



A Conceptual Model for Reverse Supply Chains and Information Sharing

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Abstract

Reverse supply chain is the process of returning the products from their production or consumption centers back to the supply chain in order to extend their life cycle and gaining competitive advantage. In this paper, these chains and their difference with forward supply chains are introduced from previous researches. Then the different flows of products, disposal options, processes and members are presented. For reverse supply chains the level of information sharing and the uses of IT are modeled at this paper. Finally, the criteria for selecting an information sharing technology are identified and a hierarchical model is suggested to achieve the managerial insights conceptually.

Keywords

Reverse Supply Chain, Information Sharing, Logistics, Data, Technology, Flow

1. Introduction

Reverse supply chain as “the process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point to a point of recovery or point of proper disposal” (www.rev-log.com), includes all the activities of a traditional supply chain in the reverse direction. In other words, reverse supply chain is the process of moving backward in a supply chain, from the destination to the proper place for disposal. This flow takes place in different parts of a supply chain and can increase financial performance, customer loyalty and return, decrease costs, and improve quality level (Gecker & Vigoroso, 2006). On the other hand, these chains help in protecting the environment and decreasing the waste problem.

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Though sometimes reverse chains are considered as cost centers, they can be a competitive advantage for many organizations. Moubed & Zare Mehrjerdi (2014) studied reverse supply chains as competitive advantage in the two generic competitive strategies: cost leadership and differentiation. They also introduce some cases of countries and leading companies in each group (Moubed & Zare Mehrjerdi, 2014). Vaz et al. (2013) also gather examples of advantages obtained by the adopting reverse supply chains: complying with environmental restrictions, cost reduction, gaining competitive advantage in relation to competition and differentiation in the corporate image (Vaz et al., 2013). However, the main reasons for implementing these chains used to be the economic ones, the environmental reasons and their impact on supply chain and organization's green image cannot be ignored.

Reverse supply chains can be categorized into open-loop and closed-loop ones. In the open-loop supply chain used products do not return to the original chain, and they will be disposed by a recovery center in another chain. In closed-loop supply chains, used products return to the original producer or another member of the same supply chain. Sometimes open loop supply chains are considered as forward supply chains. But there are some differences between forward and reverse supply chains that make them different, for example:

- One of the most important differences between these chains, is in their uncertainty level. In forward supply chains the demand side from customer has larger uncertainty level, but in reverse supply chains the supply side has the most uncertainty in the chain. Therefore, the supply is more predictable and manageable in forward supply chains than the reverse ones.
- Another main source of reverse supply chains' uncertainty is in quality. The quality level of supplied material and products is more constant in forward supply chains and can be continued by statistical process control techniques and in collaboration with suppliers. But in reverse supply chains the quality of supply is more variant, as they are usually the used products from various members of the chain. Also in forward supply chains the suppliers are identified and evaluated and the organization can decide between them, but the suppliers of reverse supply chain cannot be selected by organizations usually.
- The forward supply chain usually contains supply, production, distribution and selling processes; but there are other processes in reverse supply chains such as collection, inspection, separation and reprocessing.
- In forward supply chains the final destination is customer or user, but in open loop supply chains the destination differs by product type, its lifecycle and situation and the proper disposal options for that.

In Table 1 we collect and summarize some of the main differences between forward and reverse supply chains form literature (Fleischmann et al., 2004; 1997; Gobbi, 2008; Lee & Chan, 2009; Cheng & Lee, 2010). These differences show that forward and reverse supply chains cannot be regarded the same. Also it shows the higher levels of uncertainty for reverse supply chains that is one of the main reasons of bullwhip effect in forward and reverse chains. Information sharing can reduce the bullwhip effect by decreasing uncertainty levels. Information sharing can add transparency to the members and their situation and decrease the uncertainties in reverse supply chains.

Table 1. The main differences between forward and reverse supply chains form literature

Specification	Forward Chain	Reverse Chain
Value stream	Creating value	Recovering value
Driving mechanism	Demand driven	Supply driven
Products' flow	Divergent	Convergent

Specification	Forward Chain	Reverse Chain
Uncertainty level	Demand side	Supply side
Supply side members	Raw material suppliers	Customers/ end users/ distributors/ producers
Suppliers' selection	They are evaluated and chosen, having less bargaining power.	Usually they have more bargaining power
Supply side	Controllable and predictable	Non-controllable and highly uncertain
Supply volume	High quantity of similar products	Small quantity in different types
Destination	Certain	Uncertain
Demand side	Customers / end users	Recovery centers/ producers
Main processes	Procurement, production, distribution	Collection, inspection, recovery, redistribution
Main motivation	Economical	Economic and ecological
Cycle time	Certain	Uncertain
Stock keeping unit	Boxes or pallets	Weight unit
Routing and scheduling	Simple	Complex
Product quality	Uniform	Not uniform

2. Products' Physical Flows in Reverse Supply Chain

Reverse supply chains are not just planned for returning products from customers, they also can be returned from other parts of supply chain. [Fleischmann et al. \(2000\)](#) using a simple model show the different types of returns and their origin and flow in open loop and closed loop reverse supply chain. Some of the products' types that flow in a reverse supply chains include:

1. End-of-life returns (EOL): the products that reached their end of lifecycle and cannot be used any more, for example a burned out light bulb.
2. End-of-use returns (EOLU): the products that their original use has been completed. But, they may be usable by other members of supply chain. For example, a leather bag that one customer doesn't need it anymore, but may be useful for another customer in second hand market.
3. Commercial returns: the products returned to the supply chain according to their status and condition. These returns can be from customers to the retailer or from retailer to the manufacturer subjected to some contracted situations for example obsolescence or overstock inventory of a supermarket that are returned to the distributor ([Gobbi, 2008](#)).
4. Product recalls: whenever a complaint or a known problem with a product encounters a manufacturer, a proactive removal from the supply chain is known as recall. At the recalls every link from the manufacturer to the distribution, retail and customer will assist the program. The recalls can be from customers' homes, retail stores, distribution centers and any other points along the supply chain.
5. Packaging: the items containing products and help in carrying them, can return back to the previous process simply. For example, pallets, racks and containers of products that can be used by the manufacturer or retailer again. Usually these kind of packaging are constructed by durable materials like metal, plastic or wood and can endure the handlings in logistics system.
6. Warranty returns: the type of returns because of a problem in product, usually return to the manufacturer by the end user, retailer or distributor. The failure might occur during use or transportation in the supply chain and the guaranteed ones are usually mentioned in the contracts.

7. Production scraps: or by-products that are made by manufacturing operations because of manufacturer's output.

These various returns flow between different steps in a reverse supply chain to recover their value.

Some of the main processes in a reverse supply chains are:

1- Collection or acquisition: the process of gathering and obtaining the products from different members of reverse supply chain like end users, customers, retailers or any other members. It is usually the first and most critical step of a reverse supply chain and accounts for a significant part of its costs (Gobbi, 2008). A large uncertainty in quality, quantity and time of returns is usually experienced here. There are many different settings and choices to collect returns. Beullens et al. (2004) studied and introduced some efficient cases for return collections in different industries and categorized them as below:

- *Refuse collection from households.* In this collection program the users are responsible for gathering the returns in the specific points and the collection process will be designed by the reverse supply chain members. The companies in this group gather a variety of return in curbside or drop-off collection points, for example city wastes. A source separation program shows its performance in reducing these costs in a city. Some other decisions here include the collection frequency, combining or separately collection of returns, the vehicle type and combining or separating the inspection and sorting processes in the collection points.
- *Collecting hazardous material from industrial firms.* Many industrial sites produce some hazardous contents as their by-product or waste, for example oil filters and used oil in a car repair center. Usually law forces the sites to collect and transport these wastes by special vehicles and special transporters to special disposal sites. Professional transporters of these materials collect them in special periods according to the material and site type. The main costs for these transporters usually include the vehicle type and number and the routing costs.
- *White goods collection.* A group of heavy and durable appliances like refrigerators, washing machines, stoves, etc., are in this group. The collection scheme for this group differs in many companies. A usual plan is to use a call system for retailers or distributor with a timely collection. The retailer usually takes the goods back from customers and when its returns reach a special inventory level, it will call the collection center. The center will collect reruns within special time period after the call. However, this collection is named with goods collection, it can be used for other returns too.
- *Combining deliveries and collections.* Combining the transportation of old products and delivery of new products is another choice that is used in some products like printer cartridge, IT equipment and power tools. In such collection schemes after distributing the new products, the old ones will be collected and transferred to the reprocessing facilities. In some industries like health and food sectors, the vehicles with separate compartments are used to have cold storage space (Beullens et al., 2004)

2- Inspection/ Separation/ Sorting: it is the process that evaluates the quality level of returned products to sort them according to their situations and choose their destination in the most profitable manner. The process may include disassembly, shredding, testing, sorting, and storage steps (Fleischmann et al., 2000). It also can be a separate step or combine with other centers. If inspection takes place in the collection process and before acquiring the product form the user, users cannot abuse the service by including goods that are not part of their contract. Another choice is inspecting the collected returns at the collection centers and split them according to their next destination. For some products like EOL automobiles, inspection can just take place in the disassembly process to find out the

disposal option for each part. The decision about the returns' destination usually relates to the remaining life of that. Some technologies like condition indicators and self-monitoring facilitate the decision by showing the situation of product of its parts. For example, automobiles with on-board computers and large electronic equipment such as medical devices can show the maintenance time or the wear state of components (Ferrer & Whybark, 2000).

3- Transportation: logistic as a part of reverse supply chain, encompasses physical transportation all the way from return generation to their destination. Therefore, it starts from collection process, to the inspection and until reprocessing facilities. One of the main concerns in transportation activities is about finding the best routes to decrease the supply chain costs and increase the amount of returns collected and reprocessed. Usually these problems form the main practice of Vehicle Routing Problems (VRP) in the reverse chain. Combining the VRP with inventory problem makes Inventory Routing Problems (IRP) and combining with location problem makes Location Routing Problems (LRP). Another version of these problems is about the location of different centers in the reverse chain, their inventory level and the routing of vehicles between centers, or Location Inventory Routing Problem (LIRP).

4- Reprocessing/ Recovery: after collecting and inspecting the returned products, they must be reprocessed. We used the reprocess or recover as the general word to describe the different options for recovering value from return flow. The decision about recovery option is made according to some situations like customers' requirements, product's lifecycle, the existing recovery options and governmental and environmental regulations. Some of the different options for recovery that are introduced in previous researches are:

- Reuse / resell: it means directly reusing the returned products in a process or by a customer. Typically, in the case of commercial returns, packaging, and some of the EOU products this option will be applicable. The reuse may be by return receivers or by selling them in the second hand market to the customers.
- Repair: this recovery option will fix the returned product to recapture its original functionality (Gobbi, 2008). Warranties, commercial returns, products recalled and sometimes by-products can be repaired and come back to the chain again.
- Refurbish: bringing the specified quality standard back to the return by inspecting, fixing and replacing the modules and components is called refurbishing (Gobbi, 2008), for example personal computers.
- Recondition: is the process of changing the conditions of return to be usable again. Usually this option is used for old batteries. However, many people believe that old batteries must be thrown away, reconditioning will get back the battery functionality.
- Remanufacture: for this option, the returned product is disassembled, the parts are fixed or replaced with new ones and the product with the same quality level will be produced again.
- Recycle: for some returns the components may be not usable or fixable, therefore it cannot be reused, refurbished, reconditioned or remanufactured. In this case, the last option is to use the raw material used in the components that is called recycling.
- Energy recovery: if the raw materials of returns cannot be recycled, the next option is incineration with energy recovery. By this option the hidden energy of returns will be used before disposing it.
- Incineration: as a thermal treatment, this option is usually used for waste treatment and the ones that their energy cannot be used due to environmental or health problems.

- Landfill: all the remaining returns and materials which cannot be recovered by the previous options, will be landfilled. It is one of the oldest forms of waste management and usually were used for municipal solid waste. The landfill locations and specifications are specified in environmental regulations.

However, the main concern in all of these options is about reducing the natural resources usage and wastes volume. Therefore, the options are written by their importance and environment friendly.

5- Redistribution: it is the process of distributing the recovered returns to the new markets or returning inventory to the previous step of supply chain. This process doesn't make sense for the products that are disposed or incinerated at their last step. But usually other types of product recovery that their product must be sold again, need this process. In distribution that is usually used in forward supply chains, inventory must be shipped between the retailers, after their demand is observed or with a forecast of their demand and it is for a fee. But in reverse supply chain, redistribution is occurred in different phases, for example when the retailer wants to return the excess, obsolesced or perished products back to the manufacturer. This type of redistribution usually does not incur an explicit fee for the redistributed items. Again, transportation is a big part of redistribution problems and the same transportation problems will occur. The redistribution centers in a reverse supply chain are the centers that the recovered returns are kept and distributed to the retailers or users.

6- Reselling: selling new products in the market needs lots of marketing skills and information. Then, reselling the recovered products in the first hand or second hand market as the final step in reverse supply chain will add value to all the previous steps. Usually the recovered products are sold in special markets like second hand markets.

These steps differ per case of reverse supply chain, and they can be done by different members. Also some of the steps may be not meaningful for some supply chains. The members of reverse supply chain depend on many factors such as forward chain members, the return volume and importance and the reverse supply chain costs. Some of the members usually work in a reverse supply chain, include:

- Collectors: these are the centers for collecting and sometimes inspecting and sorting returns. In some cases, forward supply chain members take this role and collect the returns from users, for example distribution centers. These centers can also combine delivery and collection processes. By these members, the reverse chain total cost will decrease, but the centers are not professional in collecting returns and sometimes cannot collect the returns efficiently. In some other chains, professional members that are expert in collection, do the process. These members will add some costs like opening costs to the chain, but can do the process more efficiently. A problem in collection process is about the number, type and location of centers for collecting returns. For high volume and spread returns, like city wastes, two main types of collection centers are local collection points (LCP) and centralized return center (CRC). Another subject of collection process is about how to motivate the customers to bring back their returns, especially in the case that they must bring the returns themselves or hold the returns inventory for a while. Usually financial incentives like discount for buying new products or penalty for disposed products are introduced in literature.
- 3rd {=Third}-part logistic service providers: these members, known as 3PL or TPL are the specialized companies in operations such as logistic, warehousing and transportation that are used by companies or supply chains to do their logistic operations. In other words, some logistic operations of supply chains are outsourced to these members. In many reverse supply chains also, when there is not enough resources or competencies to manage the activities; these logistic parts are outsourced to the third party logistics providers.

- Scavengers: the group of people who collect the rubbish and discarded items from others are known as scavengers. In city waste management this group of people help in collecting returns from all over the area and return to the collection centers. Also sometimes they inspect and sort return and send to the recovery position.
- Recovery centers: as explained before, there are different options for a return to be reprocessed. These recovery centers (for example recyclers, remanufacturers, repairing facilities, etc.) are other important members in a reverse supply chain. These processes also can be combined with the main manufacturing or other forward supply chain members, that is closed loop supply chain, or done in a completely separate part, named open loop supply chain.

These decisions are summarized in Table 2. By the wide range of decisions, for a special product we suggest a matrix like Table 3 to define all types of disposals for all returns of a supply chain or an organization. In each cell of this matrix the special type of return and special disposal option can be defined. The table is filled simply for a leather clothing example.

Table 2. The different decisions of reverse supply chain

Supply Chain Type	Return Type	Process Steps	Recovery Options
Open loop Closed loop	End-Of-Life (EOL) End-Of-Use (EOU) Commercial returns Product recalls Warranty returns Repairing returns Packaging Production scraps	Collection Inspection Separation Transportation / logistic Reprocessing Redistribution Resell	Reuse / Resell Repair Refurbish Recondition Remanufacture Recycle Energy recovery Incineration Landfill

Table 3: Return/disposal type matrix

		Recovery Option							
		Resell	Repair	Recondition	Remanufacture	Recycle	Energy Recovery	Incineration	Landfill
Return Type	EOL				*	*			
	EOU	*	*	*					
	Commercial Returns	*	*	*					
	Product Recalls		*		*	*			
	Warranty Returns		*	*	*				
	Repairing Returns		*	*	*	*			
	Packaging					*	*		*
	Production Scraps	*				*			*

3. Information Sharing

Before using computer systems in the production management and supply chain processes, managing a company or a supply chain was very slow and unproductive. Using computers and information technology helps the supply chains to better manage their activities and processes. However, data that is created in a company, if kept in personal computers or data silos and not shared between other members of supply chain, will not be productive enough and sometimes will cause a lot

of rework and cost for other members and the whole supply chain. Information sharing as a way to solve this problem, helps in exchanging of data between supply chain members. [Clark et al. \(2001\)](#) used a seven layer model to show the organizational interconnectivity in forward supply chains. We used their classification here to explain such levels in reverse supply chains:

Level 1: physical data transfer. As the lowest layer of the model, this traditional paper –based way of connectivity works using post services for sending and receiving data between any two firms of a reverse supply chain, and relies on direct physical transfer of data and information. This level of connectivity is slow, very basic and just applicable for low volume and not important data. Using this level of information sharing, needs to maintain a lot of paper work and documents. Therefore, it is hard to keep tracking and use the data for future analysis and decision makings. Nowadays by spreading use of internet and other IT infrastructures this level is not used widely. But some contractual and financial documents and payments are still done in some supply chains by this level of technology.

Level 2: technology-supported order transmission. At this level the information is transferred vial simple technologies such as telephone and fax. More structured and unambiguous information can use this level of connectivity. Many of the previous connections can be done by this level technologies, except payments and some financial documents.

Level 3: electronic data interchange. These technologies replace the previous levels technologies from early 70s and are ways for transferring structured data, by specific standards, between computers of different companies, for example members of a supply chain. Using EDIs eliminates several manual steps of reverse supply chains and replaces telephone or fax orders with more reliable and error- free technologies.

Level 4: new information-intensive processes and data transmission. At this level, extended features of EDI especially the financial ones such as electronic payment, invoicing systems, electronic funds transfer, etc. are added to the technologies. At this level, the financial features are not human- free yet and need some intervention.

Level 5: new policies and integrated operations. At this level of connectivity, a process integration will take place and many of previously human- based processes will be done by technology. For example, in Vendor Managed Inventory (VMI) systems, the retailers don't need to place order to suppliers and they ship products for retailers as needed to replenish inventory.

Level 6: joint channel optimization relationships. This level expands the relationships form simple ordering to integrated reverse supply chain operations containing collection, inspection, sorting, value recovery, logistics, meetings, decision makings, etc. in order to improve the operations and relationships within the chain. To achieve this integration, mutual incentives and goals and a high level of trust between members are needed.

Level 7: virtual channel integration. At the highest level of connectivity the managers of reverse supply chain members establish close relationships with each other based on mutual trust. At this level all the supply chain members behave as a unique firm. Therefore, they shift from implementing individual processes to mutual objectives, operations, innovations, improvements and risks.

Some of information sharing and integration techniques that are introduced in supply chains are Material Requirement Planning (MRP), Manufacturing Resource Planning (MRPII), Enterprise Resource Planning (ERP), Warehouse Management Systems, Satellite tracking systems, Point of sales tracking systems, Intranet, Extranet and many other web-based technologies ([Shi et al., 2012](#)). These techniques can be used in reverse supply chains too. By changing the information sharing concepts to cloud computing environments, there is not any need to keep servers within the organization. Cloud

computing can provide infrastructure, platform, and software to manage the supply chain via Internet. As an example, a third generation ERP is considered as a cloud platform to use the ERP in supply chains. These ERPs should be compatible to different devices such as mobile phones, laptops, tablets, etc. and can be integrated between companies (Dos Santos & Marins, 2015).

Expert Systems (ES) and Artificial Intelligence (AI) are also other information sharing and decision making systems that can help in reverse supply chains. Expert systems help the decision makers as a skilled consultant to select the best options and artificial intelligence as a “thinking machine” is capable of mimicking, learning, and replacing human intelligence. These systems can be used in different parts of reverse supply chain such as demand planning and forecasting, customer relationship management, negotiation, network design, inventory planning and supplier selection (Min, 2010). Using these technologies in reverse supply chains are less studied in previous researches. However, they can be very useful in inspection, sorting and decision making about returns’ recovery.

Internet of Things (IoT) seems to be one of the near future information systems for reverse supply chain management. IoT is defined as a network of physical devices embedded with artificial intelligence tools which enables them to connect and exchange data and information. This technology seems to change every aspect of reverse supply chain while adding huge amounts of data every second.

Information sharing and cloud computing helps reverse supply chains to identify and track a product in its whole lifecycle, locate that during its route to final destination, communicate between supply chain members and make better decision. Some of the IT and cloud computing applications in reverse supply chains are:

1. Identification. Identifying returns in different steps of the chain, especially in collection centers and other temporary storages, needs some identification technologies. These technologies will speed the processes up and help in sorting and decision making for future routes and destinations of the returns. The advanced technologies in this group are known as Automatic Identification and Data Capture (AIDC) or “Auto-ID” that are methods for identifying, collecting and entering data to the computer systems, without any human effort. Some of these technologies include barcodes, QR codes (Quick Response), RFID (Radio Frequency Identification), magnetic stripe cards, Optical Character Recognition (OCR) and smart cards. As an example, Lee & Chan (2009) suggested an RFID based reverse supply chain to return products to disposal and second hand markets. In their developed model, the RFID tags are attached to the returns at collection points (Lee & Chan, 2009). However, using these technologies from the first steps of forward supply chain will reduce the work and effort volume in reverse supply chains.
2. Planning and forecasting. Forecasting future demands and returns will help in planning for returns’ collection and next steps of reverse supply chain to reduce the bullwhip effect. Data about past is a critical need in forecasting future. Collaboration between different members will help in sharing these data between members and making the best decisions. Social media and sharing the events and experiences by supply chain members in real time using a data mining technique will help in forecasting future. Also for some products like batteries or industry machines, there are condition monitoring and health forecasting technologies that determine the remained life of product. Linking between such these systems and data sharing technologies will help in a better forecasting and planning.
3. Sourcing. In forward supply chain finding, identifying, evaluating and selecting between different sources of raw materials helps in better managing the chains. In reverse supply chains the main sources are returns, thus identification, evaluation and control of these sources is not a real process. Since one

of the main goals of reverse supply chain is to expand the products life cycle, collecting as much returns as possible is an objective in these chains. However, identifying, prioritizing and contracting with these members can reduce the uncertainty level of the chain and helps in planning for future. The procurement and sourcing technology market is evolving rapidly using IT applications, virtual assistants, artificial Intelligence, business intelligence tools and B2B markets. Different versions of ERP and purchasing management applications include supplier selection module as a main part. But for reverse supply chains these modules and applications must be defined again specifically.

4. Warehouse management. These systems help in detecting, tracking, holding and managing returns inventory in the temporary and permanent warehouses during the reverse supply chain. Identification, location and tracking technologies will complete these systems.
5. Reverse logistics systems. The systems for carrying returns from their origin to their destination through reverse supply chain members are known as reverse logistics. Using identification, locating and tracking systems reduces the uncertainty level of these systems.
6. Collections systems. The systems to collect returned products from customer, retailer, and manufacturer in a physical or non-physical collection center is facing a lot of uncertainty. The centers to refer and the amount of returns to collect are not predictable and schedulable like the retailers to sell the product in forward supply chain. Using identification technologies like RFIDs for products of a supply chain, can keep the information on returns status to reduce the uncertainty.

4. The Main Information Flows in Reverse Supply Chain

Different types of information flow within a reverse supply chain, which must be shared between members. The main types of information (showed in [Figure 1](#)) include:

1. Inventory data and information: it is one of the main information needed in a forward supply chain ([Lotfi et al., 2013](#)). In reverse chains also, having updated information about inventory levels of different members allows better forecasts and planning of the chain for future. The inventory level of collection centers, is one of the main inventories to be monitored in a reverse supply chain. Also information about inventory of recovered products can help in sale forecasting and planning.
2. Sales and order data: this information also is used in forward supply chains ([Lotfi et al., 2013](#)). In reverse supply chains, since the most usual returns take place after sales, it can help in forecasting the return amount and time. By sharing these data, each member in the reverse chain that relates to the used products and returns can have a prediction of the time and amount of returned products.
3. Quality information: these information, that is useful in forward supply chains too ([Lotfi et al., 2013](#)), in reverse supply chains includes two main groups:
 - Information about quality level of different members in forward supply chain: It can help in forecasting the return amount and time for reverse supply chain members. Especially for those who work with production scraps, this information directly shows the return volume.
 - Information about the quality level and specifications of returned products in different centers of reverse supply chain: the group of information helps in determining the recovery option, its emergency and returns' destination, to plan for future routes and centers.
4. Center capacity and its free capacity: the information shows the emergency and time to collect the returns to the next members of reverse supply chain. If the center is just used for reverse supply chain, the free capacity can be calculated by inventory level of the center and knowing the capacity.

5. In-transport returns: the information is also used by members of reverse supply chain to estimate the arrival time and type of recovery needed for returns from downstream. This is most important when lead time is longer.
6. Need for return: however, in the reverse supply chain the returns flow from downstream to the top at their collection time; sometimes these members send returns just at their need time. In such chains, the need for return must be transferred from the upstream members down the chain.
7. Delivery status: the time and quality of received returns by upstream members, if shared between related members, can help in evaluating the delivery process and estimation accuracy.
8. Cash and financial: one of the main flows in supply chains is cash and financial flow that is considered differently from information flow. But the information about these flows helps in better management of the physical flow in reverse supply chains. The financial flow in reverse supply chain usually moves from upstream members to the downstream ones, opposite to the forward chains. However, their information flow in two sides of the chain.

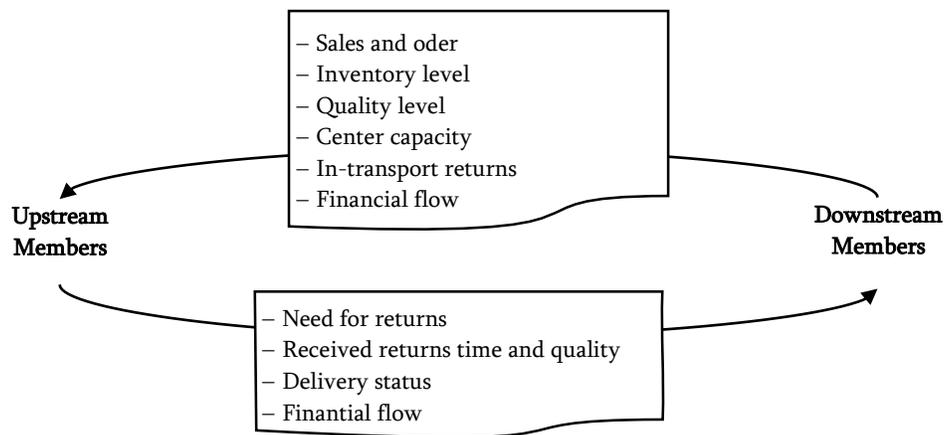


Fig. 1. The main information flows in reverse supply chain

The different types of information in reverse supply chain can be categorized in a matrix like [Figure 2](#), according to their importance and volume. This matrix shows how much speed and security is needed for information sharing system about each piece of information. The higher the importance of data needs higher levels of security and the higher volumes need higher speeds. In cell (1) since there are low volumes of not important data, the main concern is efficiency and simplicity of information sharing technologies. In cell (2) a high volume of less important data are created and maintained. The speed of systems here is more important since it must manage a lot of data and information. In cell (3) we may ignore the speed and gain more security in our information sharing technique. The most important parts of information that must be managed in a reverse supply chain, are the ones in cell (4). Usually updated, high speed technologies are used for these information.

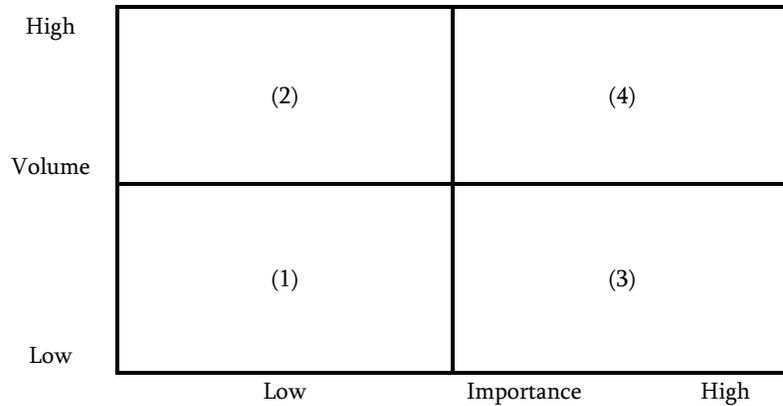


Fig. 2. Importance-volume matrix for information in a reverse supply chain

5. Hierarchical Model to Select Information Sharing Technique

Selecting the best and most economical information sharing techniques is a multi-criteria decision making problem in reverse supply chains. In this part some of the criteria will be recognized. To identify the needs of an information sharing system between reverse supply chain members, a decision tree (Figure 3) is used. In this tree the main factors affecting selection of information system are firstly introduced. Then for each factor, some sub-criteria are designed.

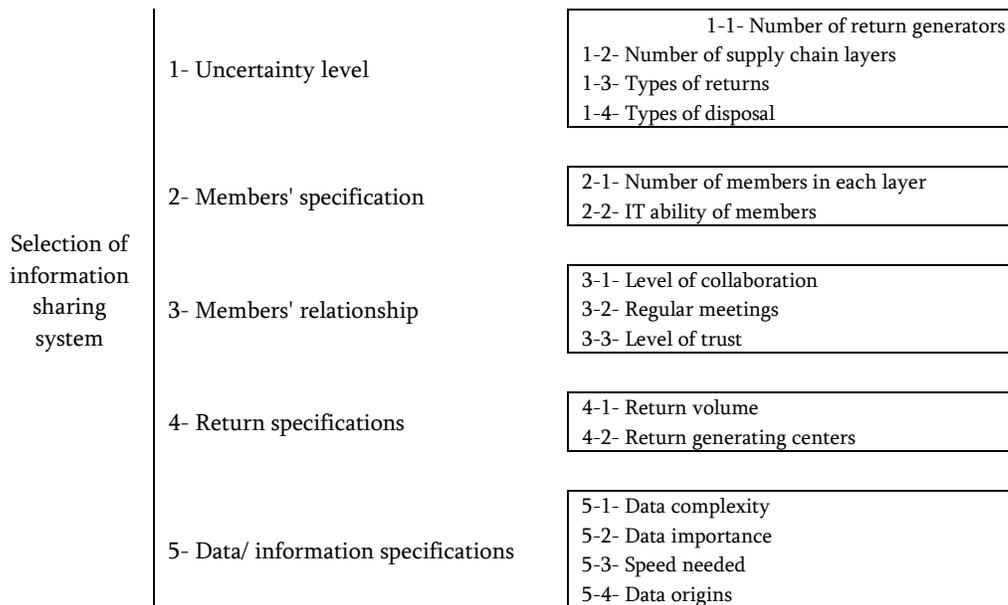


Fig. 3. The decision tree for needs of information sharing system between reverse supply chain members.

By the above tree, some of the factors affecting the decision about information sharing system are introduced. In order to evaluate and select between information sharing systems, we propose some criteria including:

1. The system specification: it is one of the main options for information sharing system selection and includes:

- a. System speed: as described in previous parts, the higher information volume is, the more speed is needed for information sharing system, in order to stand the volume of information. The system speed is represented in the entry, processing, retrieval and reporting phases.
 - b. System appearance: the appearance of the system for example its themes, colors and user interface, being user friendly and easy to learn have importance in reverse supply chains, especially when they are working with people or final consumers.
 - c. Compatibility of the system: the capacity of system to work without any change, with other systems and devices.
 - d. System flexibility: it is the ability to adapt to special characteristics of reverse supply chain and changes in a timely and focused manner. Due to high level of uncertainty in reverse supply chains this ability is an important factor in evaluating different systems.
 - e. System security: it is one of the most important aspects of selecting an information sharing system and is defined as:
 - Confidentiality: restricting the access of different people to see the information is meant confidentiality.
 - Integrity: assuring that the information is not changes and shows its real purpose.
 - Availability: information can be accessed and modified by the right members in the right time.
2. The financial issued of technology: usually it is one of the first issues for decision making about an information sharing technology and includes:
- a. Total cost of ownership: an important factor for managers in selecting a technology is its costs and economical influences. The costs of ownership are beyond it purchasing hardware and software; and include other expenses such as operations, trainings, licensing, maintenance, updating and other technology related costs.
 - b. Total profits of the system: however, costs are the very early financial issues of information systems, it must be taken in to consideration that poor communication in a reverse supply chain can be very costly and lead to false decisions with unreliable data. In order to select about an information sharing system its advantages like more transparency, efficient collaboration, integrated workflows and decreased risks must be considered.
3. Human behavior side: however, technologies are trying to remove human from their operations, human is a main part of them yet. Interestingly, the current information sharing researches about supply chains usually do not take the human side of technology into consideration. We believe that one of the main factors for selecting an information sharing system is about its relation with human resource. Some of its human- side factors of selecting information sharing technology include:
- a. Human abilities for use information system. It is important to consider all the people related to the system and must work with it. They must have the least abilities needed for the system.
 - b. Human motivation for using information system. The people's resistance to change can be an obstacle to select and work with a system.
 - c. Personality characteristics. Personality traits and characteristics can change the level of system acceptance. The impact of some traits like agreeableness, conscientiousness and openness are studied previously.
 - d. The motivation systems. A main decision in human- technology selection is about how to motivate people to work with it.

6. Conclusion

In this paper reverse supply chain, its different types, flows and recovery options are introduced. To study the information sharing in these chains the researches of forward supply chains are used and modified to be compatible to reverse supply chains. Also the different applications of information technology in reverse supply chain are defined, that are identification, collection, tracking, planning and forecasting, sourcing, warehouse management and reverse logistic. The various information flow in the reverses chains are introduced and a matrix is suggested to classify this information. Finally, some criteria for selecting a reverse supply chain information system are introduced. Also some real world examples of using information system in reverse supply chains are described finally. By the above descriptions, it is obvious that information systems, and especially the new ones, are of importance to study in reverse supply chains. Technologies and systems like Internet of Things, Artificial Intelligence and Expert Systems are some of the suggested topics in the subject.

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