A Test-Bed System for Supply Chain Management Incorporating Reverse Logistic

Shigeki Umeda

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Shigeki Umeda
shigeki@cc.musashi.ac.jp
1-26 Toyotama-kami Nerima Tokyo 176-8534
Japan

Abstract. Due to environmental and ecological responsibility, enterprises are trying to reuse, remanufacture and recycle the used products to reduce the negative impact on environment. Reverse logistics is one of essential elements to implement such sustainable supply chain system. This paper proposes simulation-based test-bed system for supply chain management incorporating reverse logistics.

Keywords. Supply chain management, Reverse Logistics, Simulation, Test-bed system

1 Introduction

Modern manufacturing enterprises need to collaborate with their business partners through their business process operations such as design, manufacture, distribution, and after sales service. A supply chain system is a chain of processes from the initial raw materials to the ultimate consumption of the finished product spanning across multiple supplier-customer links. It provides functions within and outside a company that enable the value chain to make products and provide services to the customers. Many discussions have been done [1].

In the last decade, due to environmental and ecological responsibility, enterprises are trying to reuse, remanufacture and recycle the used products to reduce the negative impact on environment, especially the manufacturers of the electrical consumer products. Electrical and electronic scrap also known as e-waste or e-scrap – has increased dramatically.

Requirements for corporate responsibility and sustainability are getting more urgent. The reverse logistics in supply chains is strongly related to all stages of a product development and is also a critical problem to all level of the industry.

Reverse logistics systems require taking back products from customers and the repairing, remanufacturing (value-added recovery), or recycling (material recovery) the returned products.

The reverse logistics makes more complicated material-flows in supply chain. There are different kinds of material-flows in a chain. One is forward-flow which starts at part/material suppliers and reach customers. The other is reverse-flow which starts at customers and reach remanufacturer or recycler. Accordingly, introduction of reverse logistics in supply chain system would have profound effects on operations such as material-handling and procurement. This relationship is similar with arterial-flow and venous-flow in a human body.

System design and implementation of a "supply chain system with reverse-flow" would be extremely difficult in comparison with the cases without reverse-low. This is because considerations of reverse logistics would promote many issues in both configuration design phase and operations design phase. A generic method is needed to support supply chain system with reverse logistics.

System modeling technologies often provide useful operational analysis of system behaviors. The SCOR model is the most prominent process model in supply chain system [2]. This model provides a set of core models, which represents business processes in supply chain operations. The SCOR model includes five core models (PLAN, SOURCE, MAKE, DELIVER, and RETURN). Individual model describes activities in detail. Such macro-level models are, needless to say, useful for generic system descriptions at initial stage.

Modeling and simulation is one of the general purpose tools to optimize designs and operations of manufacturing and logistics systems. Especially discrete-event simulation provides predictions of system's behaviors potential status by "what-if scenario". Thus, simulations have been used as a powerful solution tool for various operational management problems, such as capacity planning, resource planning, lead-time planning, supplier selection, and outsourcing planning. The disadvantage of modeling and simulation is that system analysts need to implement simulation models of their own target system. This workload is very huge.

Analysts would be able to use modeling and simulation if typical generic simulation models are provided as a simulation model library in advance. In this case, the analyst chooses proper models in library, and customizes them as the need arises [3][4].

The objectives of this paper are (1) to propose a generic supply chain model with reverse logistics for product reuse, (2) to implement generic simulation models for the test-bed system by using generic models, and (3) to represent effectiveness of the proposed test-bed system by numerical examples. These models include component members, which enables to organize a supply chain system with reverse logistics. All models represent both material-processing logic and information-processing logic in the chain.

2 Reverse logistics models

2.1 Member elements model

First, we configured models that provide regular flow in a supply chain system. This feature is composed of elements, which include a Supplier, a Manufacturer, a Retailer, a Customer, and a Chain manager. Second, we also arranged components that realize reverse flow for product reuses. These elements are "Collector", "Remanufacturer", and "Recycler". A set of these elements would be a generic supply chain model with reverse logistics (Fig.1). Data descriptions of these elements include input (information/material), output (information/material), Pre-defined information, activities sequences, and performance measurement data. The summaries of activities of these elements are as follows.

Fig.1 represents a configuration of this model. This model is based on an analogy between arterial-venous blood flows in a human body and material-flow in a supply chain. Solid lines are production generation flow (arterial-flow), meanwhile, dashed lines are reverse logistics flow (venous-flow). Arterial-flows and venous-flow should be synchronized with each other. The system synchronizes venous flows with arterial flows. A set of simulation models represents above elements was implemented as a test-bed system for supply chain management incorporating reverse logistics.

- **Chain manager:** The major task of this element is to generate orders to elements which belong to an arterial flow in a chain: these are "Supplier", "Manufacturer", and "Retailer". This is a heterogeneous element in the chain. It predicts Customers' demands, and it gives orders to other members by using the predicted data. It keeps Customers' purchase data in a particular duration, and it uses them to predict demands in next ordering cycle. We developed an IDEF0-based hierarchical function model, that represents ordering process mechanisms in a chain [5].
- **Supplier:** This element is a start point of material flows in a chain. It generates parts by a sourcing order from Chain manager. And, it sends the parts to "Manufacturer" by using a transporter.
- **Manufacturer:** It receives parts from the Supplier and keeps them. When it receives an order from the Chain manager, it starts to generate products. After predefined lead-time, it sends the products to "Retailer" by using a transporter.

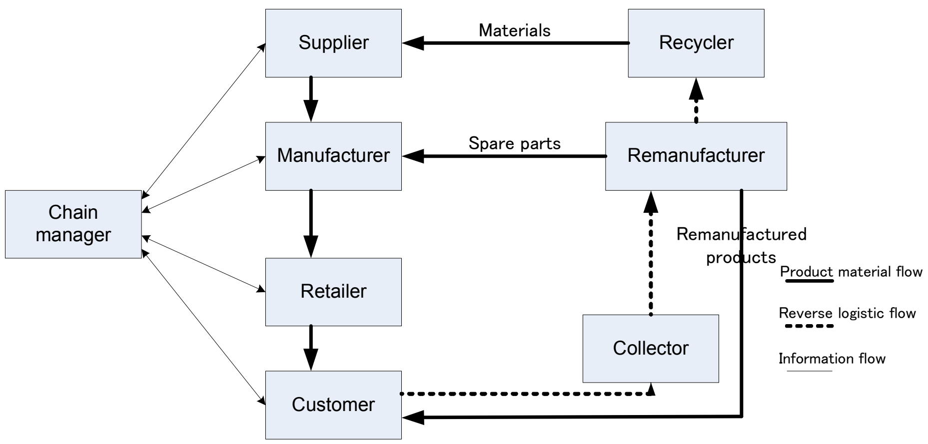


Fig. 1. Generic supply chain model with reverse logistics

- **Retailer:** The activities of this element are similar with Manufacturer. It receives products from Manufacturer, and it sends them to the Customer according as purchase orders.
- **Collector**: It reclaims used products from Customer, when he/she disposes the used product. And, it detaches reusable materials from the disposed product, and sends them to Remanufacturer.
- **Remanufacturer:** It produces remanufactured products by using materials from Collector. Examples of the remanufactured product are spare-parts. It provides the regenerated objects to Manufacturer.
- **Recycler:** It reclaims materials from wastes produced by Remanufacturer.

2.2 PUSH-type and PULL-type reverse model

Fig.2 represents configurations of reverse logistics models. These models are based on an analogy between arterial-venous blood flows in a human body and material-flow in a supply chain. Solid lines are production generation flow (arterial-flow), meanwhile, dashed lines are reverse logistics flow (venous-flow). Arterial-flows and venous-flow should be synchronized with each other. The system synchronizes venous flows with arterial flows. A set of simulation models represents above elements was implemented as a test-bed system for supply chain management incorporating reverse logistics.

The flow from Customer to Remanufacturer by way of Collector is a reverse logistics flow. There are two ways to control this flow: PUSH-type and PULL-type. Customer sends “used-products” to Collector, when Customer disposes them. The role of Collector is to distinguish reusable materials from the disposed products, and stores them.

One way is that Collector and Remanufacturer sends reverse products to Manufacturer in an orderly manner. This is PUSH-type flow, which is illustrated in Fig.2 (a). Another way is that Remanufacturer regenerates reverse products as the need arises in Manufacturer. The same logic is applied in between Remanufacturer and Collector. This is PULL-type flow. The implementation of this logic needs two pull signals, which is illustrated in Fig.2 (b). The first one is from Manufacturer to Remanufacturer, and the second one is from Remanufacturer to Collector. Collector acquires reusable materials from Customer with constant collection rate. Remanufacturer *pull*s materials from Collector, when it requires materials. Manufacturer also *pull*s materials from Remanufacturer as the need arise.

In PUSH-type, remanufactured products are sequentially pushed into Manufacturer, synchronizing with occurrence of reverse. Remanufactured product would be kept as material inventory in Manufacturer. In PULL-type, reverse products are stocked at Collector. These products stay at there, during no PULL signal from Remanufacturer. And, Remanufacturer does not work until it receives PULL signal. When high volumes of reverse products are generated, they are stopped at Collector.

When demand volume by Retailer increases, volume of used product flowed to Collector would rise. These are recycled by Remanufacturer, and are stocked as refreshed parts in Manufacturer’s buffer. Meanwhile, in PULL-type, even if demand volume decreases, volume of used product flowed to Collector would move down.

Synchronized with the used product volume, the volume of spare parts and reuse materials would increase or decrease. When manufacturing order increases after low production continues, parts shortage is possibly occurred in Manufacturer.

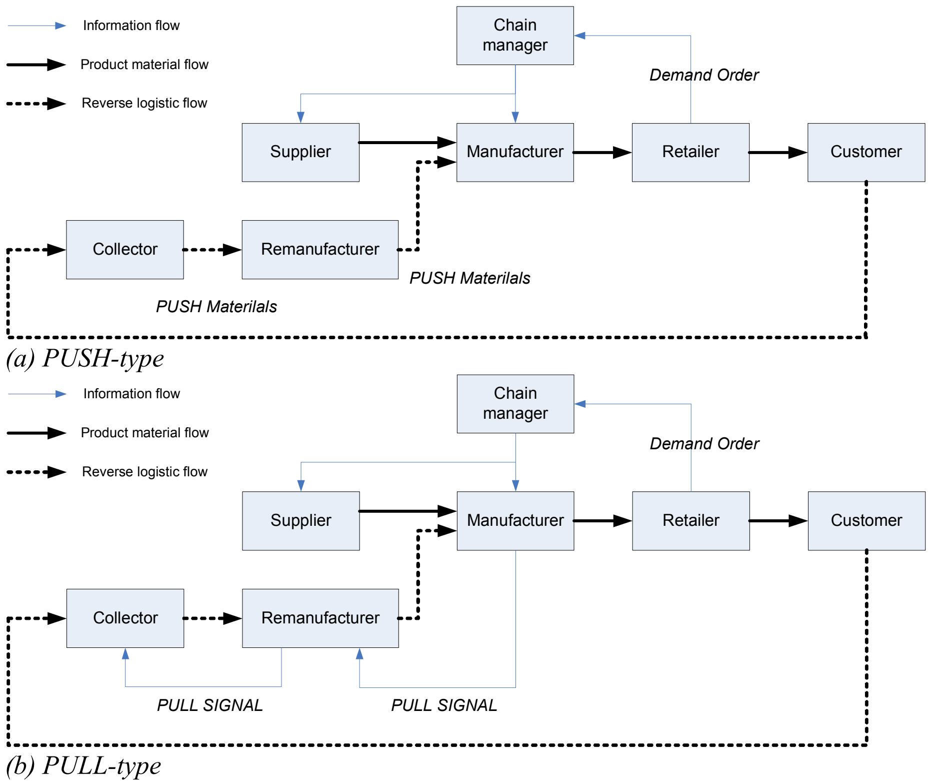


Fig. 2. Push-type and Pull-type reverse model

3 Simulation examples

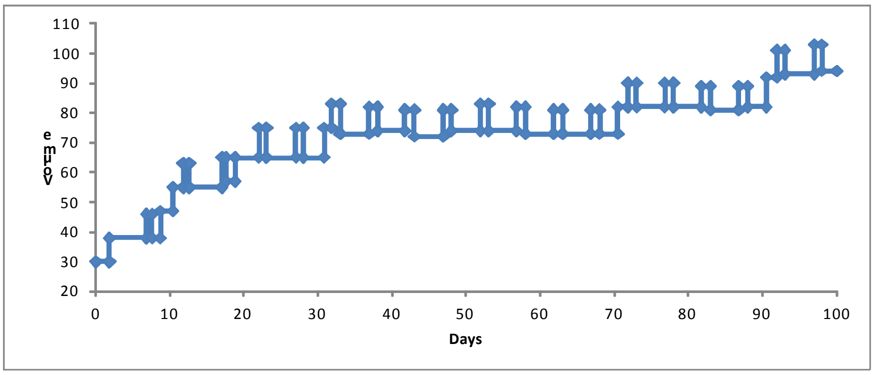
Based on the generic supply chain model described in 2.1 and 2.2, we implemented two types of model of reverse supply chain systems. One is Push-type reverse supply chain model, and another is Pull-type reverse supply chain model. In these models, Chain manager predicts market demands, and gives orders to both Supplier and Manufacturer in every week (5 working days).

Performance of reverse supply chain system depends on the “collection rate” of reusable materials from disposed products in market. In this case, we defined this value as 60%. Remanufacturer provides high performance; meanwhile Collector needs comparatively long lead-time to get reusable materials from the disposed product. Balance of these two reverse suppliers would be a key issue to determine whole of reverse supply chain system.

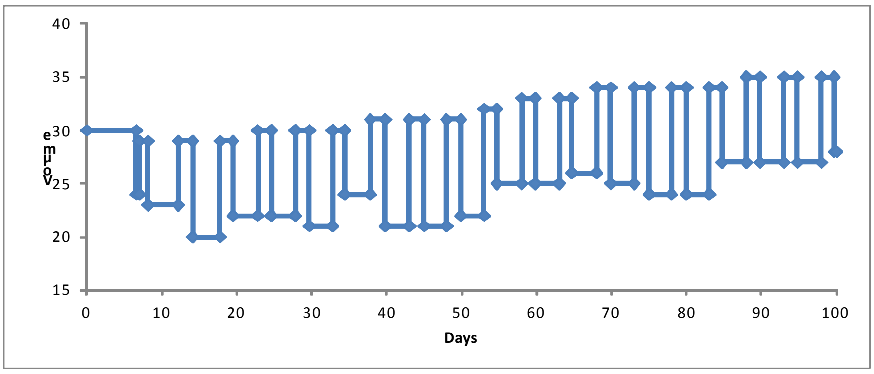
Other parameters of this simulation are lead-time and lot-size of chain members (Manufacturer, Retailer, Remanufacturer, Collector, and Deliverer). Chain manager generates the orders to Manufacturer and Supplier. Manufacturer and Retailer own almost same resource capacities. Meanwhile, Collector, Remanufacturer, and Retailer own almost similar resource capacities.

Operations during a hundred days are simulated, and the ordering cycle is a week (5 working days). Chain manager gives an operation order to Supplier and Manufacturer in every 5 working days. When the manager gives orders, he/she predicts demands in market by using exponential smoothing method. Each chain member gives transportation orders to Deliverer, when its operations are finished.

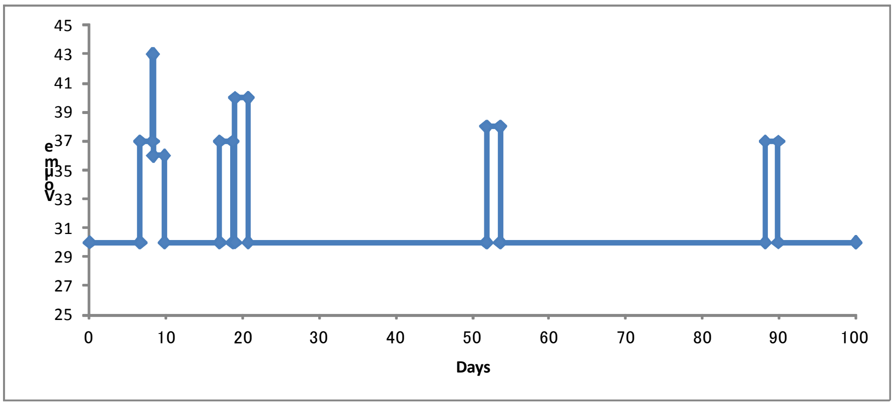
Figure 3 represents transitions of material volumes in the Push-type reverse supply chain. Retailer and Remanufacturer represent a steady state transition (Figure 3 (b) and (c)). Manufacturer represents a tendency that material increases, and Collector represents a material shortage state.



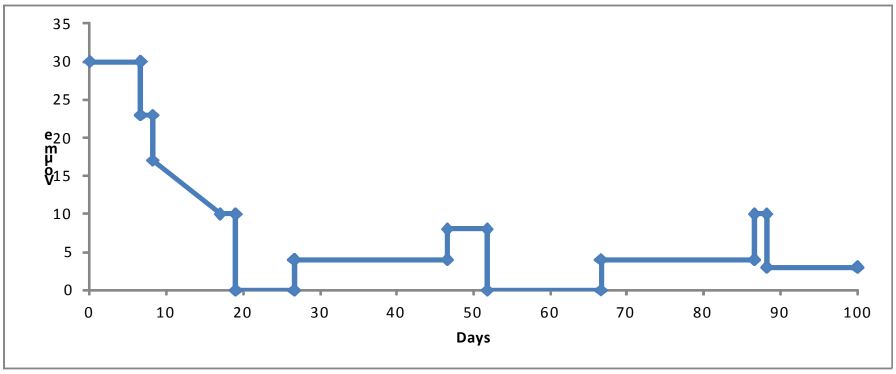
(a) Material volume at Manufacturer



(b) Material volume at Retailer



(c) Material volume at Remanufacture



(d) Material volume at Collector

Fig. 3. Material volume at chain members

Collector needs independent lead-time to collect reusable materials. Nevertheless, Collector cannot withdraw all materials that consumer used. In this simulation scenario, Collector sends materials to Remanufacturer as soon as possible. Accordingly, materials in Collector would decrease. Simulation configures considerable input materials as initial value; however, material shortage has occurred in midterm. This phenomenon is fully predictable, considering operational policy in Collector.

Manager makes production plans for both Manufacturer and Supplier considering Market needs. Manufacturer would additionally own the remanufactured materials by Collector and Remanufacturer. Accordingly, materials in Manufacturer would be increased.

In Pull-type system, Manufacturer *pulls* materials from Remanufacturer, when it is needed, and Remanufacturer *pulls* materials from Collector. Accordingly Manufacturer does not own over-need material. Besides, the collected material would stay at Collector. The only way is that Manager would make plans considering predictions of recycled materials from Collector at any situation.

However, it is very difficult to predict how many recycled materials in any operational phases. We would have no choice without preparing materials at suppliers' buffers, considering available materials at suppliers in a chain. Simulations based on other scenarios would be needed to discuss this issue.

4 Conclusion and future research

The work described in this paper is the first step in simulation researches for reverse supply chain management. Recovery, recycling, or reuse of products will be important issues in current supply chain management. A formal study of SCM incorporating reverse logistics is critical. The proposed test-bed simulation system would be a useful tool for designing supply chain incorporating reverse logistics.

There are various types of supply and reverse chain management problems. Design and planning would be the most popular scope. When a system planner designs a supply chain or a manager reviews performance of the existing supply chain, he/she would attach importance supplier selection problem. It is a significant decision since it affects the system performance for a long time. From the supply chain performance viewpoint, it affects all the problems discussed above. Mature decisions would be needed.

First of all, we should organize problems in reverse supply chain management. Design and planning problems, suppliers/venders selection problems, and outsourcing planning problem would be discussed. These problems are interlinked. Among them, discussions of Push-type and Pull-type reverse models would the most important.

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