Evaluating Performance of an Integrated Flexible Reverse Enterprise System (RES)

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Abstract

This paper proposes an integrated flexible Reverse Enterprise System (RES) which aims at enterprises to assessing their returns management capability, benchmarking best practices, and improving overall performance. The proposed model is an extension of conventional reverse supply chains and can be readily implemented on a simulation platform.

Keywords: Reverse Supply Chains; Performance; Flexibility; Product Recovery System

Introduction

There has been considerable research into flexibility and the performance of a forward supply chain, but there seems to be a gap in literature as to what and how flexibility strategies and performance measures need to be developed for an effective product recovery system and how to measure them. A generic framework will help us to model flexible reverse supply (Wadhwa & Madaan, 2007). These models can be used to demonstrate improvement in decision-making in product recovery system. While investigating decision and information synchronization requirement, need for integrated model of forward supply chain and reverse supply chains was realized. The model comprises of an end customer, an end supplier and a number of interconnected nodes among them from supplier to customer and back vice-versa. Its architecture considers almost for all possible products recovery scenarios. Still measures proposed are not exhaustive, and an argument can be made to incorporate more measures depending upon the enterprise requirements. The proposed architecture takes into account the maximum number of nodes and levels that are physically possible in a RES. It has the capability to take into account for the flexible path for product and information flow. In other words, this “flexible node” network structure takes into account the scenario where the product and the information have flexible flow through the number of nodes. For example, products may actually reach the “Asset Recovery” center after “Gate-Keeping” without even passing through the regional distribution centers and the Centralized Return Centers (CRC). But the “flexibility” was designed to account for any product and information flow involving the regional distribution centers and the CRCs that may happen anytime in the future. The network can be developed on the assumption that the Original Equipment Manufacturer (OEM) is responsible for returns, whether directly or indirectly which emphasizes possibility of multiple layered recovery chains interactions on product type attributes as shown in fig 1. Therefore, this flexible RES (FRES) is a generic model and can handle both end consumer and commercial returns.
As described, a typical RES starts from the “gate keeping” operation where the incoming products are checked for their eligibility to enter the RSC. This step ensures that only truly deserving products traverse the RSC. It is ensued by a series of operations like “transportation”, “sorting”, “storing” and “asset recovery”. The transportation is typically from the gate-keeping center to a “Centralized Return Center (CRC)” through a “Regional Distribution Center”. From the CRC, the product can be transported to a variety of locations like the recycling center, secondary market etc. Since we assume the flexible network, it passes through the “Recovery/Reprocessing options” site that makes the disposition decision. In reality, this center may itself host a variety of recovery options like remanufacturing, refurbishing and repair. After the “Recovery”, the product is again transported to the appropriate location. This marks the last RES operation done on the product. Therefore with this architecture shown in figure 1 it is possible to model Reverse Enterprise System, comprising of recovery chain for multiple products on multiple levels forward and reverse supply chain. The proposed architecture of the demonstrated models together determines the functional requirements of the simulation environment. It is seen that enterprise continually strives for achieving cost savings in their production processes. If an enterprise has efficient product recovery process, it will make money (Shrivastava, 2007, Stock, 1998).

![Figure 1](image_url)
The economic benefits of product recovery are direct gains in input materials, cost reduction, value added recovery and also indirect gains like impeding legislation, market protection by companies, green image for companies and improvement in customer/supplier relations. The recovery of the products for remanufacturing, repair, cannibalization, and recycling can lead to profitable business opportunities (Andel1997). Product recovery is now perceived by the enterprise as an ‘investment recovery’ as opposed to simply minimizing the cost of waste management (Schmidheiny1992). A reverse supply chain program can bring cost benefits to the companies by emphasizing on flexibility in resource allocation, and reprocessing options to gain value from returns effectively (Samar et al.2013). To achieve this objective we model product recovery system as a flexible system to enhance the performance of the reverse supply chain.

**Product Recovery System Design**

After identifying the inter-relationships between the various attributes that are necessary to evaluate the reverse supply chain as an enterprise system. The attributes identified are the product lifecycle stages, reprocessing functions, product recovery enabling strategies as performance measures. Figure 2 depicts the various inter and intra relationships between the various attributes of product recovery system. The process of analyzing these relationships between reprocessing operation is an extensive and painstaking process, but very critical with respect to implementing the flexibility and developing the FRES.

![Figure 2- Operational Flows in Flexible Product Recovery System](image)
A significant difference between our model and previous research on reverse supply chains is that this model explicitly captures the cost of lost product value due to time delays at each stage of the returns process. Since returns are time-sensitive and enterprises frequently lose much of the value remaining in their returned products by not making quick disposition decisions (Souza et al., 2003). This is especially true in high clock-speed industries such as consumer electronics, perishable food products, etc. Studies of time-based performance evaluation (Blackburn et al., 2004) have demonstrated that faster and flexible response in business processes can be a source of competitive advantage. Recovery rate essentially captures the time taken to perform the reprocessing operation for different products, and help managers to identify appropriate levels of flexibility and improve the process performance.

We propose and develop a generic discrete event simulation program, based on the Flexible Supply Chain System Frameworks (FSCSF), using the ARENA® V 7.0 discrete-event simulation language by Rockwell software (Kelton, 2002). The ARENA® package is selected for modelling as it provides a good graphical interface and also the animation utilities which will help in modelling and its verification. It provides the programming facility for developing modules to customize the simulation model according to requirements. In ARENA® package, there is no available feature to explicitly model the flexibility features with product recovery scenarios. However extensive efforts have been carried out to achieve this feature also. Here the idea was to evaluate how variable related to effective product recovery varies under these three scenarios (FSC, Non Flexible RSC and Fully Flexible RSC) and how can one anticipate those variations using the simulation results to adjust recovery process. We have run two different strategies and then compared the performance of the model under both. For the individual analysis of each one of the formulated models we will use those variables that we considered more important than other and that allowed us to observe the effect of the flow of return products in the management of inventories.

The comparative analysis of the results is made through a study of the costs derived from the management of inventories for each one of the models, in agreement with a habitual structure of costs in the systems of management of stocks. The performance of integrated FSC & RSC depends upon the levels and stages of flexibility. Supply chain stages refer to the number of members in each level, for instance two to four levels at each supply chain stage and if number of stages increase supply chain member’s flexibility increases. In our case, we consider four levels in forward chain and three levels in reverse supply chains and 3 stages for the reprocessing/recovery operations. Since, longer the delay or the recovery transit time, the more value of the item is lost due to obsolescence. The revenue gained by getting returned product quickly back into the forward chain to control obsolescence is significant. If an enterprise does RSC well, it will make money (Stock, 1998). The recovery of the products can lead to profitable business opportunities (Angerhofer and Angelides 2006). An efficient value recovery process in place can bring significant cost benefits to an enterprise by emphasizing on resource reduction, adding value from the recovery of products, or from reducing the disposal costs. Therefore the main objective of an FRES in terms of value recovery is to get returned product available in to the main chain at the highest possible price and in lowest possible time. Recapturing value from recovered products through RSC activities of waste reduction and cost savings, organizations can contribute to bottom-line improvement (Bacallan 2000). We select, inventory carrying cost of returns and order fulfil rate, as a performance measure in FRES context and discuss them in next section.
Evaluating Configured Flexibility RES

We analyze our model by means of simulation, using the off-the-shelf simulation package, ARENA 7.0. Specifically, we set flexibility conditions for products to choose reprocessing station based on availability products and inventory at respective stations. The novelty of this fully flexible inventory model for FRES is the assumption that returned products comes to a system having varying levels and types of flexibility, employed with dynamic changing ability. The selection is based on the static and dynamic parameters throughout the RES. The associated properties are kept constant throughout the recovery chain in all experiments. In the process of selection of alternatives for reprocessing (Disassembling, cleaning, refurbishing, re-assembling) returns, first check the inventory position on available options. The returned products arrive at reprocessing nodes and after following steps in recovery chain they go back to the forward chain “as good as new” condition. Re-manufacturing, cannibalization and refurbishing are typical tasks, which are considered not to be directly linked to forward chain. Recycle, repair and reselling are reprocessing options directly linked to the forward chain.

As mentioned before once the model is fixed the decision problem is reduced to choose an appropriate level flexibility. As for conventional product recovery models, determining best possible parameter values by means of a quantitative analysis does not appear to be attractive in a practical setting. Therefore, we develop several heuristics, which can easily be implemented on a spreadsheet as well as can be simulated, using the off-the-shelf simulation package like ARENA. Specifically, find the total cost of the system for that policy. We then adjust the value of returns and find the total cost for this value, searching for the optimal value of returns. We use analytical work described in previous sections to narrow the simulation search and to develop bounds and heuristics. In this way, we aim at understanding the behavior of the product recovery system when push policy is employed and to gain insight into the effect of return rates, backorder costs and lead times on system performance and use the following variables:

1) Average stock of marketable per period (S_{FSC}, t).
2) Average number of penalties for stock-outs per period (F_t).
3) Average number of returned R_t
4) Average stock of returns per period (S_R, t).
5) Average number of original/new products per period (O_t).
6) Average number of periods by cycle of FSC (P_{fsc}, t).
7) Average number of periods by cycle of RSC (P_{rsc}, t).

The results obtained in this dynamic simulation are deterministic as much by a set of parametric values. For testing the heuristics, we employ the experimental design shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>FSC</th>
<th>RES F=2</th>
<th>FRES F=3</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_{FSC}, t</td>
<td>1001.39 units.</td>
<td>1603.72 units.</td>
<td>1777.46 units</td>
</tr>
<tr>
<td>S_{RSC}, t</td>
<td>-</td>
<td>-</td>
<td>51,14 units</td>
</tr>
<tr>
<td>B_m</td>
<td>2.97 units</td>
<td>5.52 units</td>
<td>2.49 units</td>
</tr>
<tr>
<td>R_t</td>
<td>-</td>
<td>124.15 units</td>
<td>24.99 units</td>
</tr>
<tr>
<td>P_{fsc}, t</td>
<td>10 periods</td>
<td>16.19 periods</td>
<td>16.27 periods</td>
</tr>
<tr>
<td>P_{rsc}, t</td>
<td>-</td>
<td>-</td>
<td>3.24 periods</td>
</tr>
<tr>
<td>Service Level</td>
<td>98.52%</td>
<td>98.30%</td>
<td>99.25%</td>
</tr>
</tbody>
</table>
To test a variety of lead time settings, we first vary the FSC lead time and the individual reprocessing lead time in RSC. Likewise, to test a wide range of backorder/holding cost ratios, we vary the backorder. Furthermore, we have selected a range of variation for the backorder on the basis of the behavior of such systems. Recall that our study employs cost per unit as measure of performance. Since backorder cost is quite high and therefore we generate policies that have very few backorders (Fleischmann et al., 2001). It is also to be noted that the return rate is always less than the demand rate. In general, we observe three stages in a product reprocessing or value recovery. The value here is defined as the function of costs related to inventories. Considering product recovery system as flexible system, require an easy-to-use front-end simulation in order to allow administrators to change critical parameters during the course of various “what if” scenarios. Therefore, this demonstrates the results of the sample study on the inventory based performance reverse supply chain model as flexible system. The main focus of this section is to see the influence of operational flexibility with individual resources’ inventory in RES. Service level has also been proved to a performance measure in product recovery since it’s also providing early availability of products. The demonstrative model for simulation has run for 1000 units for all scenarios. The results of this exercise will be extensively discussed in chapter 5. The operational/routing flexibility varies from RF=1 to RF=3. At return rate R_t=0 and RF=1 we consider it to a forward model and there is no role of RES. Later flexibility level at RF =2 and RF= 3 are considered to demonstrate performance level for various product recovery scenarios. These scenarios were initially simulated by having various sequencing and dispatching rules like FCFS, SPT, MBPT and LPT as sequencing rules and MINQ, MWTQ and MQMWT as dispatching rules. The results indicate that; (a) At RF= 2 and 3, we get maximum significant impact in terms of time in all scenarios, with MWTQ/SPT. However the greater benefit is obtained at RF= 1 and Flexibility at RF=2 and RF=3 is higher for defined parameter set. To demonstrate simulation we choose the parametric set, for example: Q_{FSC}=200; Q_{RSC}=25; R_t=0.4; O_t=50; C_t=2; ALT_{FSC}=2; ALT_{RSC}=2.

Figure 4- O_t at ALT_{FSC}= ART_{RSC}=2 time units. C_t=2, Q_{FSC}=200, R_T=40%.
Finally, we will evaluate the service level that indicates the capacity of the model for meeting the demand without backorders (Samar et al., 2013). The results obtained in this scenario will be used in model with RF= 3. After examining the behaviour of each one of the variables we will simulate scenarios with variation in lead time of FSC to fulfil the orders of new products (ALT_FSC), with variation in lead-time of RSC to fulfil orders from returns (ALT_RSC), the batch size of in RSC (Q_RSC), the time of consumption (C_t) and the rate of returns (R_t). Comparing the performance returns model with flexibility level =2 shows a lot of similarity with model having highest flexibility level =3. Some interesting results demonstrating the benefits coming from flexible product recover model, can be summarize in the following scenario:

For the scenario that we have considered, the existence of a flow of returns allows replacing new products. This simulation demonstrates reduction in the requirement for new or virgin products and improves the availability of products at the retailers’ end in FSC as shown in figure 4.

![Figure 5- P_FSC at ALT_FSC=ART_RSC=2 time units. C_t=2, Q_FSC=200, R_t=40%](image)

As far as the mean level of the inventory of products available at the retailers’ end, we observed that RSC model with highest level of flexibility tends to generate a greater number of units availability to take care of the market demand as shown in figure 6.
The effect of substitution generates a smaller frequency in the launching of orders for the new products from FSC or acquisition of new products. This can be visualized through figure 5.

**Conclusion and managerial implications**

This paper focuses on the development of reverse supply chains which are further developed as RES. The VB based decision modification in ARENA simulation enables modelling of elements of RES with flexible flows. Here, besides demonstrating the performance improvement through flexibility at operational level this model can also demonstrate performance improvement at tactical/control level through decision and information sharing in product recovery system. Each node of the forward and reverse chain is realised by combining the basic supply chain processes, aiming to plan, source, make and deliver products to store. Number of interconnected supply chain nodes thus constitutes a RES framework. This framework can interact with number of interconnected chains. Based on the conceptual framework for flexibility paper uses deterministic value but considering more realistic value as model input can further be taken as future extension of paper comprising resource flexibility. Each of these flexibility types act in series to generate a progressively enlarged list of alternatives at a decision point. Therefore some studies can further be conducted to demonstrate the performance improvement through accurate and timely decision and information transfer.

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