufacturing widely, even it has the advantage of retaining the value of the used products. Because, the end-of –life products needs to recall back to original manufacturing companies to preside the remanufacturing process and for this complex legists system and good infrastructure needed. At the end majority of original equipment companies thinks that remanufacturing used products may not be profitable for them. The used and discarded products also used materials and components all of this process is inside product recovery process. All activities in remanufacturing system , such as the product collection, the inspection for the retuned products, disassembling and sorting the parts for the quality, the remanufacturing process, recycling the scrap and disposing the waste are consist inside the product recovery (Toffel, 2004).

In comparison with the ordering new products, product recovery is more environmentally and economically beneficial. The concepts, such as recycling, reuse and remanufacturing are under the concept of product recovery. When the product does not satisfy the user's needs, product recovery's aim is to win back the product inherent value. Product recovery has more potential economically and environmentally advantage for recovering product's inherent value comparing other alternatives (Bras et al., 2005). The focus of product recovery from the industrialized world was limited during the last century. They preferred to produce the products from the virgin materials, for example non–recycled. The focus for product recovery now becomes more interesting for the manufactures because of some reasons, such as the awareness of the societies towards environmental problems now increasing for the use of the material and products. As a result of the social pressure, the legislative pressure for environmental aspect increased from the European Union (EU). They launched the ELV2 and WEEE1 directives to improve the product recovery. (Johan Östlin, 2008). Remanufacturing covers the process that makes the used product looks like new, such as disassembling product, cleaning, inspection, repairing or replacing warn out parts and finally reassembling the parts. In other words, it produces the products from used item which are as good as new one considering the quality and capability. The terms, such as refurbishment and rebuilding are the synonymies of remanufacturing. Now 'remanufacturing' is uses commonly in the literature as a generic industry term for the process which given above. The row material for remanufacturing process is used products (called 'cores' in the industry) are collected from the customers, and then brought to the factory for the remanufacturing process. During the process the components of used products are disassembled, cleaned, inspected, refurbished or repaired in in good condition, but if not the new parts preplace them. The component parts are cleaned, inspected, repaired or refurbished if useable; otherwise they are replaced. At the end the parts reassembled and the final product tasted to see if it satisfies the original performance specifications. The remanufacturer could upgrade the product, by changing the material of the parts or adding new functions, as an example the printer remanufacturers improve their product adding new functions and improving software.

The main component for the remanufacturing process is the cores. In most case retailers and distributors that sell the new and remanufactured products collect the used products, and sent it to the remanufacturer. The worn out or broken products, hand out to them by customers. Also there are some remanufacturers which are established their own direct exchange loops whit their customers. The returned products ownership usually belongs to the remanufacturer, but there are some case that which they provide the rebuilding service to the customers who claim rights of the products and want the same product after it rebuilt. It could be said that remanufacturing fundamentally is a form of recycling, but it offers additional benefits for the remanufacturer. In this process the product not only recycles, also the value of original product added to the used product. When a product's useful life ends or if it has a defect or defects, repairing will only extent it's useful life or make it useful, but in other hand remanufacturing will provide new full life cycle for it. The repaired products returns to the owner after the repairing process, but remanufactured products are unclaimed until it purchased by the customer. Now day's large number of products is remanufacturing; which includes, single-use cameras, printers, toner cartridge, telephones, office furniture, vending machines, automobiles, automobile parts, tires, industrial equipment, personal computers, compressors, television and so on. Despite, all these different type of products that are remanufacturing, the strongest tradition and strongest representation is in automotive sector. This sector is covers about 65 percentage of all remanufacturing process in the world. In industry sometimes different terms use for remanufacturing of different products. As an example, 'recharged' is used for products like laser and toner cartridges, 'rebuilt' for automotive- vehicle parts and systems. The terms, 'repaired', 'recycled', 'reconditioned', 'restored' and 'used' are used for different process. According to The Remanufacturing Institute (TRI), the product must to meet the conditions which given here to considered as a remanufacturing product.

1. The primary components must be reused.

2. The product has to be disassembled to learn the condition of components, also to now the deterioration and wear out.

3. Parts completely cleaned and examined.

4. The parts that damaged or missing are replaced whit new ones, or reconditioned so that they are look like as new one. Sometimes using used items is acceptable if their functionality is not affected.

5. The process, such as machining, rewinding or refinishing will be done to restore the used parts working condition.

6. The product that goes under these processes or refurbished will be same as new one (Steve Statham 2006).

1.2 History of Remanufacturing

The beginning of remanufacturing industry started whit the Second World War. During the war time and after the war the needs increased and can’t meet the demand, due to the war natural resources became unreachable and scarce; manufacturers start to look for an alternative to meet the demand from the customers. As a result manufacturing activities were replaced with rebuilding and remanufacturing of used products or parts from the original ones. Even there were an on–going war, an alternative economic and industrial growth past needed to produce by manufacturing industries for the society running. (Özer, 2012). According to Hauser and Lund (2008), there were around 2000 firms in U.S that doing remanufacturing. The estimated distributed across multiple functional applications and different industries. The environmental issues become more sensitive for the customers as well as the manufactures during past decades. Also the economic factors plays main role in the manufacturing industry. As a result the remanufacturing industry becomes a very popular among the manufacturing industry for the environmental requirements and economic benefits. Remanufacturing is practiced in many industries, especially and mostly in the automotive industry. Some examples of remanufactured products are automobile parts, military vehicles, aircraft parts, industrial robots, furniture’s, electric home appliances, photocopiers, computers, printers, toner cartridges, tires, telecommunication equipment’s , cellular phones, single-use cameras, heavy-duty engines, construction machineries, medical equipment’s etc.

1.3 Problem Statement

The main problem in this thesis that is too complex for effective resolution, for this reason it will divided to sub-problems. The reason for this is that, there are four main factors that we want to analyses; which are customer behavior, service agreement with customer, recollection effort and company reputation. Customer behavior and service agreement with customer are combined under collection index. Recollection effort and company reputation are combined under green image. The first sub-problem is effect of customer behavior and service agreement with customer, on the total profit and cost, and collection rate of remanufacturing system. The second sub-problem is effect of company reputation and recollection effort on the total profit and cost, and collection rate of remanufacturing system.

1.5 Objective of the Study

Remanufacturing becomes one of the main interests for the manufacturing companies because of it are economically and environmentally benefits. Remanufacturing companies are in a more complex and difficult position compared to traditional manufacturing companies (Guide, 2000). Remanufacturing operations is more complex than manufacturing. The additional complexity needs to be considered when organizing the remanufacturing system.

The objective of this thesis is to improve a simulation model for remanufacturing system using System Dynamics methodology, focusing the factors that have influence on the behavior of the system and analyses their effect on the system.

Propose of this thesis can be summarized in the following three points:

1. To maximize the total profit of remanufacturing system.

2. To minimize the total cost of remanufacturing system.

3. To maximize the collection rate of remanufacturing system.

1.4 Scope of the Study

The thesis will partially discuss the System Dynamics simulation model for remanufacturing. A number of interesting questions and factors regarding the remanufacturing system were chosen to be excluded from this thesis.

1. The design of the product to be remanufactured has a high degree of influence as to how the remanufacturing process will be organized (Sundin, 2004). Although this is an important factor, it is excluded from the scope of the study. Still, the importance of the design of the products should not to be neglected when considering the competitiveness of the remanufacturing system. In many situations, the design of the product has the major impact on the future possibility to economically remanufacture a product.

2. The rerun process of used product is also excluded from this study. Making this limitation does not means that return process does not important for remanufacturing, indeed this factor is very important for remanufacturing system and more detailed study need for this. Another factor that excluded in this study is the capacity planning for collection process. Because of the limited source and time this factor does not included in our research scope, but again for this factor needed a more detailed study for better results.

1.6 Significance of Study

1. The significance this thesis is that remanufacturing would allow manufacturers to respond to environmental and legislative pressure by enabling them to meet waste legislation while maintaining high productivity for high-quality, lower-cost products with less landing filling and consumption of raw materials and energy.

2. Conventional manufacturing is unsustainable because of its significant adverse environmental impacts. Manufacturing generates more than 60% of annual non- hazardous waste (Nasr and Varel, 1996) and causes problems including pollution and shortages and therefore high cost of landfill space and virgin materials.

3. Remanufacturing can help companies address these competitive, legislative and environmental pressures. For example, it simultaneously improves competitiveness and limits environmental damage due to production by reducing production costs via reductions in processing and raw material usage. By integrating waste back into the production cycle it limits landfill and cost of waste disposal.

1.6 Thesis Outline

The first chapter will encompass the description of the general problem area, leading to the more specific problems and the defined sub-problems. The importance of the topic will be discussed as well as a description of the approach, delimitations and the key assumptions of the research treatise.

The second chapter of thesis is about the literature survey. This chapter provides a discussion about remanufacturing in general and the area which is going to explore. This chapter will attempt to provide an explanation of the research methodology utilized in order to carry out the empirical (practical) research to establish the potential needs for the remanufacturing system.

The third chapter will describe how the research has been conducted. The method is used develop the remanufacturing system simulation model and the method for data collection and the measurement technique will be presented.

The fourth chapter is about the model development and data analysis. The development process of simulation model for remanufacturing system using System Dynamics methodology is explained. The analysis of collected data using different scenario is also explained in this chapter.

The fifth chapter of this thesis is about the discussion, future contribution. In this chapter de discussed the result of this simulation analysis, also our contribution for future studies is given in this chapter.

Sixth chapter is about the summary of the thesis, and conclusion of the thesis. The general summary of the thesis is presented in this chapter. Final conclusion for the thesis is given is this chapter.

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