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Research Article

An Optimal Remanufacturing Centre Selection Algorithm for Reverse Logistics Alliance

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Abstract: Reverse logistics has been an emerging field both in academic as well as in applied research since last two decades because of increasing consumer awareness, legislative initiatives and profits associated with reuse of products or components. The costs associated with reverse logistics are usually high and these need to be minimized. The current study focuses on the formulation of alliance for cost reductions in reverse logistics. Remanufacturing, refurbishing, repair, cannibalization and reuse are the processes which add value to the reverse logistics system and are capable of converting it into a profitable venture. Used products contribute a cheaper source of components and spares required to remanufacture a product because of the less costs associated with the labor and material resources when compared with the manufacturing of new parts or products. When a defective part is removed from a product or assembly, it can be restored to its original state of functionality. Instead of purchasing a new, the same can be restored from repair/remanufacture centre just replacing defective part with a new part or spare. Furthermore, for manufacturers to reduce investments in reverse logistics, the formations of alliance and sharing of facilities for remanufacturing can lead to more profitability. In this study a focus has been made for the formation of remanufacturing alliance and an algorithm has been formulated for the selection of optimal remanufacturing center for the reverse logistics alliance. A case company has been selected from emerging Chinese electronic manufacturing industry. The case has been solved by using data set of the selected company with the help of formulated algorithm.

Keywords: Optimal warehouse selection, remanufacturing alliance, remanufacturing facility, reverse logistics

INTRODUCTION

The Council of Logistics Management (CLM) has defined reverse logistics as "The process of planning, implementing and controlling the efficient and 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" (Rogers and Tibben-Lembke, 1999). Generally the reverse logistics is the method of transporting products from consumers (end users) to the manufacturer or OEMs for the purpose of repair, refurbishment, remanufacturing and recycling (recapturing value) or for waste disposal (Dowlatshahi, 2000). Efficient and controlled flow of goods from the manufacturer or origin to the point of end users has been the focus of logistics science since long. However the return flow of products for any particular reason is the new area for logistics management. This kind of flow is termed as reverse logistics. A reverse logistics system is the supply chain designed for the flow of parts or products destined for repairing, remanufacturing, recycling, reuse and proper disposal with intention to effectively use the resources. Currently the return of products has increased for almost all types of the products. According to Wadhwa *et al*. (2009), the return rates are as high as 20% for many of the products in different sectors. The reverse logistics system consists of a sequence of functions that creates a continuous system dealing with returned products until they are recovered properly or turned into scrap. Collection, inspection, cleaning, disassembly, testing and segregating, storage, transportation and recovery or disposal operations are the main functions of reverse logistics system (Beaulieu *et al*., 1999). According to Thierry *et al*. (1995) and Fleischmann *et al*. (1997), four kinds of basic reverse logistics classifications and networks are identified in the literature which includes recycling, reuse, re-manufacturing and repair service networks. Figure 1 represents the generic reverse logistics system.

Remanufacturing is a process in which used and defective products or items are recovered into the state of originality either by changing some parts of that

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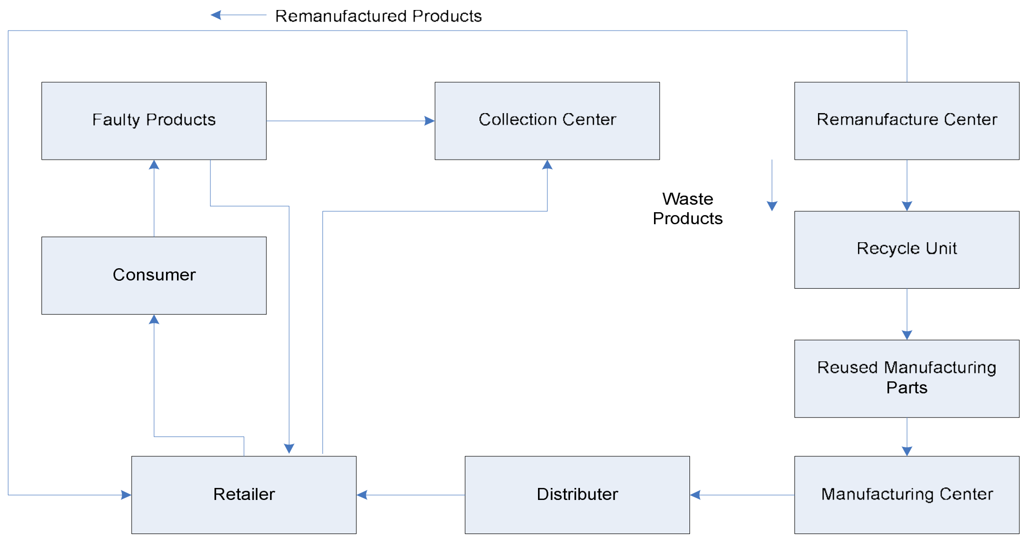

Fig. 1: Reverse logistics system under study

product or integrating new modules to the product. Lu and Bostel (2007) stated that, remanufactured or refurbished items or products can be sold in the market on some promotional offers depending on demand and supply situation. These refurbished items can even be sold in the same market as new products. It is also common for the companies to send these refurbished items or products to the underdeveloped or developing countries because of their less technological exposure or low buying power, African countries are the best examples for selling of refurbished Toyota cars.

Usually re-manufacturing processes are often carried out by the original manufacturer or OEMs because of the constraints of the technical expertise and product knowledge relevant to the products and specialized testing and manufacturing facilities at their premises. Thus, such a remanufacturing system can likely to be a closed-loop logistics system (Srivastava and Srivastava, 2006). By implementing remanufacturing strategy the companies not only can find the ways for managing the discarding of their used products but also gains a chance for efficient reduction in the costs of production. These companies can also contribute their share towards saving the raw material for our next generations.

The application of remanufacturing strategy in logistics system is not new; the auto parts industry may be the first to use this strategy in World War II. Remanufacturing of auto parts was encouraged to overcome deficiency of auto parts in world war II (Giuntini and Gaudette, 2004). Remanufacturing not only helps to save raw materials it also conserves a considerable amount of other resources to be used for manufacturing new products or parts. According to the APRA (Automotive Parts Rebuilder Association) approximately 50% of the original alternators and starters are recovered in the remanufacturing process in USA. This may result in saving of machine, material and human resources. ARPA estimated that the savings in raw material can be in tons worldwide if remanufacturing strategy is implemented in true aspects (Giuntini and Gaudette, 2004). Due to high rise in material and labour costs, the remanufacturing of used products is increasing. According to Rogers and Tibben-Lembke (1999) even the remanufacturing is being used in the manufacturing of spa crafts by NASA. In one of the main projects NASA used specialized remanufactured machine tools for manufacturing of the spacecrafts and other high-tech. machinery. According to a study to produce complex spherical components for spacecraft remanufactured machine tools were used by the main vendors of NASA. In this case the contractor chooses remanufacturing over purchasing new machine tools for manufacturing of cost effective parts. It was also claimed by Rogers and Tibben-Lembke (1999) that the cost saving can be 40 to 60% if remanufacturing strategy is applied properly. Owing to the expansion in market and global trades, it is somewhat difficult and remarkably unaffordable for companies to repair or remanufacture their returned products or parts at the manufacturing plants due to low volume of returns and high cost of transportation. Therefore, there is a need for remanufacturing facilities to be located near the main consumption points to make the reverse logistics system more efficient and cost effective across the globe. It is also not feasible for the manufacturer/OEM to build remanufacturing facilities worldwide to deal the remanufacturing processes for every product. Our proposed methodology is definitely helpful in reducing such difficulties for OEMs. In this study the focus has been made for establishing remanufacturing alliance across the world for multinational enterprises.

LITERATURE REVIEW

In today's market there are many successful manufacturers which are providing significant after sale services to their customers. It has been reported by Vlachos and Dekker (2003), the Dell computers, Saturn automobile and Caterpillar are the exemplary companies which are effectively providing after sale services to their customers. Dell being the leading manufacturer of computers provides the quick repair services. Saturn is also well reputed amongst its customer due to its after sales services and has the highest record of repeat customers. Similarly Caterpillars has a global network for spare parts delivery. There are also worst examples of companies in emerging automobile markets in the world. None of the automobile company got success in market except Toyota, Honda and Suzuki in Pakistan. Main reasons behind are the poor quality of after sales services, unavailability of spare parts and non existence of efficient reverse logistics system. Besides the government supports and even subsidies in pricing during the years 1990~1993, new automobile sellers failed to make any good repute and customer's support and affiliation. Used Hyundai and Daewoo cars being sold as scrap are the examples of this worst scenario.

Remanufacturing is applied not only for the simple as well as complex designed domestic equipments and machinery. These products can be the simple items or complex machinery having multiple modules, sub assemblies and parts. Remanufacturing is the labor intensive activity, which usually needs individual intention for testing, disintegration, reassembling and in some cases repacking also. Usually remanufacturing is carried out by OEM and independent retailers and for the later case there is no coordination and integration with the forward supply chain (Martijn *et al*., 1995). Establishing an integrated reverse logistics system for remanufacturing of electronic parts and products for OEM is complex and costly. As goods are returned from the consumers to the manufacturers, companies have to deal with them, either because they bring benefits or because they have to comply with laws and social responsibilities (Amini *et al*., 2005). In any case, advantages can be achieved and they can create a higher competitive edge. Products, components, materials, equipments and even complete systems may go backwards in the supply chain. Damaged or faulty products have very low value and cannot be sold without some degree of rework. Recovery activities involve some remanufacturing and up-gradation for the product. Remanufacturing and repairing require the least effort to bring the product to a good condition. In few cases retailers might perform these activities without reaching the manufacturer or in some cases the products are returned to OEM for remanufacturing. Remanufacturing requires the highest effort and if retailers are not able to do it, items must be returned to the OEM. Dennis and Kambil (2003) pointed out that reconditioned, refurbished or remanufactured products will result in higher revenues than products sold as scrap or salvage. Several studies encouraged the integration of reverse logistics system with the conventional forward logistics system in order to provide good service level to customers, achieve significant profit outcomes and follow legislative issues associated with green supply chain for environment protection. The most of the researchers, practitioners and managers proposed ideas which favor the implementation of remanufacturing strategy for efficient reverse logistics system (Srivastava, 2008).

There are also few studies about inventory issues of reverse logistics system. We can also find some relevant suggestions and practical implementations of remanufacturing alliance in the literature. Caterpillar Inc. is the leading enterprise in this area of logistics and service engineering. Honeywell-Caterpillar business services relationship in North America can be the best example to evident our proposed research. But so far there are few studies (if any) about formation of reverse logistics alliance for remanufacturing and till now we cannot find any study about the selection of remanufacturing centre in a reverse logistics alliance. Our proposed methodology addresses the need for remanufacturing alliance in reverse logistics system and can contribute significantly in selection of optimal remanufacturing centre selection for remanufacturing alliance for OEMs. The proposed research has wide applications in domestic electronic goods, automobile, mobile phone industry and diesel generators and even power plants at the local and global levels.

PROBLEM FORMULATION

In this research, the problem deals with a reverse logistical alliance that needs to select a particular warehouse or a number of warehouses which could be converted into remanufacturing centers. Every OEM has a number of warehouses in a particular region to cater for the forward product demand. But when it comes to return, due to their low volume, they need consolidation to reach economies of scale. Concerning remanufacturing OEM's had the choice of either converting all the warehouses into remanufacturing centers or to ship all the products back to their manufacturing plant but with the concept of alliance can circumvent these problems and reach economies of scale at warehouse level. For this, manufactures need to convert a minimum number of warehouses into remanufacturing centers that will fulfill their criteria of economies of scale. This research takes this scenario and provides an algorithm for optimum selection of the warehouse or the number of warehouses from all the available warehouses that should be converted into remanufacturing center.

Objective function: The above described optimization problem can be formulated into a simple MILP (Mixed Integer Linear Programming) equation which is given as:

$$Min\ \sum_{w=1}^{W} Q_w T_{wr} X_w \qquad (1)$$

$$w \neq r \quad \forall r,\ w \in W, r \in R$$

where,

W = {1, 2, 3, …, W} and R = {1, 2, 3, …, R} : A set of warehouses that belong to the alliance members in a particular region

wr = The transportation link between them

Q_w = The quantity of the returned products at a particular warehouse *w*

T_{wr} = The transportation cost for warehouses given by *w* and *r*

X_w is a binomial variable, equals to unity if the inventory level I_w in a warehouse w is greater than the required quantity Q_w of products on that ware house and is zero otherwise, i.e.:

$X_w = 1$, if $(I_w - Q_w) > 0$

$X_w = 0$, otherwise

RESULTS ANALYSIS

The case company in this study is the leading manufacturer of domestic refrigerator in China. We use this data to test our proposed model with this numerical example. Table 1 and 2 describe the quantities for remanufacturing at different warehouses in the city and associated unit cost for transportation of these stocks to different remanufacturing centers in the city respectively. Figure 2 represents the approximate position of existing warehouses in the city.

Table 1: Number of products to be remanufactured at different warehouses

Warehouse	Remanufacturing quantities
A	790
B	1105
C	1204
D	793
E	849
F	417
G	1008
H	1119
I	789
J	821

We assume that the company is currently dealing with ten warehouses for repair or remanufacturing. Figure 2 represents the approximate positions of the available warehouses of the company.

The quantities of products in Table 1 are taken from historical data of the warehouses and last three years average has been taken, while the warehouse "F" is newly established and we have only included one year data for this centre.

Table 2 describes the unit price for transportation. Keeping in view the fluctuating fuel prices we have only incorporated the recent transportation price for one unit of product from one centre to another. We have assumed that the price of transportation will be same for transporting a product between two centers in any order.

After solving the proposed mixed integer linear programming model, for this particular case warehouse at serial number 8, warehouse "H" can be the optimal remanufacturing centre for remanufacturing alliance because it contains the minimum possible cost of transportation 31739RMBs. We have used C++ to program and solve mix integer linear model for optimal

Table 2: Unit transportation cost matrix for inter-centers transportation in [RMB]

	A	B	C	D	E	F	G	H	I	J
A	-	50	56	55	70	80	95	85	60	40
B	50	-	50	55	65	75	90	95	70	50
C	56	50	-	40	70	65	80	90	80	60
D	55	55	40	-	30	60	70	70	55	55
E	70	65	70	30	-	50	65	65	60	50
F	80	75	65	60	50	-	20	50	65	70
G	95	90	80	70	65	20	-	45	70	85
H	85	95	90	70	65	50	45	-	60	75
I	60	70	80	55	60	65	70	60	-	35
J	40	50	60	55	50	70	85	75	35	-

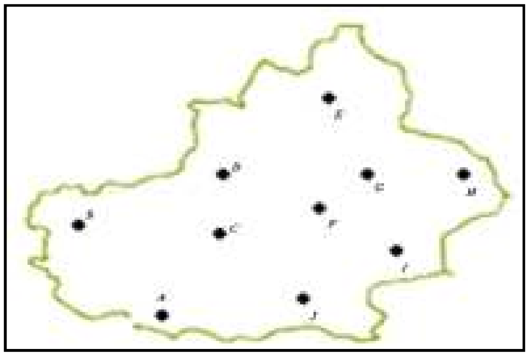

Fig. 2: Approximate existing position of warehouses

selection of remanufacturing centre for remanufacturing alliance.

CONCLUSION

This study discussed the need for remanufacturing alliance for remanufacturing and repair for the domestic refrigerator as a special case while generally this research can cope with all modular products. A mixed integer linear programming model has been formulated and this has been tested for the case company using C++. Proposed research creates a baseline in this direction and will help to raise the awareness amongst the enterprises of the benefits of remanufacturing alliance in reverse logistics and motivate OEMs to focus in this specific direction. According to proposed research, companies can make their reverse logistics system more efficient and cost effective by forming an alliance for remanufacturing and repair services. The proposed model can also be applied effectively for different other type of industries after some modification and customization. In this study the algorithm can only deal with reverse logistics environment. Furthermore, the current research can only solve general problems associated with reverse logistics, more work is still required for its broader and comprehensive application. In this research we have just focused on optimization of transportation cost, however, other parameters like optimum inventory levels, robustness and uncertainty can be incorporated in further research.

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