REVERSE LOGISTICS SIMULATION MODELLING

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ABSTRACT
Scientific research regarding reverse logistics systems in developing logistics systems are complex, often not conducted by SMEs and are continuously generating certain logistics costs. Developed logistics systems are analyzing product returns and are tending to detect differences and oscillations in returned product flows. Developing logistics systems, as Croatian, reverse logistics issues, regarding product returns are not observing as issues of priority. Detailed research analysis implicated that majority of products in return is directed from different subjects in supply chains. Paper will detect amounts and processes regarding electric and electronic products directed to service from final consumers and retail chains. Collected relevant parameters will be base for simulation model of centralized service center on the Croatian market.

Keywords: reverse logistics, simulation modeling, process optimization, reverse logistics activities

1. INTRODUCTION

In a today's globalized economy and highly competitive market manufacturers face the challenge of reducing manufacturing cycle time, delivery lead-time and inventory reduction. The rapid development of today's technology and appetite for latest models of goods and products by consumers are fuelling the rate at which new products appear every day. Advancement in information technology results in a shortened product life cycle. This situation, which accompanies consumers developing disposable habits, has caused a large amount of waste, rapid depletion of resources, and serious damage to the environment. To deal with these critical problems, many governments have announced environmental legislation associated with green product designs and encouraged enterprises to implement green supply chains and reverse logistics so as to improve customer satisfaction, extend product life, and decrease resource investment. Reverse logistics is a recoverable system that increases product life by means of recycling, repair, refurbishment, and remanufacturing (Alshamrani, Mathur, and Ballou 2007; Amini, Retzlaff-Roberts, and Beinstock, 2005). In 1998, Stock defined reverse logistics as the processes associated with the flows of product returns, source reduction, recycling, material substitution, material reuse, waste disposal, material refurbishment, repair, and remanufacturing. Hence, the recoverable system deals with the physical flows of products, components and materials from end users to re-users. Reverse logistics is becoming more important in overall industry area because of the environmental and business factors. Planning and implementing a suitable reverse logistics network could bring more profit, customer satisfaction, and a nice social picture for companies. But, most of logistics networks are not equipped to handle the return products in reverse channels.

Environmental management aims primarily to reduce waste volume by moving away from one-time use and disposal to having control of the product's recovery. This encompasses of reuse, remanufacturing and materials recycling, which can be the three end-of-life (EOL) alternatives determined by the product's characteristics at the end of the product life cycle (Rose and Masui, 1998). As these concerns start to affect the customer's purchasing decisions, manufacturers are increasingly forced to consider their product's impact on the environment. This changing trend extends the responsibility of producers beyond the production and distribution to the responsibility for their products at the end of their life cycle. In order to address these problems, producers have to extend the traditional forward logistic distribution chain and consider the total environmental effects of all products and processes until they are returned at the EOL, which is also referred to as reverse logistics (Beomon, 1999, Kooi et al., 1996).

The aim of this paper is to define a model for centralized service centers where items directed to services should be processed with reduced disposition cycling time. Research for simulation model is conducted on the Croatian market by measuring relevant parameters.

2. MAJOR HEADINGS

Reverse logistics is the backward flow of what logistics operators, distributors and manufacturers wish would be a forward-only process. Products, components, materials, equipment and even complete technical systems may go backwards in the supply chain.

Products can be reworked during manufacturing due to unsatisfactory quality, or with good materials or components being returned from the production floor because they were left over after production (manufacturing returns). Defective products may be detected after they have entered the supply chain resulting in a pullback of products through the chain (product recalls). From this stage there are more actors in the chain involved with the reverse flows on the basis of commercial agreements such as returning vs. taking back obsolete stocks of short-life products (B2B commercial returns). In addition, in the business-to-consumer scenery, products may be sent back due to mismatches in demand and supply in terms of timing or product quality (B2C commercial returns). A particular situation is e-commerce where high percentages of returned products are not a surprise. During use and in presence of warranty or service possibilities, products may also be returned to be substituted by others, or to be repaired (warranty and service returns). Ultimately, even after use or product life, products are collected to be e.g. remanufactured, recycled or incinerated (end-of-use and end-of-life returns). At this point both material’s hazard and environmental impact have to be taken into account. Concluding, products may reverse direction in the supply chain for a variety of reasons as listed below (see also Dekker and van der Laan, 2002; Dekker and de Brito, 2002):

1. Manufacturing returns
2. Commercial returns (B2B and B2C)
3. Product recalls
4. Warranty returns
5. Service returns
6. end-of-use returns
7. end-of-life returns

Summarizing, a product is developed and goes into production following the supply chain with the purpose of reaching a customer. However, at any moment, the product may go back in the chain. From this moment on, the chain does not deal any longer with supply alone, but also with recovery related activities. This denomination underlines the possible integration of forward and reverse flows. Furthermore, it embraces both the closed loop supply chains, where supposedly the reverse flow goes back to the original user or original function, as well as open loop supply chains.

Reverse logistics is gaining increasing levels of attention because of environmental factors as well as economic reasons (Ginter and Sterling, 1978; Gupta and Veerakamolmal, 2000, Haberland et al., 1997). Unfortunately, reverse logistic systems are more complex than forward logistic systems. This complexity stems from a high degree of uncertainty due to the quantity and quality of the products (Gungor and Gupta, 1999). Although it is desirable to develop an integrated model to incorporate forward and reverse flows of new and used products, one common approach to designing reverse logistic networks is to model reverse distribution independent of forward distribution (Fleischmann et al., 2003; Ginter and Sterling, 1978; Minner, 2001; Klebber et al., 2002; Teunter and van der Lann, 2002).

3. SIMULATION MODELLING IN LOGISTICS

A simulation is a model that mimics reality, defined as:

„*... the imitation of the operation of the real-world process or system over time. Simulation involves the generation of an artificial history of the system and the observation of that artificial history is draw inferences concerning the operating characteristics of the real system that is represented*“. (Banks, Carson, and Nelson 1996)

In general, models can be divided in conceptual, mathematical and simulation models. This segmentation refers to the levels of development of individual models. In designing of any model, it is primarily to define a conceptual model, and then this conceptual model can be used as a basis for the development of mathematical and simulation models (Hompel and Schmidt 2007).

Simulation models are models which are used in dynamic systems, systems that change in time and when applying simulation models, solution is obtained by experimenting system model, whereby simulation experiments result in a set of points. For this reason, planning and analysis of simulation experiments requires a statistical approach. When performing simulation elements (parts of model), simulation conditions must be controlled and provide conclusions.

The model is defined as an abstract representation of a system that describes objects systems, their interaction and usually contains a mathematical (i.e. budget period, activities) and logical relations (conditions of the action, the rules for the selection of entities) that correspond to the structure and mode of system operation. Models include objects with specific properties and their interaction causes changes of the system per time unit.

There are two basic groups of simulation models. The first group includes deterministic (those whose behavior is completely predictable) and stochastic models (those whose behavior is unpredictable, but it is possible to determine the probability of a status change). The second group includes discrete models (i.e., manufacturing processes and transportation systems), continuous models (i.e. position and speed changes continuously over time during the flight of the aircraft), and continuous-discrete models (i.e. arrival of tankers with oil in the harbor, where they differ continuing variables such as the level of oil in a tanker and tank and discrete events such as the arrival of the tanker).

Simulation of discrete event is a method for simulation modeling that describes the state changes which occur discontinuously in time, only in some specific moments. The interaction of objects in the system activities is causing changes in system status. These changes or events occur in discrete (discontinuous) time points (Thierry, Thomas, and Bel 2008).

Modeling of logistics system (supply chains) requires an understanding of the types of logistics systems and the objectives and issues associated with each type of system. Logistics systems can be arbitrarily complex and difficult to understand due to large number of data which is necessary to provide supply chain modeling.

In supply chain, decisions taken are usually classified as strategic, tactical, or operational. Strategic decisions are related to the company's strategy and are long term (2-5 years) with involvement of the most partners in the supply chain. Tactical decisions are mid-term (a month to 1 year). Operational decisions are short term, which are related to the day-to-day activities. Tactical and operational decisions are taken in individual area of the supply chain (e.g. plant and warehouse). They deal with issues in demand, procurement, production, warehouse and distribution.

Many researchers are investigating the possibility of creating a simulation-based real time scheduling system that will be able to monitor the system status and make decisions in real-time. To have the capability, it is desirable to have (1) capability to interface with legacy databases to obtain information (2) hardware and software processing capability to run simulation within very short time- at least, pseudo in real time (3) capability to interface with the control system to assign tasks and receive feedback on system status and performance.

Currently there are several commercial simulation tools available. These tools can be divided in three basic classes: general-purpose simulation language (requires that user is proficient programmer as well as competent simulationist), simulation front-ends (are essentially interface programs between the user and the simulation language) and simulators (they offer graphical presentation and animation, easy to use).

In this article authors used "Flexsim" simulation tool for simulation of centralized service center. Mentioned tool is specifically designed to simulate discrete events, primarily when simulating warehouse processes, airports, terminals and manufacturing complexes. Each model simulated in software is a system that consists of queues, certain processes and transportation. It enables the development of 3D models and accurately captures the actual system.

Reverse logistics issues are suitable for simulation modelling regarding to complexity of reorganization on site and focus on forwarding channel. Simulation modelling of directing amounts of products through different processing options in reverse logistics has a benefit of redesigning for an optimal solution. Returned amounts in reverse logistics are significant and need to be observed from supply chain point of view. Paper will present amounts and modelling directing to service centers from subjects in supply chain, including final consumers.

4. REVERSE LOGISTICS CASE STUDY – RETURN TO SERVICE CENTERS

Performed studies on the Croatian market regarding reverse logistics included 19 different companies, i.e. retail chains of a major share on the market, suppliers, producers, distributers and service centers. Companies provided basis for conducting research and insisted on anonymity. Researched infrastructure included detecting processes, warehousing and data regarding reverse logistics and inventories in distribution flow.

Regarding goods in return directed to service centers from retail locations, those are transported in an average of two times a month, according to research conducted at retail locations. Of all products (approximately 16) returned in one day from different reasons at a retail location category III (this means "Retail location assortment of 33000 products"), an average of two will be directed to a service center. The service center employs trained personnel to carry out inspection and repair of the returned product. Time periods required to conduct certain activities are used as input parameters of the simulation model of proposed centralized service center.

Retail locations are in different ways directing the goods in service centers, depending on the organization within the company, but also it depends on the current quantities of goods which are necessary to transport. Although transportation to a service center is secured, the organization is often ununiformed, performed in 20% cases *ad hoc*, when it's noticed that returned goods on service wait too long, and the legal obligation of goods repair should be within "a reasonable time". The goods are transported at the expense of distributors, suppliers or manufacturers, depending on the agreements between the companies. Because of non-uniformed processes, transporting goods for service often is dedicated to salesperson, or any other person to whom specified route this permits, and is operating within retail and service chain or a business associated with it. On the market there are two different returns from retail chains:

- Products intended for the service are collected at retail location, and then by organized transport are directed at service centers.
- Products intended for service are not collected at service centers, and the end users themselves are obliged to deliver the goods to the location of the service center and to collect.

Because of the mentioned above, the double transport processes are detected in handing the goods, as users primarily returning the goods to the location of purchase, and then at the company's expense, because company is contractually bound to the above, the goods are delivered to the service location.

At the level of the service center, the goods are received on a daily basis, and based on semi-annual data of one company that has been involved in the study, in a total of 31,723 orders. The service center, which is one of the major service centers in Croatia, and is a manufacturer and distributor of electronics and consumer goods, goods in return primarily categorize:

- Commercial return which includes goods returned by the end user within 8 days of purchase unpacked and for defects in using, but technically unused goods, used for the purpose of promoting or goods damaged at the retail level.
- Service orders that include only goods that are returned due to a malfunction.

4.1. Amounts and product quality in return

Data collected for the purposes of research have shown that in the six-month period, from August 2012 until January 2013 year, the service center has received a total of 8,500 orders categories of commercial return, and a total of 23,232 service orders, as graphically shown in Figure 1.

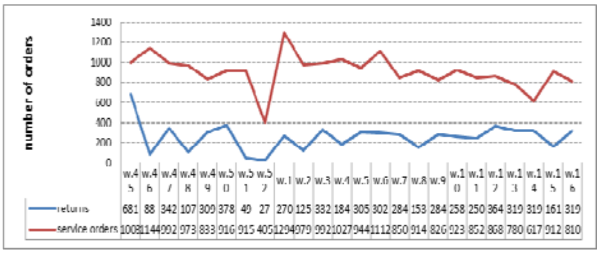

Figure 1: Return of goods to a service center

Service orders in 72% of cases involve the inspection, repair and return to the final consumer, 16% of the products are damaged, but products that can still achieve certain market value, 10% of them are for directing at the disposal, and 2 % to the manufacturer.

Statistical data resulted in the fact that after inspection of the commercial return category by trained employees in the service center, most of the goods are directed in the reverse logistics channel where the goods will be sold at a lower price, then the channel in which the goods will be sold at full market price. Other channels include the disposal at 21% of the cases, the return to the manufacturer in 8.9 % of cases, and a return to the status of an unauthorized in 0.6 % of cases. The study confirms that uniformity in procedures affects the return of unauthorized returns in minimal amounts. Disposed are those products that after control present group for which cost of repair is greater than cost of disposal. Products are destroyed completely, and parts thereof, cannot be reused. Manufacturers are usually insisting on return for the purpose of verifying the status of return processes, where each manufacturer ensures that the product is reviewed in accordance with their terms. The above statistics are shown in Table 1, were processing is at the example of 3445 orders received.

Table 1: Status of commercial return after reviewing by trained employees

	Number of orders	Percentage
Secondary market – sales price	1243	36.1%
Primary market – full price	1149	33.4%
Disposal	725	21%
Return to manufacturer	306	8.9%
Unauthorized return	22	0.6%
Total	**3445**	**100%**

4.2. Necessary time periods for processing

Different categories of return characterize different periods of time necessary for the employee to inspect and repair goods. Studies have confirmed that the average period of time required for treatment depends on the condition of the product. At total of 31,732 orders observed in six month period, it was found that the product inspection by employees requires time period from 1.96 to 2.06 working days. The differences are reflected in the time required for repair, where the products include fewer failures and are categories of commercial returns, and require much less time to repair, ie 4.7 compared to 7.81 workday for service orders product category. The above data are shown in Table 2.

Table 2: Time periods necessary for inspection and repair

Category of non-defective defectives (product is

	Time period for product inspection (calendar days)	Time period for product inspection (working days)	Time period for product repair(calendar days)	Time period for product repair(working days)
Commercial return	2,74	1,96	6,58	4,7
Service order	2,88	2,06	10,96	7,81

properly working), which is one of the strategically important categories, and the categories that need to be reduced when entering the reverse logistics system, are analyzed on the basis of service orders and status after a review of the product in return. From a total of 23,232 service orders in the period of August 2012 until January 2013, 3.14% are orders whose status confirms that the product has been tested and is fully correct. Share of non-defective defectives at a service center is not considered significant, while the cause of the quantity of returned products in this category are considered uneducated users, and unused instructions.

As relevant parameters for comparison with the output parameters of the simulation model are defined:

- Number of employees in charge and their cost.

During the research it has been noticed that at every level of the supply chain there are employees solely responsible for processing goods in return. Respondents pointed that disburden of the distribution flow employees could reduce costs and/or provide additional resources to handle the distribution of goods.

- Average disposition cycling time.

Disposition cycling time is important indicator of the return flow quality. Reducing the disposition cycling time, organization allows returned product directing to the secondary market in a shorter period of time and increases the possibility of achieving maximum market value.

All costs and presented as an approximate value for employee salary on the Croatian market in January 2014, while disposition cycling time is measured at researched locations for products in return. Mentioned parameters are presented in Table 3.

Regarding service centers and retail locations, during the research, necessity for reduction of costs was continuously highlighted. Costs that are considered as issues include unnecessary transport process, employee occupation with return and number of employees provided for returned items, especially at retail locations. Disposition cycling time generates costs from product point of view, where prolonged processing reduces the value of the product and the possibility to gain maximal possible profit.

Table 3: Research results regarding disposition cycling time and expenses at retail locations and service center

	Number of employees /hours a day	**Expenses brutto/day**	**Total expenses / day**	**Disposition cycling time**
Retail location	3/16	25 EUR	75 EUR	5-10 days
Service center	38/8	30 EUR	1140 EUR	10-14 days

5. SIMULATION MODEL OF CENTRALIZED RETURN TO SERVICE CENTER

Simulation model is made in simulation tool “Flexsim” that is used for simulation modeling of logistics processes. Due to unnecessary transport processes, ununiformed procedures and prolonged disposition cycling time organizational model for centralized service center is proposed.

Conceptual model is based on presumption that service center is formed on the market as an business subject that is processing facility for inspection, repair and other reverse logistics activities. Service center is formed for the benefit of reducing the disposition cycling time and prompts the positioning of returned products on the secondary market containing reverse logistics channels in form of outlet and internet sales. Model contains activities that are triggered when item is returned, if unauthorized return appears it will be rejected, positioned in the shipping zone for directing to producer or back in chain. If authorized, inspection is obligatory. Detailed inspection provides individually based information regarding product in return and necessity for repair. Temporary location is provided while ordering parts and/or repair. Educated personnel evaluate products and its disposition to proper in-house or another reverse logistic channel. If product is consumer return it is positioned on temporary location while collection by consumer.

Mentioned structure is presented in Figure 2.

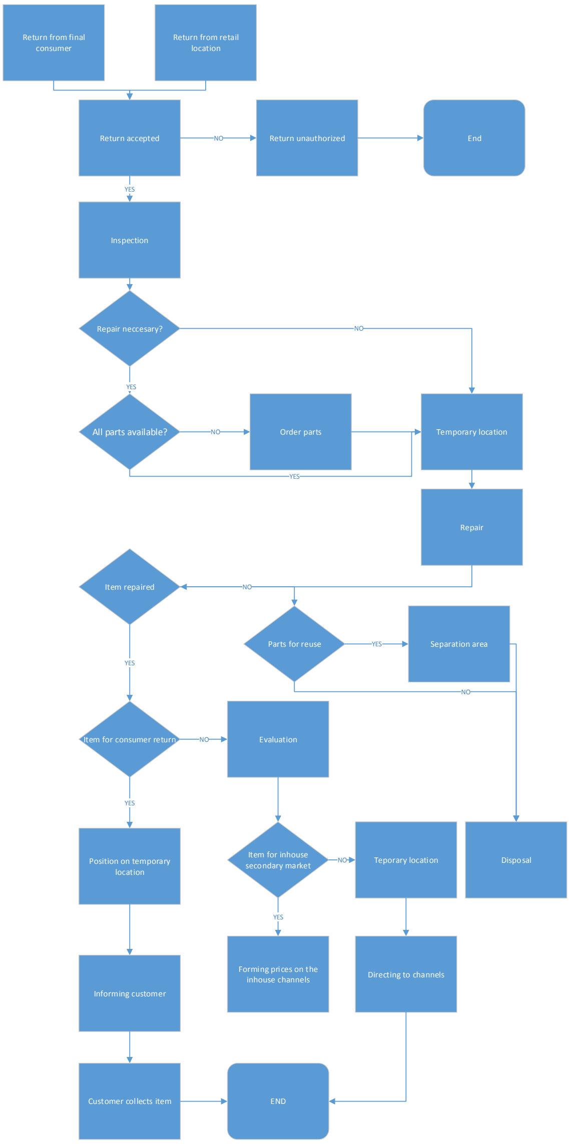

Figure 2: Model of centralized service center

Simulation model contains of processing objects and three modules, receiving area, processing and directing to secondary markets.
Simulation modeling included:

- Objects formation from the simulation software tool library.
- Defining the relationship between objects by setting connection.
- Objects parameters (variables) input.
- Simulation runs with the execution of simulation experiments.
- Summary Statistics.

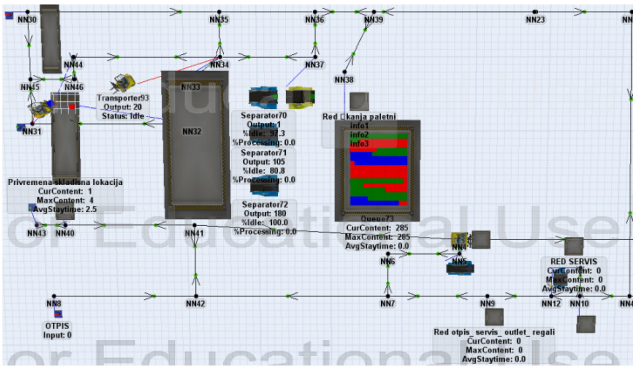

Figure 3: Simulation model proccesing modul of centralized service center

For the purpose of verification of the simulation model, testing of individual activities was conducted, objects, their conditions and interrelationships. Procedures, planned events, the association of fixed and mobile objects and their defined variables, and the movement of the entities within the conceptual model, were tested in the form of modules, where one module is a closed function of the observed system. In this manner modules are individually verified and after for simulation model was defined the limited time period of replication in the range of 10,080 rpm.

After 120 replication of limited time duration in the range of 10,080 rpm, different output variables were observed. Model of the service centers, has resulted in direct benefits for critical points related to the business in return of goods. Reducing the disposition cycling time at averaged 280.85 minutes, or goods are in the house after arrival processed within one business day, which significantly shortened the disposition. The disposition cycling time on the Croatian market for products directed to service centers in its minimal share is 15 days and in its maximum 24 days after the products is received. The disposition cycling time in centralized service model directly depends on the number of service workers and can be prolonged by reducing the number of employees with parallel reducing of the costs. The cost of employees was reduced at each retail location category III for approximately 2000 EUR per month. Channels of reverse logistics in a simulation model include outlet and internet sale which is significant for electric and electronic devices because of their continuous value loss, and positioning items in short period of time on the market.

Except mentioned, evaluation of products on retail level results in ununiformed values, processes and provided activities (if existing), while processing products in return in the service center results in evaluation by educated personnel.

6. CONCLUSION

Reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. To achieve this objective, companies need to have better visibility into the entire reverse logistics system of their own plans as well as those of their suppliers and customers. Companies today should be agile enough to adjust and rebuild plans in real time, to take care of unexpected events in the supply chain. These needs have propelled the application of discrete event simulation for analyzing entire supply chain process.

When developing reverse logistics simulation models, first of all a good understanding of the overall supply chain is most important. Good understanding of the business characteristics (e.g. performance measures, make to-stock or make-to-order) is also essential since every industry has different business characteristics and supply chain management processes.

Organizational issues of reverse logistics, including reverse logistics problems in all aspects of the supply chain, need to be researched continuously. Detailed analysis of processes, reasons of return and specifications of products in return can be fundaments for reorganizing the reverse part of chain for the economic, ecological and sociological benefits.

Specific part of logistics should be often simulated due to uncertainty and often impossibility to reorganize processes to measure optimization. Except in-house simulations, reverse logistics issues very often become issues of other parts of chain where they generate certain logistics costs in form of warehouse, transport and manipulation costs. Because of mentioned subjects of supply chain should coordinate their business to optimize reverse logistics processes.

For the same reason simulation model was formed regarding centralizing the goods aimed for service from final consumer and retail locations. For directing those products in return it is necessary to provide specific activities. In the service center is necessary to define the activities that will be in accordance with the needs of the customer service or own business and specifications of the products that will be directed to a service center.
Primer activities should be the core of the centralized service center defined for the purpose of the offer and to short disposition cycling time as repair, dismantling of the components, reuse and disposal. Activities of repair and re-use are provided by trained employees and service workers, while these activities imply that the product needs for specific (and in some cases very small) changes. Depending on the contract, it is necessary to provide activities to replace worn out or dysfunctional components of the product or packaging, in order to re-use products.

Also, it is necessary to provide possibility for packaging original state by conducting activities such as cleaning, polishing, painting, etc. if a manufacturer or supplier requires. If this is not the case, after evaluating, products will be repaired or renewed in the manner prescribed by the service center, with the aim of adding value in order to achieve the maximum possible value of the potential markets and in-house reverse logistics channels.

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