HYBRID INVENTORY MANAGEMENT FOR MANUFACTURING-REMANUFACTURING PROCESS (A LITERATURE REVIEW)

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Abstract

Inventory management deals with determining the exact time and quantity of order to support the production plan. Excessive inventories incur extra cost while insufficient inventories can ruin the production schedule, hurting both the strategic value elements of delivery dependability and speed. This indicates that inventory is a crucial element of the production process.
This literature review is addressed to the management of inventory in manufacturing process as well as the one in remanufacturing separately, and at the end, the inventory management in system where manufacturing and remanufacturing process occur simultaneously. Recommendations for future work are proposed at the end of this review.

Keywords: Manufacturing, Remanufacturing, Inventory Management.

INTRODUCTION

Environmental concern of waste materials and product disposals has encourage some manufacturers to operate their businesses more efficient while minimizing waste. This purpose could be achieved by collecting product disposals from their customers after used. Then, the returned products is remanufactured and sold again as good as new product to customers.
As the returned product is uncertainty and not all of them is remanufactured then the company still need to produce new products to fulfil their customer demand. The manufacturers want to put both manufacturing and remanufacturing together in one system. Hence, the problem comes how to manage the inventory from both production line of manufacturing and remanufacturing in order to minimize inventory cost.

Inventory management deals with determining the exact time and quantity of order to support the production plan. Excessive inventories incur extra cost while insufficient inventories can ruin the production schedule, hurting both the strategic value elements of delivery dependability and speed. This indicates that inventory is a crucial element of the production process.
Numerous studies have been investigated by researchers in the area of the application inventory control both for manufacturing as well as remanufacturing. Each system has advantages and disadvantages. Some researchers have examined the possibility for joining the systems by considering their advantages and disadvantages (Aras 2006, Inderfurth 2002, Kiesmuller 2003, Konstantaras 2007, Van der laan 1999 and 2003). The combination of the systems is very essential since the increasing trends for reducing new product in inventory as well as increasing the use of used product.

This review is addressed to the management of inventory in manufacturing process as well as the one in remanufacturing separately, and at the end, the inventory management in system where manufacturing and remanufacturing process occur simultaneously. Recommendations for future work will be proposed at the end of this literature review.

INVENTORY MANAGEMENT IN MANUFACTURING

Nowadays, inventory management has emerged such complex system varying decision variables. The policy for using periodic review or continuous review with options of PULL system or PUSH system is one of the decision should be made to optimize inventory control. Besides, the stochastic demands and uncertain lead time also be considered as key factors in this area to build a good inventory system to minimize cost.

Some optimization techniques have been developed to solve these complex systems from simple procedure to the hard one. One of them is Minimax distribution free procedure that can be used for periodic review inventory control where lead time and setup control are treated as not constant (Chung 2004). In addition, Ching (1998) also develop an inventory model which suitable for determines optimal policy by considering

delivery time. Furthermore, as the inventory problems become more complex, the use of evolutionary computational such as multi-objective electromagnetism-like optimisation (MOEMO), multi-objective particle swarm optimization (MOPSO) and evolutionary pareto optimizers also have been developed. For example, how to determine lot sizing and safety stock in a continuous review inventory control policy where lead time is normally distributed can be solved using evolutionary Pareto optimizers (Tsou 2008).

INVENTORY MANAGEMENT IN REMANUFACTURING

The increasing trends of human concern on environmental issues and economic reason make remanufacturing process become famous recently. It is also supported by environmental laws that applied in many European and other countries in the world. The content of this law is that a company has responsibility for managing used product after consumed (van der Laan, et.al. 1999). Due to the decreasing handling cost of waste material, it is important to recycle or recovering value waste material as good as new product that it called by remanufacturing product (van der Laan, Fleischmann and Dekker 2003). This system can be called reverse logistics. Fleischmann et al. (in Sbihi and Eglese 2007) mention that reverse logistics includes the process of modification used manufactured goods to become valuable and marketable product. Konstantaras and Papachristos (2007) and van der Laan, Fleischmann and Dekker (2003) also explain that remanufacturing is the recycle process that consists of "disassembly, cleaning, testing, and re-assembly" to upgrade the quality product close to the new one.

Recently, inventory management in the framework of remanufacturing and product recovery has been addressed by many researchers as it is expected to achieve the target of sustainable development. Despite of its advantages, remanufacturing also has its drawback as pointed out in some publications.
Toktay, Wein and Zenios (2000) revealed that the management of inventory in remanufacturing becomes complicated by the return flows of used product from the customer into remanufacturing operation. Consequently, products that are in customer-use stage be regarded as inventory - a crucial component in supply chain. However, the inventory at this stage can not be detected by the manufacturer. In this stage, how long the product's stay with the customer equals the lead time, and the quantity of products that are returned is the yield. The lead time, the yield, and the on-hand inventory associated with a given stage are key pieces of information in production planning and inventory management decisions. However, in the customer-use stage of a remanufacturing supply chain, these quantities are not available directly.

The complexity and other variety of problems caused by remanufacturing also mentioned in Guide (2000). In line with that, van der Laan et al. (1999) in their analysis of the effects of remanufacturing in PUSH and PULL controlled production/inventory systems have affirmed that efficient planning and control in remanufacturing systems tends to be more complex than in traditional systems without remanufacturing.

Nevertheless, although remanufacturing seems obscure the inventory management, Muckstadt and Isaac (cited in van der Laan et al. 1996) introduce production planning and inventory control models in which remanufacturing process is modelled by a multiple server queuing system, with stochastic remanufacturing lead-times. This model is relevant to the situation with remanufacturing.
The authors deal with policies in the context of two inventory facilities, one of new products and the other is remanufactured items. The model is based on unit demand and unit returns with independent Poisson processes. For this system they consider three different procurement and inventory control strategies i.e., the (sp, Qp, sd, N) strategy, the (sp, Qp, sd) strategy, and the (sp, Q, AJ) strategy. The control parameters in these strategies relate to the inventory position at which an outside procurement order is placed (sp), the inventory position at which returned products are disposed of (sd), the outside procurement order quantity (Q,), and the capacity of the remanufacturing facility (N). For each of the strategies they derive exact expressions of the total expected costs as functions of the control parameters.

Muckstadt and Isaac consider a system that applies to a situation with stochastic remanufacturing lead times, determined remanufacturing capacities, and nonzero outside procurement lead times. Further, fixed outside procurement costs and backordering costs are included in the cost function. On the other hand, fixed remanufacturing costs are disregarded, and the option of product disposal does not exist. The system is controlled by a two-parameter (sp, Qp) PUSH-policy, where sp is the inventory level at which an outside procurement ordering of size Qp is placed.

Additionally, Mahadevan, Pyke and Fleischmann (2003) and van der Laan et al. (1996) also discuss models that suitable for the inventory in remanufacturing. In more complicated system with stochastic demand and lead time, van der Laan et al. (1996) make a numerical comparison between two replenishment policies, namely PUSH and PULL. Both the PULL and PUSH policies (with and without disposals) assume that the lead times for manufacturing and remanufacturing are constant and equal.

However, not all manufactured products can meet costumer needs. This can be caused by the uncertainty of demand, lead time, and the quantity of remanufacturing that can be provided. Consequently, companies must produce new products to meet consumer demand.

JOINT MANUFACTURING AND REMANUFACTURING

In order to meet market demand, many companies today have a tendency to coordinate their remanufacturing operations with the manufacturing process. Manufacturing-remanufacturing hybrid system may involve common facilities shared by two separate processes or facilities that are managed in an integrated manner. Sharing facilities where manufacturing and remanufacturing processes occur simultaneously is expected to increase to obtain the benefits associated with a higher overhead costs reduced and the utilization of assets (Aras, Verter and Boyaci 2006).

Aras, Verter and Boyaci (2006) in reporting Geyer and Wassenhove study mentioned that the ratio of demand that is met by remanufactured products is typically between 0.25 and 0.75. The similar research has also been conducted by Ketzenberg et al. (cited in Aras, Verter and 2006). They use the same range of values for the return ration- i.e., the proportion of sold items returned by the end-users. Unless a product is in the process of being phased out, the end-user demand rate is normally more than the return rate of used products. Consequently, company has to produce the new product to satisfy the costumer demand. Therefore, to satisfy the entire demand by remanufacturing alone is impossible, and hence joint management of hybrid systems is a necessity.

The next sub-section will be focused on the management of inventories in hybrid manufacturing-remanufacturing process.

HYBRID INVENTORY MANAGEMENT FOR MANUFACTURING-REMANUFACTURING

In recent years, the management of inventories in hybrid manufacturing-remanufacturing systems becomes such interesting issue that keep growing. The combination of manufacturing and remanufacturing is called by hybrid manufacturing and remanufacturing. The main problem is how to manage the inventory system with combination between inventory of manufacturing and remanufacturing. In this system, remanufacturing inventory integrates with the manufacturing inventory and becomes one system, hybrid inventory management. Remanufacturing process becomes the main production to fulfil the customer's demand. If the finished goods from remanufacturing process can not satisfy the costumer's need, production of new material is conducted (Kiesmuller, 2003, Inderfurth, 2002, van der Laan, Fleischmann and Dekker, 2003).

Inventory management in a joint system of manufacturing and remanufacturing is relatively complex as a result of the return flow of products from end-users to the upstream level of the system. Since remanufacturing a used product cost less than manufacturing a new one, it may seem that fulfilling all the demand by remanufacturing is the best way (Aras, Verter and Boyaci 2006). In support, Kiesmuller (2003) pointed out that remanufacturing process should become the main production to fulfil the customer's demand.

There are some inventory control policies that already done by previous researchers concerning the combination of inventory in manufacturing and remanufacturing. Kismuller (2003) investigate the using of PULL system to solve the problem of combination between manufacturing and remanufacturing inventory to get the optimal performance. He classifies the system based on the lead time. In system with larger remanufacturing lead time, production quantity is determined first followed by how many recycled products will be ordered by considering net stock, and all outstanding production and remanufacturing order. However, in system with larger manufacturing lead time, manufacturing quantity is also decided first, but it also needs to consider the recoverable on-hand inventory.

At the same time, Van der Laan, Fleischmann and Dekker (2003) describe a more detail quantitative model for inventory in the joint systems (Figure 1).
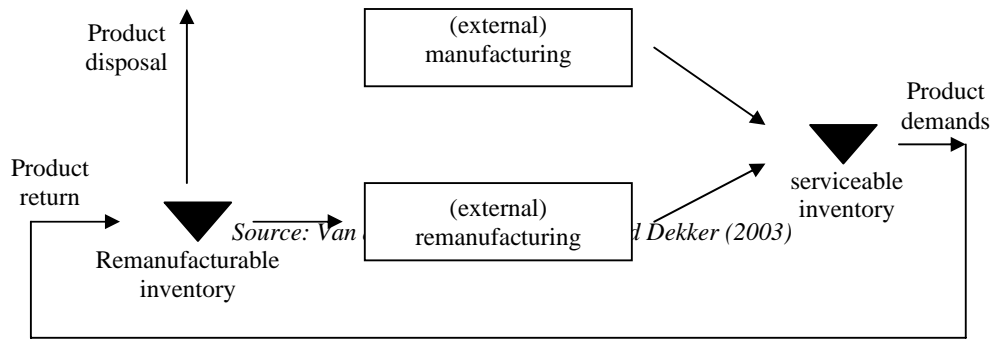
Figure 1   A hybrid system with manufacturing and remanufacturing operations, and
stocking points for remanufacturables and serviceable

The model is satisfied the criteria developed and allows investigating various control policies on several conditions such as stochastic lead times and correlation between return and demand flows. In other words, the description of the model can be explained as the demand and return processes are stochastic and this can be modelled by Markovian arrival process. In case of product disposal, there are two scenarios, first, if disposal of product is not allowed than an assumption of return intensity (the average number of returns per unit of time) is less than demand intensity and vice versa (Van der Laan, Fleischmann and Dekker 2003). Also, the framework enables to investigate the influence of other system parameter, such as the holding cost structure. It was also figured out that characterization of manufacturing and remanufacturing lead time plays a significant role in controlling policy.

Furthermore, Inderfurth (2004) pointed out the system of hybrid inventory management in manufacturing and remanufacturing as can be seen below:
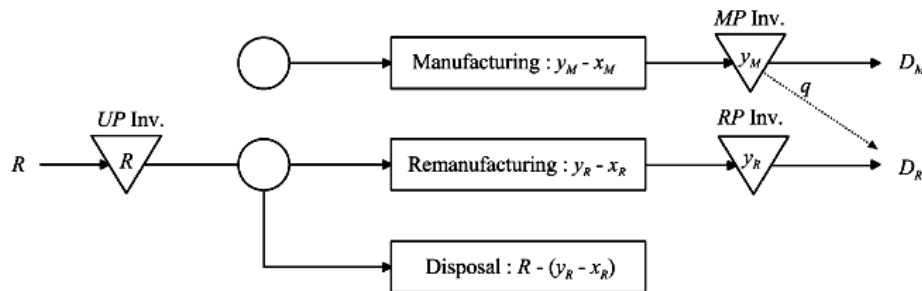

Figure 2   Hybrid manufacturing/remanufacturing system
Source: Inderfurth (2004)

It can be seen from the diagram that used product is accumulated in used product inventory (UP Inv.) until remanufacturing process start. Used product that suitable with the standard is continued to remanufacturing process, however used product that have under quality standard is collected in disposal. The result of remanufacturing process is collected in RP Inv. If the RP can not fulfil all the market demand, company produce new product and it is collected in MP Inv then combine with RP inventory to satisfy market demand.

In addition, Inderfurth (2004) observes 'single-stage single-period problem with independent stochastic demand' which both of manufacturing and remanufacturing has deterministic lead time. He also determines the system based on lead time but with different decision. First, if the system has shorter manufacturing lead time, remanufacturing product is processed first and followed by manufacturing process. Second, conversely, if the remanufacturing lead time is shorter than manufacturing lead time, manufacturing process has to be started under the uncertainty of the number of recycle product. In brief, the problem analysed is regarding coordination and optimization of decision in manufacturing/remanufacturing for certain selling policy.

Other researcher, Aras, Verter and Boyaci (2006) develop a model of a hybrid system where the quality of the returns is uncertain. They integrate an explicit representation of the manufacturing facility, including a raw material/new component inventory stocking point. In order to highlight the impact of remanufacturing uncertainties, they model manufacturing with constant unit processing costs, and constant procurement and

manufacturing lead times. This basic setting is shown via a simulation-based optimization framework, which two prioritization strategies priority-to-manufacturing (PTM) strategy and priority-to-remanufacturing (PTR) strategy be compared. If priority is given to manufacturing, a replenishment order is placed first with the manufacturing facility and remanufacturing is used only when manufacturing is not possible due to insufficient inventory of new components. They refer to this strategy as priority-to-manufacturing (PTM) strategy in the sequel. The alternative strategy is the priority-to-remanufacturing (PTR) strategy, which (as in existing models) places a replenishment order to remanufacturing and resorts to manufacturing only if the remanufacturable inventory is empty.

The most recent research that was conducted by Konstantaras and Papachritos (2007) also investigates the problem solving to combine manufacturing and remanufacturing in one system but use a different method. They use periodic review inventory with constant demand. The difference of this method compared to the previous method that mentioned above is that consumer's demand is satisfied only by either manufactured or remanufactured product in each period. The first certain periods in the horizon is satisfied by remanufacturing product first, and the rest of horizon fulfilled by manufacturing goods. In addition, they considered policies for certain manufacturing and remanufacturing set up and establish holding cost stability regions for interim period as an interval for the two holding cost parameters.

IDENTIFICATION OF CURRENT LIMITATIONS

The existing inventory management for manufacturing process only, is inadequate for hybrid process which includes manufacturing and remanufacturing process together. Therefore, a new development of inventory management for this complex system is needed to find the most optimal policy.

There are several different models with some assumptions have been discussed above. In spite of advantages of each model, there are limitations for each model as well. Firstly, the model developed by Kismuller (2003) is not suitable for dynamic model, because he only consider local properties as well as the model only applied for deterministic lead time. Secondly, in Van der Laan's (1999) model, the computational burden involved with the optimization of these strategies, and the four parameter strategy in particular, is considerably large and probably not very practical. Further, model developed by Van der Laan, Fleischmann and Dekker (2003) even though enables broader variety of control policies analysis but it was only applicable for specific situation and analysis for general situation is needed. Next, in Inderfurth's (2004) model, it was only suitable for single period and can only solve problem regarding system without downgrading. More research needed for extending the model so it can be applied in the multi period system that considers the downgrade product. Lastly, model developed by Konstantaras and Papachritos (2007) has drawback as they assume that sufficient return product is available in the beginning of production period. It is far from the realistic, that everything is probabilistic and stochastic. That is the reason why stochastic return product and the variability need to be considered for the future research.

CONCLUSIONS

Generally, the main objective of the models developed above is determination of control policy in inventory management of manufactured and remanufactured product. Some assumptions have been applied for different model but still there are other models with different assumption need to figure out. One of the model variations that is possible to developed is by using periodic review or continuous review with option of PULL and PUSH system. These model variations have not been discussed before. Therefore, a development of model by using PULL periodic system policy in manufacturing and PUSH continuos system policy in remanufacturing would be recommended for a future work. A simulation based optimisation could be conducted and the result from the simulated model could be analysed to evaluate its performance. It is also expected to show how the management of inventory in hybrid system can be analysed for continuous improvement opportunities using simulation.

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