IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Product Refurbishment Optimization Using Multi-Period Model Integrated Fuzzy Controller

[1]Aravind P V,[2]Dr. Boby K. George

[1]M.Tech Scholar,[2] Assistant Professor

[1]Department of Production Engineering,

Govt. Engineering College, Thrissur, India

Abstract:

Product refurbishment is one of the most profitable and environmental benefit processes, drawing more and more attention from both product manufacturers and customers. Reverse Logistics (RL) is the basis of the process that returning products from their consumer destination to capture their value or proper disposal. The RL process is inherently a value-added activity in which the values of previously shipped parts, materials and products are recaptured. The RL operations, therefore, add significantly to the value chain by considering the reverse flow that is capable of adding value to the products and generating a competitive advantage for companies. This research project focuses and optimizes the process of product refurbishment, considering inventories and uncertainties. A multi-period model is established. To deal with the uncertainties, an innovative fuzzy controller embedded with a quality indicator is proposed. Fuzzy controllers have been proposed for physical systems which do not lend themselves to easy and accurate mathematical modeling and crisp variables, and therefore, cannot be tackled by traditional strictly analytic control design techniques. Instead, control variables are represented by fuzzy variables which let the level of uncertainty of the variables be modelled in a systematic way. Numerical experiments have been carried out to test and demonstrate the optimization quality of the proposed method. The generic model prepared is further taken into apply in a selected industry. The objective in this paper is to give a comparative review of these resources and techniques, and introduce the reader to the state of knowledge in fuzzy controller design research and education in subjects such as fuzzy set theory, fuzzy logic, fuzzy ruled based expert opinions. The results of numerical experiments proved the effectiveness of the proposed fuzzy controller that can deal with the uncertainties of supply and demand in an efficient way. Hence to suggest an effective way to optimize the total cost, this framework helps to determine the total cost and factors and how the return process of products/parts works. Also the managerial implications and future research directions are provided.

***Index Terms* - Optimization, Refurbishment, Fuzzy controller, Sustainability**

1. INTRODUCTION

Product recovery is one of the most popular research fields in Closed Loop Supply Chain (CLSC). The processes of product recovery include product recycling, remanufacturing, refurbishment, reuse, resell, etc. Among these processes, product refurbishment is one of the most profitable and environmental benefit processes, drawing more and more attention from both product manufacturers and customers.

The process of products refurbishment starts from the collection of returned products. In the collection center, companies have to make decisions of collect or not for each returned product. Additionally, if customers trade in their used products for brand new ones, companies also have to decide the trade in allowance. The simulation network in this project provides decision supports for these decisions, considering each returned product's quality and the inventory level. It helps companies minimize the total inventory costs and maximize customer profitability simultaneously. In the process of product refurbishment, one of the important and complicated problems is the uncertainty of both the demand and supply.

Besides of reduction in total cost, Improved life cycle management of electronics, through source reduction of materials used, increasing reuse, refurbishing, extending the life of products, and recycling of electronics, can reduce the total quantity of waste that needs to be managed domestically and globally.

2. LITERATURE REVIEW

One of the earliest definitions of reverse logistics (Lambert and Stock 1981) described the process as one that goes the wrong way down a one-way street because the majority of product shipments flow in one direction. As time moved on, more sophisticated definitions began to emerge, and Rogers and Tibben-Lembke (1998) defined reverse logistics as “the process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value, or proper disposal”. The methodology followed in the study was, the empirical work involved collecting data using three different approaches during a 12-month period from the middle of 2003 to the middle of 2004. The study conducted in United Kingdom (Michael Bernon& John Cullen, 2007)

The objective of study (MohdRizaimyShaharudin, Kannan Govindan, SuhaizaZailani, KeahChoon Tan, Mohammad Iranmanesh, 2017) represents, CLSCs’ implementation is highly encouraged by the Malaysian government for the sake of achieving the developed nation status and the realization of the country’s sustainability objectives. Most of the studies have focused on the causes on why customers are sending back products. Hence, it is difficult to recognize the role of product returns and this study is expected to provide a better insight of the importance of product returns towards the adoption of CLSCs and the achievement of sustainability in the operations..

Another study put forwards lights on the interactions of strategic and tactical decisions in the context of designing a CLSC network and DLB under uncertain environment. To cope with the issue of uncertainty, a two-phase interactive fuzzy programming procedure has been applied. In the first phase, the original model is converted into an equivalent auxiliary crisp model by applying two different defuzzification approachesby introducing an efficient CLSC network design model that integrates strategic (e.g., the quantity of flows between facilities and purchasing) and tactical decisions (e.g., refurbishing and disassembly line balancing) simultaneously under uncertainty. After that Comparing two techniques that transform the fuzzy multi-objective model into the auxiliary crisp multi objective model on a CLSC network design problem. (ErenÖzceylana&TuranPaksoya, 2013)

There is no single optimal solution that can optimize all the objective functions simultaneously, decision makers usually look for the “most preferred” solution.. In this study, the constraint method is also applied to solve the MOMILP model first. Then, in order to select the “best” compromised solution among the Pareto-optimal solutions, two interactive fuzzy methods are further considered. The main findings of this paper can be summarized as, general, but practical network structure supporting multiple recovery options, like repair, remanufacture, redistribution, and recycling, was proposed. Such a configuration catered to the relationship between environment protection and social development. The constraint method and two interactive fuzzy methods were adopted to solve the multi-objective network design problem. Furthermore, the proposed multi-objective methods were compared in detail to provide more insights into their relations, which was exactly verified by the numerical experiments. And from the view of the managerial decision, this paper also provided valuable strategic and tactical references on how to promote the economic benefit of the enterprise while achieving sustainable development.(Guanshuang Jiang, Qi Wang , KeWang , Qianyu Zhang and Jian Zhou, 2020)

3. RESEARCH METHOD

For the study first identified and selected an industry where there is Returns of product applicable. Developed a mathematical model considering the whole factors. Incorporating a fuzzy controller to deal with the uncertainties. Developing a Simulation, while the model of the inspected system is a non-linear multi period integer programming, that cannot be solved by mathematical algorithm

Data

The sincerity of answering questionnaire considered to be 100% by motivating them to respond according to the reality. The project is proposed for handle the uncertainties. The customer who trades their consumed products to company either for updating or to sell it away. The firm give importance to the customer who trades their products to company to upgrade with new one. because they use the services of the company for another period of time. In the process of product refurbishment, returned products will be disassembled into returned components. These returned components will be tested and classified as relatively good quality and relatively poor quality. The relatively poor-quality returned components will go through further processing, while relatively good quality components will be refurbished and assembled into refurbished products.

Two steps are considered during the process of refurbishment. Multi periods are occupied in this problem. Period t is considered for example. In period t, first step is implemented as in the decision center. If customers simply return used products, then can decide collect it or not. If customers trade in used products for brand new ones, then decide the trade in allowance. In period t + 1 , disassemble workstations disassemble collected returned products from period t into returned components. Meanwhile, refurbishment work stations produce the refurbished products using returned components from period t. After refurbishing and quality tests, the finished products, called certificated refurbished products, are sold to fulfill the demands of customers.

4. MATHEMATICAL MODEL

The mathematical model consists of indices, parameters and decision variables are shown as follows.

The indices:

p	returned product p
q	returned product q
t	time period t

Parameters:

rc_p	unit refurbishing cost of returned product p
dc	unit disassembly cost of each returned product
n	the quantity of returned products in consideration batch
R_p	quality vector of returned product p
vc_q	unit inventory cost of returned component q for each period
vq_q^t	inventory quantity of component q in period t
Q_t	returned quantity of returned products in period t
D_t	customer demands of finished products in period t
rvc	unit inventory cost of each returned product for each period
rvq_t	inventory quantity of returned products in period t
fvc	unit inventory cost of each finished product for each period
fvq_t	inventory quantity of finished products in period t
rsc_q	unit shortage cost of component q
fsc	unit shortage cost of finished product
rsq_q^t	shortage quantity of component q in period t
fsq_t	shortage quantity of finished products in period t
rq_t	the quantity of refurbished products in period t
dq_t	the quantity of disassemble products in period t
$reduq_q^t$	the quantity of component q reduced in period t
$incrq_q^t$	the quantity of component q increased in period t

Decisions Variables:

$$x_i^t = \begin{cases} 1 \; if\ returned\ product\ i\ is\ refurbished\ in\ period\ t \\ 0 \; otherwise \end{cases}$$

Objective function,

Min. $TC= PC+IC+SC$ (1)

$$PC = \sum_{p=1}^{n} dc\,.(1 - x_i^t) + \sum_{p=1}^{n} x_p . R_p \quad (2)$$

$$IC = \sum_t \sum_q vq_q^t + vc_q + \sum_t rvc.rcq_q + \sum_t fvc.fcq_t \quad (3)$$

$$SC = \sum_t \sum_q rsc_q . rsq_q^t + \sum_t fsc.fsq_t \quad (4)$$

The total cost includes the processing cost in both the disassembly workstation and the refurbishing workstation, the inventory cost of returned components, renewable products and finished products, and also the shortage cost of returned components and finished products. The processing costs are shown in Eq. *(2)* . Eq. *(3)* displays the inventory costs and Eq. *(4)* indicates the shortage costs.

And these equations are subjected to,

$$Q_t = rq_t + dq_t \quad (5)$$

$$\sum_n x_p^t = rq_t \quad (6)$$

$$\sum_p (1 - x_p^t) = dq_t \quad (7)$$

$$vq_p^{t+1} = vq_p^t - reduq_p^t + incrq_p^t \quad (8)$$

$$fvq_{t+1} = fvq_t + rq_t - D_t \quad (10)$$

Fuzzy controller

A fuzzy control is a control system based on fuzzy logical and mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0.

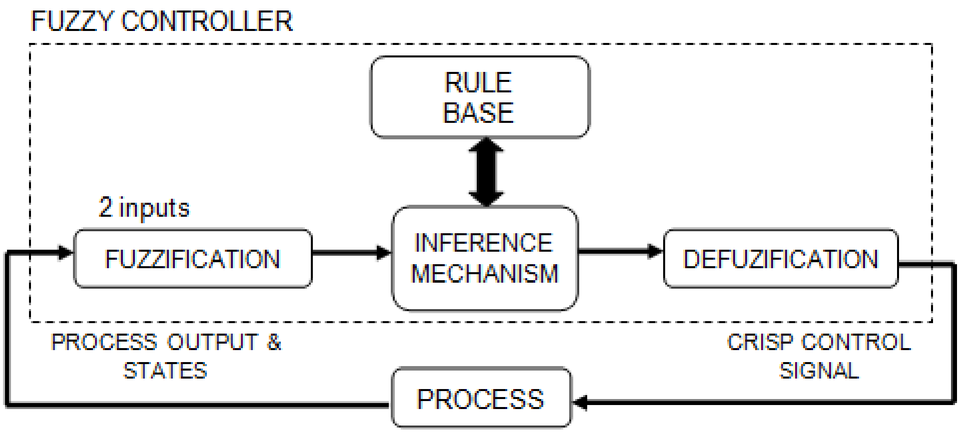

Fig. 1 Fuzzy Controller

Mamdani method is the type of fuzzy controller widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human like manner. Hence it is widely used in particular for decision support application. The supply in this system is the quantity of returned products which is further compared with the expert knowledge and database.

Fuzzy rules are the basis of inference. The focus is on the uncertainty of the returned products and demand. In this part, a finished refurbished returned product is assembled from the returned components. To deal with the uncertainty of supply and demand, a fuzzy controller is implemented for the solution

D: the total demand of the finished refurbished products (L, RL, N, RH, H).

FRE: the inventory level of finished refurbished products (L, RL, N, RH, H).

RRE: the inventory level of returned products (L, RL, N, RH, H).

Here, L means low,
RL means relatively low,
N means normal,
RH means relatively high,
H means high.
IND: the indicator of the fuzzy controller (VL, L, RL, N, RH, H, VH).
Here, VL means very Low,
L means low,
RL means relatively low,
N means normal,
RH means relatively high,
H means high,
VH means very high

In the defuzzification process, the center of area method is selected. The center of area method is the most commonly used technique. It determines the center of area of membership function, and can work efficiently with three inputs fuzzy controller in this simulation. The general equation is,

$$Y = \frac{\sum_{q=1}^{N} w_q \overline{C_q A_q}}{\sum_{q=1}^{N} w_q \overline{A_q}} \quad (10)$$

5. RESULTS AND DISCUSSIONS

The Mathematical modelling is done using the above equations and developed a SIMULINK (matlab) by considering each segment. Also incorporated the fuzzy controller to help in decision making during uncertainties. The model is shown below,

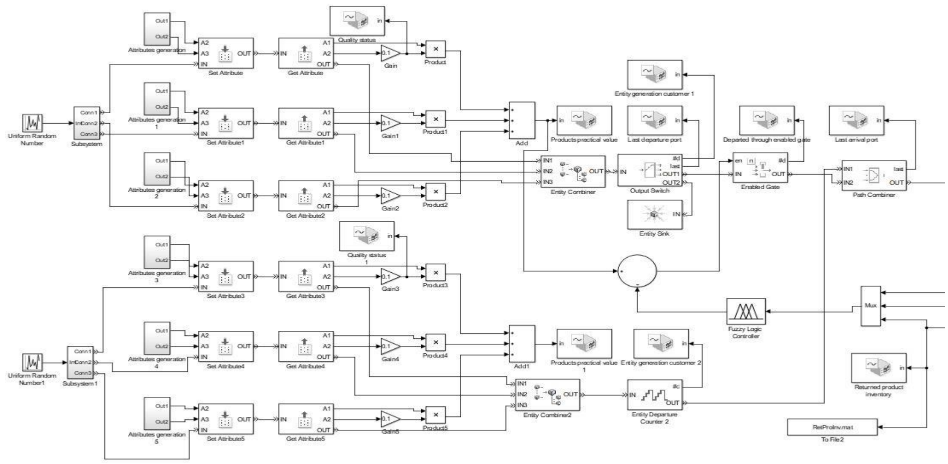

Fig. 2 Simulink Model Part 1

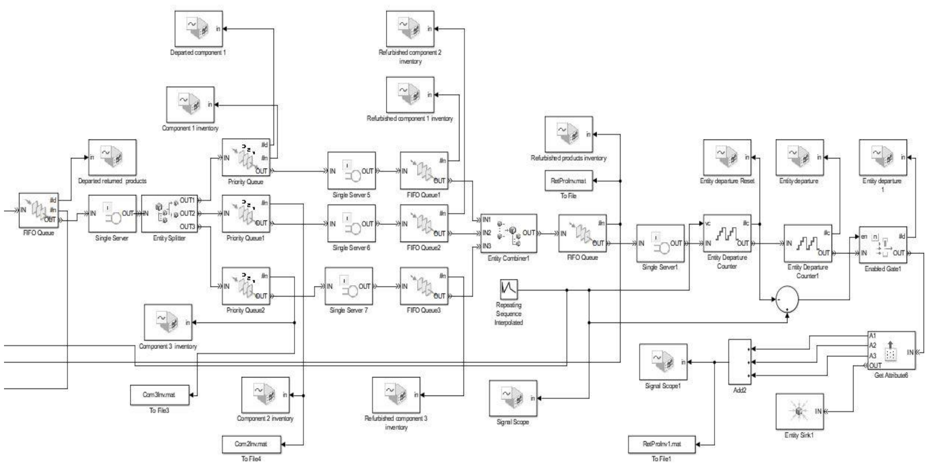

Fig. 3 Simulink Model Part 2

The objective of this simulation experiment is to demonstrate the effectiveness of the proposed fuzzy controller. Using the input data, the results of indicators are shown in Fig. 4, which is the fuzzy controller output. Fig. 5 shows the inventory level of refurbished products. The profits of each sold refurbished products are shown in Fig. 6. From Fig. 4, it can be seen that the demands in the first 10 s keeps zero. Since this period of time is for inventory accumulation, the inventory of refurbished products and returned products increase rapidly. From Fig. 5 and Fig. 6, it can be seen that in the first 110 s, named the first period is the warm up period. After the first 110 s, which means at the beginning of the second period, the fuzzy controller starts a nearly regular change. The inventory level of refurbished products reached a nearly stable level. Fig. 6 shows the data after the warm up period, called stable periods.
The fuzzy control output after simulation is recorded as,

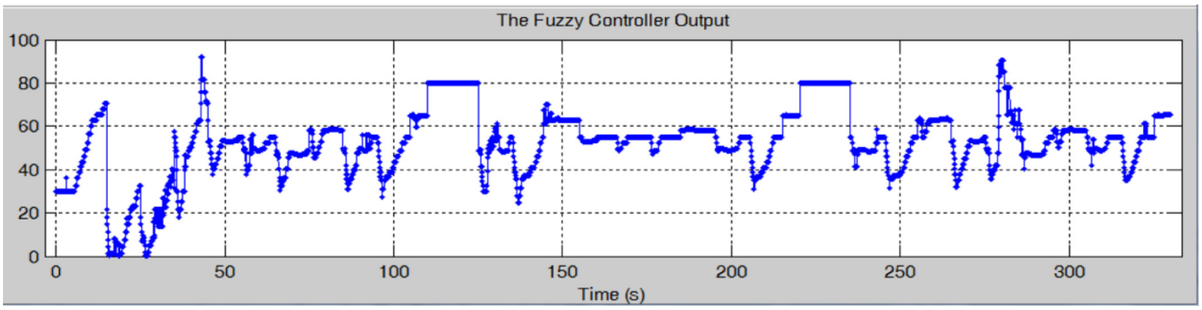

Fig. 4 . The fuzzy controller output.

From the graph we can see, the variations according to the time and the acceptance level from the Y axis. The quality level gets changed according to fluctuations in demand.

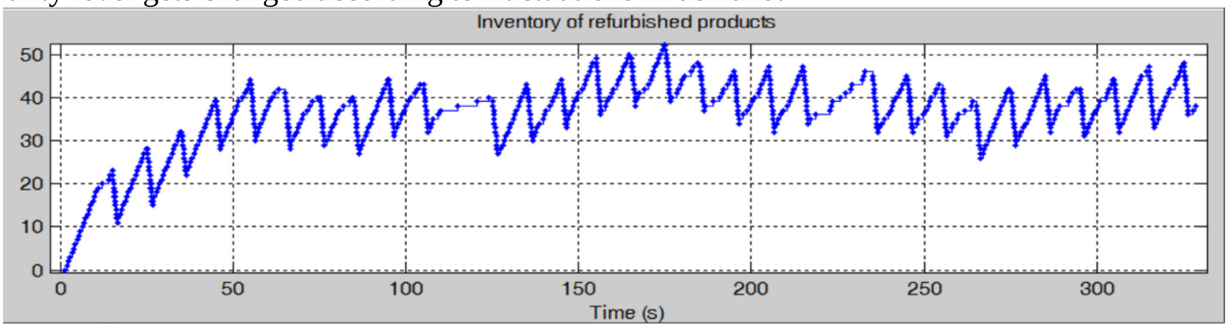

Fig. 5. Inventory of refurbished products.

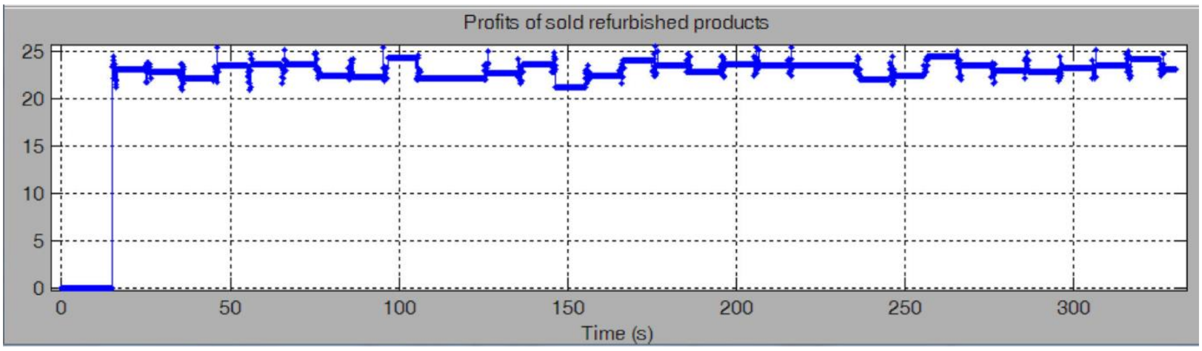

Fig. 6. The profits of each sold refurbished products.

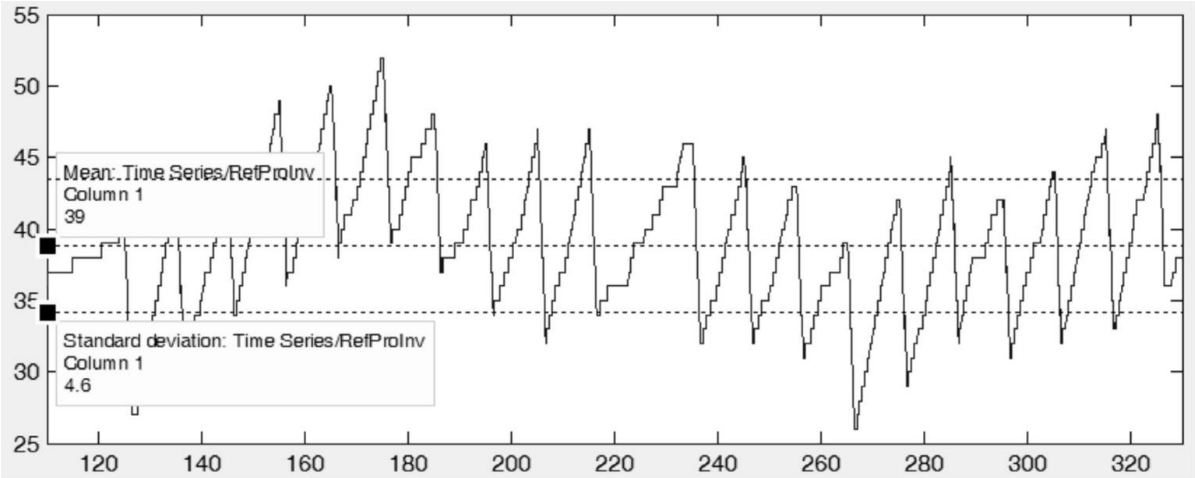

Fig. 7. The refurbished products inventory of stable periods.

From the Fig. 7, it can be seen that the mean of refurbished products inventory is 39, the standard deviation is 4.6, which means the proposed fuzzy controller effectively controlled the inventory level around 39 and the volatility is 4.6.

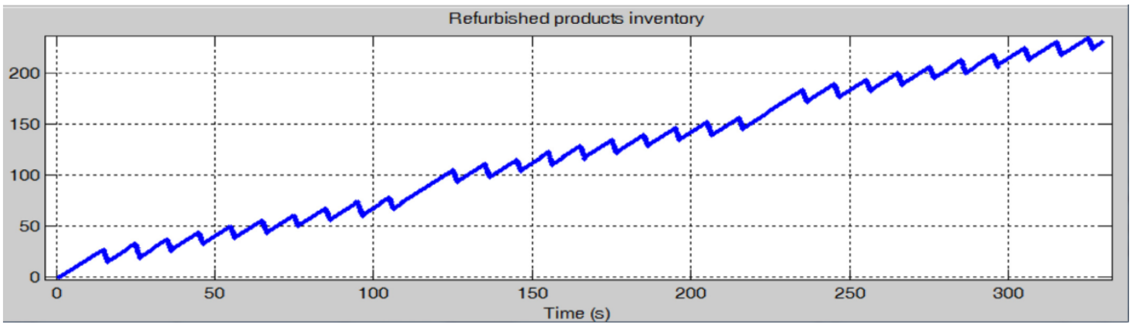

Fig. 8. The inventory of refurbished products.

To compare Fig 4, 7 and 8, it can be seen that the refurbished products inventory can be controlled at a stable level with fuzzy controller. While without fuzzy controller, the inventory level rises straightly.

5.1 MANAGERIAL IMPLICATIONS IN THE SOUTH EAST ASIAN CONTEXT

Results have clearly rectified the effect of equipping refurbishment along with existing production system. The costs associated with production and manufacturing process may differ along with different regions. The acceptance level of quality may vary according to the market demand of returned products. This approach helps to reduce a good number of electronic wastes in society. The practice of refurbishment process is difficult to implement but if it get succeed the company can make a huge profit, and also customers can buy good quality used products.

5.2THEORETICAL IMPLICATIONS

The survey conducted among 3 leading laptop / desktop manufacturers and service centres. The value of the product gets changes and the number of damaged or returned pieces remains uncertain. This paper opens a future scope for scholars to conduct the survey study on different industries and put a benchmark or common model which is applicable for the similar industries by changing parameters. This study shows that the definitions, models, and determinations of the elements in refurbishment process affect our understanding of how the product accepted or not, and especially related to diversification. Simulink model should include each and every aspect of a supply chain process in order to achieve maximum efficiency.

6. CONCLUSION

Due to environmental issues, product refurbishment is becoming more and more important nowadays. Optimization of products refurbishing process in closed loop supply chain needs to be studied. However, in the literature, few papers focus on this problem. In the process of returned products refurbishment, the uncertainty of the quantity and quality of the returned products makes the problem much more complicated.

This model structures and optimizes the process of product refurbishment, considering inventories and uncertainties with multi periods. Additionally, a novel fuzzy controller with value indicator is proposed to solve the uncertainty of the returned products quantity considering the various qualities. The simulation results of numerical experiments prove that the proposed fuzzy controller can solve this multi-period uncertainty

problem in an effective way, especially with the quality indicator, which enhances the ability of the proposed fuzzy controller in dealing with uncertainties in both quantity and quality.
The study focused on achieving green manufacturing practices thereby improve the sustainability. If the firm and product is more responsible with environment, it can impact positively to a good image customer. The person who seeks good functional products will go for the refurbished products and he can buy the same products almost in 25 percentage reduction of its market price. It makes customers attracting and also who trades their products to buy a new one which is more focused due to the long-term commitment of customer with the firm.

7. REFERENCES

1. S. Jorjani , J. Leu , C. Scott , Model for the allocation of electronics components to reuse options, Int. J. Prod. Res. 42 (6) (2004) 1131–1145 .
2. W.H. Tsai , S.J. Hung , Treatment and recycling system optimisation with activi- ty-based costing in WEEE reverse logistics management: an environmental supply chain perspective, Int. J. Prod. Res. 47 (19) (2009) 5391–5420.
3. S.H. Amin , G. Zhang , A three-stage model for closed-loop supply chain configuration under uncertainty, Int. J. Prod. Res. 51 (5) (2013) 1405–1425 .
4. M. Chouinard , S. D'Amours , D. Ait-Kadi , A stochastic programming approach for designing supply loops, Int. J. Prod. Econ. 113 (2) (2008) 657–677.
5. T. Davis , Effective supply chain management, Sloan Manage. Rev. 34 (4) (1993) 35.
6. E. Simangunsong , L.C. Hendry , M. Stevenson , Supply-chain uncertainty: a review and theoretical foundation for future research, Int. J. Prod. Res. 50 (16) (2012) 4493–4523.
7. R. Mason-Jones , D.R. Towill , Shrinking the supply chain uncertainty circle, IOM Control 24 (7) (1998) 17–22.
8. C.J. Vidal , M. Goetschalckx , Strategic production-distribution models: a critical re- view with emphasis on global supply chain models, Eur. J. Oper. Res. 98 (1) (1997) 1–18 .
9. E. Ozceylan , T. Paksoy , Interactive fuzzy programming approaches to the strategic and tactical planning of a closed-loop supply chain under uncertainty, Int. J. Prod. Res. 52 (8) (2014) 2363–2387 .
10. D. Nakandala , H. Lau , J.J. Zhang , Optimization model for transportation planning with demand uncertainties, Ind. Manage. Data Syst. 114 (8) (2014) 1229–1245.
11. Y. Zhou , et al. , Closed-loop supply chain network under oligopolistic competition with multiproducts, uncertain demands, and returns, Math. Prob. Eng. 2014 (2014) 1–15.
12. S. Behdad , A.S. Williams , D. Thurston , End-of-life decision making with uncertain product return quantity, J. Mech. Des. 134 (10) (2012) .
13. D. Kumar , et al. , A fuzzy logic-based decision support system for evaluation of sup- pliers in supply chain management practices, Math. Comput. Modell. 57 (11-12) (2013) 2945–2960. M.H.F. Zarandi , S.V.
14. Moosavi , M. Zarinbal , A fuzzy reinforcement learning algorithm for inventory control in supply chains, Int. J. Adv. Manuf. Technol. 65 (1-4) (2013) 557–569.
15. H.-d. Wan , V. Krishna Gonnuru , Disassembly planning and sequencing for end-of-life products with RFID enriched information, Rob. Comput. Integr. Manuf. 29 (3) (2013) 112–118 .