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A Conceptual Model for VMI in Reverse Supply Chains

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Abstract

The importance and role of reverse supply chain in gaining competitive advantage has been recognized especially in recent years. However the high costs of implementing and installing these chains works as an impediment for managers. Collaboration as a key to success in supply chains can be a way to decrease the costs and make reverse supply chains economically attractive. This paper proposes a conceptual model for collaboration between reverse supply chains in accordance with VMI in forward supply chains. Firstly a conceptual model is defined by introducing members and assumptions needed for that. Then a collaborative process for collection and routing between members of these chains and a heuristic method using modified tabu search for finding the best routs are defined. Finally an example is solved for some separate reverse supply chains once in the case of isolated chains and then for the collaboration between them in the suggested form of this paper.

Key Words: Collaboration, Vendor Managed Inventory (VMI), Reverse Supply Chain

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Introduction

Reverse supply chain as defined by the RevLog (1998) is “the process of planning, implementing and controlling flows of raw materials, in process inventory, and

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finished goods, from a manufacturing, distribution or use point to a point of recovery or point of proper disposal."[2] By increasing the significance of environmental problems and the volume of used products and wastes, these chains' value is recognized and many researchers studied the different aspects of them. On the other hand, collaboration in supply chains is developed in recent years and many systems and models introduced to support that. The expanded literature about supply chain collaboration (SCC) shows its value for academic and business world. The global survey by Supply Chain Management Review and CSC in 2004 defines collaboration as the single most pressing need for supply chain (SCMR and CSC, 2004). In 2007 the survey by this company shows that collaboration is the major difference between leaders, followers and laggards in supply chain and identifies that as the key to success (SCMR and CSC, 2007). However, collaboration in reverse supply chains is a newer subject that the writers try to define a conceptual framework for in the current paper.

To achieve this goal, this paper develops a model for collaboration between some 3 tier reverse supply chains. Every chain consists of three layers: Return manufacturer (M), Recovery centers (R) and Collection center (CC). In the traditional situation with no collaboration between chains, every M has the responsibility for sending returns to the CC and CC has its own responsibility to send that to R. In some cases may be CC has the responsibility of collecting returns from Ms. In such isolation, each member just works with its own reverse chain and the supply chains compete with each other instead of cooperating. Reviewing the literature also shows that mostly the reverse supply chain for a special type of recovery center or a group of customers were studied. However usually more than one of the same reverse supply chains exist, but the study takes just one of the chains into consideration.

In our proposed model the parallel chains work together and use their resources to have a more productive network of reverse supply chains. Therefore in the model, we have more than one M, R and may be CC. In this paper a conceptual model is developed to clarify the members of reverse chains and the type of relationships between them. To be applicable, a process for collaboration in collection, routing and delivering returns in these chains is developed. To check the process, an illustrative example is described consisting of four parallel reverse chains and the traditional set with no collaboration is compared with the proposed process for the collaborative model.

Literature review

Different management theories such as resource-dependence theory (RDT) and resource-based view (RBV) imply that collaboration between members of a chain can bring about better results for the whole supply chain. Since the members of a supply chain are dependent, they should work together to gain a better performance. In other words, for a sustainable growth, organizations need to use other organizations' resources and cannot work in isolation from other members (Sarkis, et al., 2011). By such an approach a collaborative supply chain will have better performance, as shown in forward chains literature, for example (McLarn, et al., 2002), (Laseter, et al., 2008), (Audy, et al., 2010). However this large amount of literature about collaboration,

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Bellmunt, et al. (2011) by studying the researches from 1997 to 2006 have shown that previous researches seldom considered supply chain as a network of organizations. They have shown that literature usually concentrate on one organization or the relationships with its customers/ suppliers.

Kolfschoten (2007), after analyzing different definitions of collaboration, recognized some similarities such as common goal of the activity in collaboration and emphasis on interaction and joint effort between members. In the supply chain literature, collaboration is defined as "a way by which all the companies in a supply chain are actively working together toward common objectives, and are characterized by sharing information, knowledge, risks and profits. Moreover, organizations routinely make decisions that require consultations with multiple participants" (Hernández, et al., 2011). Collaboration can take place between different levels of a supply chain or in special activities and processes. The collaboration can be named according the level ad type of process. For example CPFR is collaboration in planning, forecasting and replenishment and VMI (Vendor Managed Inventory) needs collaboration in inventory management.

Kovács (2005) suggests collaboration as a way for sustainability and reverse supply chains as a tool for collaboration. Collaboration in reverse supply chains is showing its importance and many researchers and businesses consider that in their studies and works (Zhang, et al., 2004). Some researchers defined Information Systems (IS) and Decision Support Systems (DSS) and some defined communication and relationship management as tools of collaboration (Pokharel, et al., 2009). Lambert et al. (2011) added "coordination system" and "integrated information system" to the usual reverse supply chain elements that were gate-keeping, collection, sorting, processing and disposal system. They believed that coordination system is the most important element, responsible for the overall performance of reverse supply chain. Bai (2009) developed a model for coordination between customers, retailers and manufacturers to maximize returns in a closed loop supply chain. Comparing the results of coordinated model with the previous one; he showed that with the new system, return volume will increase and costs will decrease. Kovács (2005) in his paper explained the ethic and behavioral aspects of collaboration between supply chain members. Zhang et al.(2004) explored the reasons for cooperation in reverse supply chains and opportunities that arise through reverse logistics.

Inventory management is one of the main subjects in reverse supply chain as identified by researchers such as Fleischmann et al. (1997), Dowlatshahi (2000) and Jayant et al, (2012). In open-loop reverse supply chains Gou et al. (2007, 2008) developed the previous methods and introduce a modified inventory policy. They found the optimal economic parameters such as minimum inventory and delivery level and inventory costs to minimize the system wide cost. A year later they introduced joint inventory management and economic inventory levels for managing single Centralized Returns Center (CRC) and multiple Local Collection Points (LCP). Again their objective was minimizing the long-run average cost for the open-loop reverse supply chain. The main concentration of these papers was inventory management, but the vehicle routs are not considered. Also the economic inventory level is assumed the same for all LCPs that may not always be the case in the real world. The writers suggest developing other joint inventory policies, such that CRC managing the inventory of all LCPs, similar to VM in forward supply chains. Before that le Blanc (2006) defined a new concept called Collector Managed Inventory (CMI), as the reverse logistics variant of VMI in a part of her PhD thesis. In CMI had two levels for used oils and coolants inventory were defined: can-order and must-order. This thesis and the model by Gou et al. (2007, 2008) are the bases of current paper about collaborative inventory management.

Another important part of our model is the problem of routing between different members of reverse supply chain. These kinds of problems called Vehicle Routing Problems (VRP) are also studied in reverse supply chains literature. Dethloff (2001) solved a VRP for simultaneous pick-up and delivery, in which the same vehicles are used to collect returns. Beullens et al. (2004) explained the difference between collection and vehicle routing problems in forward and reverse supply chains. They first explained VRP in forward chains and then their alternate in reverse chains. After explaining CMI, le Blanc (2006) developed a simple VRP for routing between the centers that reach must-order or can-order point. The optimization problem was solved using a method defined in previous works. Aras et al. (2011) studied the reverse logistic problem where vehicles depart from a collection center (CC), pick the returns from a number of dealers and come back to CC. In this problem dealers charge the CC, so only the profitable dealers will be visited and not obligation to visit all dealers.

Supply chain members coordinate and collaborate with each other using contracts for better management of their relationships and risk management. Contracts are important for building trust and commitment between organizations. This mechanism can help in avoiding partners from cheating each other. Many studies exist about various contract formats such as buy back, quantity flexibility, revenue sharing and so on, that differ in their quantity, time, quality and price in forward supply chains. Studying coordination contracts in supply chains Govindan et al. (2011) revealed that reverse supply chain contracting literature is still far behind that of the traditional one (forward). Their review of literature also showed that most of the references in reverse supply chain focus on simple one-to-one structures and not multi-echelon settings. Each of the contract types could be revised and modified for different situations. For example revenue sharing with fixed target sales rebate, revenue sharing with fixed target demand rebate (Wanhang, 2007), wholesale with and without warranty cost sharing, revenue sharing with manufacturer taking all warranty cost, revenue and warranty sharing (Hu, 2008) and cooperative / independent and asymmetric buy-back contract (Juan, et al., 2013) are introduced in literature as contracts in different situations.

Problem definition

The high costs of holding and transferring returns from their source of production (e.g. manufacturer, retailer, wholesaler or other sources that have a gathering of returns) to the recovery centers is an obstacle for implementing reverse supply chains in application. Usually the reverse supply chains form by members responsible for collecting and transporting returns from one or more sources to special recyclers. For example production planning and control issues for reusable containers and bottles at a soft drink company in Mexico, returnable containers for Canada Post, remanufacturing of used scanners, printers, copiers, faxes in Canon and repair network of IBM. Also some chains contain many customers or return manufacturers and special recovery center for example city waste management. These case studies can be found in (de Brito, et al., 2002).

In the studied papers and case studies, as described earlier, mostly the members of just one supply chain and their relationships are studied or optimized. The results of these researches also showed improvements in the performance of supply chains. However the forward supply chains usually exit and there is no need to implement them in an industry. But as reverse supply chains are new concepts and not often employed at industries, there must be economic motivations for starting them. On the other hand, the reverse supply chain's cost is a negative aspect of them. By these explanations, the problem is that implementing and executing reverse supply chains is not economically attractive for many organizations. So there is a need to decrease the costs of these chains so that more organizations will be motivated for installing their reverse supply chains. Collaboration is introduced here as a means for reducing the whole supply chain costs.

In this paper it is suggested that for reduction in the whole costs of reverse supply chains, the parallel chains with the same return and recovery type should collaborate in their inventory management and routing of vehicles. This will remove or decrease costs such as installing collection centers, evaluation and transportation for every chain. Part (a) of figure 1 shows the traditional non-collaborative parallel reverse supply chains that work in isolation. It is assumed that these parallel chains have an initial collaboration type in using a general collection center, but they do not have any relationships. In part (b) the proposed model is depicted, that shows the transportations and information sharing between different members. As illustrated in these figures, the transportations between members will be decreased by the new model since the vehicles in each tour will serve more than one center and collection center is mostly used as an information center and not a warehouse between members. In this figure one route as a sample is shown. In this tour, the vehicle starts from CC, goes to M2 that may achieve its must-peak (MP) or can-peak (CP) level and then continue its tour to M1that also may reach MP or CP and delivers these returns to R1 and R2 that their inventory level reaches ROP (re-order point).

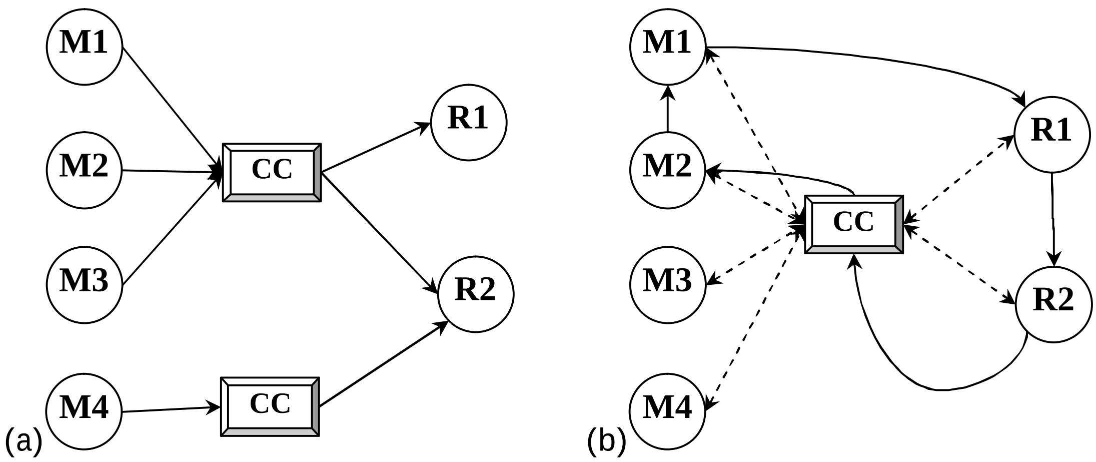

Figure 1 non-collaborative V.S. collaborative reverse supply chains

The conceptual model

A conceptual model is a set of assumptions, algorithms, relationships, and data used to describe the reality of something, as described by (Thacker, et al., 2004). In this paper a conceptual model is introduced that tries to define collaboration between different members of parallel reverse supply chains. To accomplish this objective, the members and assumptions are described in the following two parts. To define relationships and algorithms, the process will be explained in detail at the last section of this part. The relationships and information sharing are shown in part (b) of figure 2 by dashed arrows.

Collaborative reverse supply chain members

In the defined model, some three-tier reverse supply chains are assumed that each of them has the same parts of traditional one that explained before. Still the roles and application of the members are not the same and changed somehow. Members are:

- Ms- The places where returns are produced, gathered or held: For example producers may hold their scraps for some time or final users may return their used products to the wholesalers or retailers may transferring send their expired inventory back to recovery centers. These centers are called “return manufacturer” (M) in our model as a general name. In the previous examples producers, wholesalers or retailers are distinguished as M.
- Rs- The sites for recovery: Various options are introduced for returns in a reverse supply chain that are different according to product features, its life cycle phase and other characteristics. These recovery options can be reuse, resale, repair, remanufacture, refurbish, recycle or other suitable disposition options. In order to applicable for these different options, in our model we named “recovery center” (R) that can be each of these options. In the collaborative model of this paper there are multiple M, multiple R and single CC.
- CC- One Collection center (CC) in the current model relates multiple Ms and Multiple Rs by gathering information about their inventory levels and planning the vehicle routs to decrease whole reverse supply chain costs. This center also can hold returns for some time when there is no place in any Rs to accept them.

As described earlier, the chain is meaningful for different types of returns and various players; for example transferring producers’ scraps to the recycling sites or sending returns held in wholesalers’ stocks to the remanufacturing sites. Generally the chain is applicable in places where much returns are held before moving to the place of recovery. Collaboration in this three-tier reverse chain is derived from VMI (as suggested by previous researchers too).

Assumptions

The needed assumptions for the proposed model are:

- The inventory of Ms cannot be picked up whenever Rs need; but it must reach at least a CP.

- The returns are transferred via similar vehicles between different members.
- The capacities of Ms' and Rs' warehouses are limited. When the inventory of an M reaches the MP, it cannot hold them more and must dispose by the first possible way (may be landfill).
- Our objective is to deliver the returns from Ms directly to Rs and not using CC space for returns. So it is assumed that CC has a small warehouse but whenever it needs more place will rent a warehouse. Therefore the holding cost for CC is higher than holding cost for Rs and Ms.
- According to the above objective, CC's CP is considered equal to zero, that means whenever there is some inventory in CC; it can be inserted in the route and picked up. Also to simplify the model it is assumed that MP is unlimited for CC because it can hire as much warehouse as it needs.
- The lead time in the model is zero; it means that whenever a truck of returns pick up from any center, it will arrive its destination at the same day.
- Vehicles start and finish their tours at CC.

The collaborative collection and delivery process

In the suggested model for collaboration, it is preferred that vehicles collect returns from Ms and transfer them to Rs in their route. It can be called simultaneous collection, routing and delivery. The collaborative process works as shown in

Figure 2 The designed collaboration process

Figure 2 and the steps are described at next paragraphs.

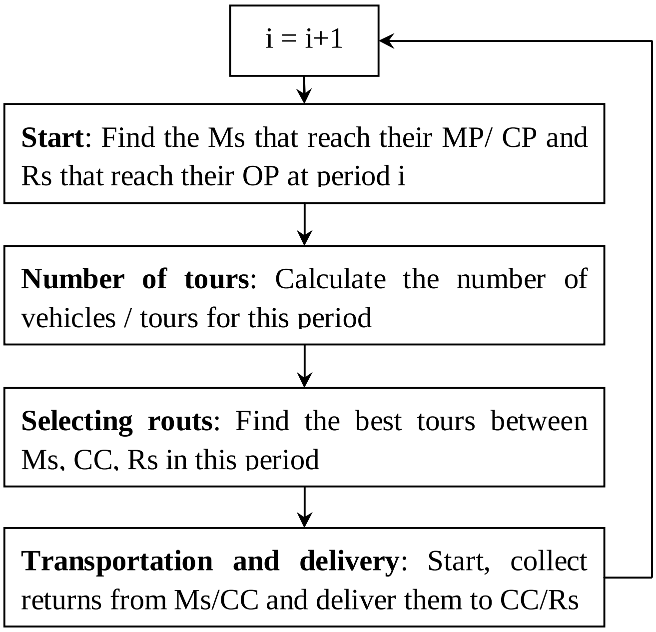

Figure 2 The designed collaboration process

Starting the collection process

As described earlier the inventory of Ms cannot be picked up whenever an R needs. Every M has a can-peak (CP) and a must-peak (MP) level. MP is the level that M is obligated to deliver its returns and cannot hold them anymore. If returns are not collected after MP is achieved, then M will need to dispose them by traditional ways that may be against the environmental policies. Therefore, the penalty cost will be imposed to whole supply chain in this case. CP is the level that M does not need collection but can profitably fill the remaining capacity of trucks and be inserted in their rout of collection and delivery. Recovery centers (R) also cannot accept the returns always; they just get returns when their inventory level reaches a special level. In this paper the special level is assumed equal to the re-order point (ROP) for Rs.

Information about inventory level of Ms and Rs are updated at the CC database. Whenever one M reaches its MP level or one R reaches its ROP, the collection process will start. If an M reaches its MP but no R needs the returns (their inventory level is above ROP), CC will hold the returns until needed by an R. If CC does not collect the returns, it must pay a penalty cost for the disposed ones. On the other hand whenever an R reaches ROP but no return is available at Ms or CC, the chain will probably encounter a shortage cost. In this case also, if sum of the inventory of Ms that reach their CP is at least equal to one vehicle's capacity, the collection process will be started.

Calculate the number of vehicles / tours

When collection process starts, all Ms that reach their MP and Rs that reach their ROP must be visited. These are the definite points of route. After selection, the number of vehicles to use for collection and delivery process (n) will be calculated according to sum of the returns from Ms (SRM), sum of the order quantities of Rs (SOR) and vehicle capacity (VC) by (1). To simplify the model, the capacity is assumed the same for all vehicles.

$$n = \lceil \max\{SRM, SOR\}/VC \rceil \qquad (1)$$

At the next step, if some of the vehicles have remaining capacity that must be filled by returns from other Ms or CC. Otherwise just these definite nodes are considered in the route generation. Then the best routes between these nodes must be generated so that the collection and delivery process have the least possible cost at that time. (2) shows the circumstances that capacity of trucks must be filled by more returns and the above explained process will start.

$$\text{if } \max\{\text{SRM}, \text{SOR}\} < n \times VC \;\; then \qquad (2)$$
$$\text{ind the Ms that reach their CP level}$$

If SRM is not equal to SOR, the quantity transferred to CC (QCC) will be calculated by (3). It shows that the remainder of returns will be kept in CC until needed by any Rs (reach their ROP). Since the goal of this collaboration is to transfer returns directly from Ms to the Rs, it is preferred not to hold inventory in CC. However, if there is no way to avoid that, the collected returns can be in held CC and sent to Rs as soon as possible. In addition, (3) shows that if SRM (returns needed by Rs) is smaller than SOR (collected

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amount of returns), then the remaining need of Rs must be filled by the inventory of Ms that reach their CP or the CC.

$$\begin{array}{l} \boldsymbol{if\ SRM} > SOR\ \boldsymbol{then} \\ \quad \mathbf{QCC} = \boldsymbol{n} \times \boldsymbol{VC} - \boldsymbol{SOR} \\ \mathbf{else} \\ find\ Ms\ that\ reach\ \text{their}\ CP\ \&\ can\ be\ inserted\ in\ the\ route\ or\ CC \end{array} \tag{3}$$

To satisfy the remaining need of Rs, inventory level of other Ms will be checked. The Ms that reach their CP can be inserted in the rout. At this point a simple decision process must be performed to select the best Ms for putting in the route. The process is explained in the next section.

The selection process

A modified tabu search is used to find the best Ms for inserting in the tours. Tabu search is introduced as a technique to improve the performance of local search. The steps of the modified tabu search are as follows:

1. The initial solution is formed by dividing members to n tours such that the total quantity of picked returns in every tour will not exceed the capacity of one truck. Each tour will be formed by putting the members sorted according to their indices. The types of these members must be like figure 3. It means that every tour starts at CC, then go through Ms with a quantity of returns equal or greater than MP and then the ones that reach CP. If there is no need to pickup something from Ms and just the inventory of CC is sent to Rs, these two parts will be empty. After peaking up returns, the tour will continue to the Rs that reach their ROP. If no R reach its OP, this part is empty. However after dispatching returns, the vehicle will come back to CC.

Start	Ms reach MP	Ms reach CP	Rs reach OP or CC	finish
	⇤ ⇥	⇤ ⇥	⇤ ⇥	
CC →	--- → ……..→ --- →	--- → ……..→ --- →	--- → ……..→ --- →	CC

Figure 3 Types of members of a solution

2. The fitness function in this model is equal to whole reverse supply chain cost that consists of holding cost in different places of the chain, transferring cost and penalty cost for delay in delivering returns to the Rs. This function will be calculated for initial solution and the value of that will set as Zbest.
3. Neighborhood structures and different moves to convert from initial solution to the neighbors are derived from the structures defined by (Aras, et al., 2011). They define seven routing moves and four selection moves. These moves are used in the current paper to find neighbors.
4. Tabu conditions or tabu list is a set of rules to ban some solutions from appearing in the answers. According to their memory structure the tabu

conditions are categorized to short-term, intermediate term and long-term (Glover, 1990). Usually the list contains a set of the recently visited solutions that is the same for this search.

5. For selecting the next solution, neighbors of current solution will be checked and the ones that are not in tabu list will be selected at the first step. Then the solution with lower fitness function (Z) will be selected and named Zbest.
6. The termination condition in this paper is when the number of non-improving iterations reaches its maximum. In our simulation this number is assumed equal to four.

Transportation and delivery

After choosing the path, vehicles will start their route to collect returns from the centers that are manufactured (Ms) and deliver them to the places that need them (Rs). If some of the returns in CC must be sent to the Rs, these returns are loaded firstly at vehicle and then the trucks continue their tour to Ms that reach their MP or CP. After collection the tour will continue to Rs that need returns for their raw material. If no R needs return at this time, the truck will come back to CC and CC will keep them until they are needed by any R.

Computational results

To perform and test the model, in this section an illustrative problem is generated for 4 Ms and 2 Rs. The produced and consumed returns in 400 periods are created using random numbers. The rate of returns' production and consumption is uniformly distributed. It is assumed that every M / R has its own minimum and maximum for the rate of production / consumption that is displayed at table 1.

Table 1 specifications of return Manufacturers and Recovery centers

Center	CP	MP	ROP	return production rate	return consumption rate
M1	100	150	--	5-20 unit/day	--
M2	180	500	--	20-50 unit/day	--
M3	80	120	--	6-20 unit/day	--
M4	150	200	--	4-25 unit/day	--
CC	--	--	--	--	--
R1	--	--	100	--	40 – 50 unit/day
R2	--	--	120	--	50 – 60 unit/day

The total cost of working in isolation consists of the same elements in fitness function for the collaborative model. The total cost of reverse supply chains is calculated for two different cases: (1) Non-collaborative case where Ms send their returns to one CC and CC sends them to Rs. (2) Collaborative case where our proposed model is used to collect and distribute returns.

It can be observed that the number of centers is the same for two cases. In other words, some kind of collaboration in using CCs exists in the first case too. But there is

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not any information sharing between members and CC works just as a warehouse for them in this case. This problem is coded and simulated via Excel by VBA. The results of comparing the two cases shows that with the same returns production and consumption rate, the collaborative model average cost will decrease an average 98% by the collaborative model. It shows a great improvement in managing reverse chains and can be a good incentive for different members to collaborate and execute their reverse supply chain by less cost. Table 2 shows the results of executing the model.

Table 2 The average results of 400 period execution of model

situation	Collaborative RSC (C)	Non collaborative RSC (NC)	Decrease Percent (NC-C)/NC
Total cost	14,706,960	544,343,672	-97%

Conclusion

As shown from studying previous literature, collaboration in inventory management of reverse supply chains is not studied so much yet. A preliminary model for collaboration between different reverse supply chains is proposed in current paper. This model is derived from VMI concept in forward chains and tries to join parallel reverse supply chain members to collaborate in managing their returns inventory. The result of solving an illustrative example with the traditional and collaborative model shows a considerable cost reduction in the proposed model. An early reason for this reduction may be using whole capacity of vehicles in collaboration. Also in many cases holding cost in CC will decrease since the returns are sent directly to Ms and will not be hold at CC any more. This straight transport will decrease transfer costs too. Other cost reduction reasons such as decrease in vehicle number and times of transportation can be identified for this improvement.

Aligned with previous studies about collaboration in supply chains, our model for reverse supply chain proved to be true by this simple simulation model. However the conceptual model presented in this paper is still in its infancy. Extension of the model in theory and practice, mathematical modeling, optimization and simulation of this collaborative framework will be opportunities for future researchers. Another suggestion for researchers is the different aspects of such collaboration; for example contracts between different members, the characteristics of members and location and capacity of CC. Also the problem can be solved with other assumptions and other forms such as simultaneous collection and delivery VRP, single vehicle routing, direct shipping from Ms to CC and CC to Rs, inventory-routing problem (IRP) and so on. A final suggestion of writers is to find some real cases and implement this collaborative model to them. This can be a good practical example for this model and can show the real strengths and weaknesses. As an essential need to perform this kind of collaboration, it is suggested to consider the collaboration costs, that are not reflected in this model.

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