Measuring performance of integrated and Flexible Product Recovery focused Supply Chains

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Abstract

The proposed model aims to facilitate enterprises in assessing their product recovery system capability, and in improving overall performance. The proposed model is a natural extension of several established policies for conventional reverse supply chains and can be verified on a simulation platform.

Keywords: Reverse Supply Chains; Performance; Flexibility;

Introduction

Using perspective from an enterprise system flexibility in product recovery can play vital role in improving performance of an enterprise. Ample of literature is available that exploits role of flexibility in conventional supply chains where product is destined to reach to customer. To take product from customer back into the chain has ample scope and developing it as flexible product recovery as systems is novel research in this domain of knowledge. Refereeing previous contribution in this area by Daniel & Guide 2000; Zuidwijk and Krikke 2001, has characterized recovery operations with complexities. Further in spite of complexities suggested decision framework that determine the effective utilization of returns not much has been stated (Bacallan, 2000). Although work by Fleischmann et al. 2001; Gold et al. 2010; Guide Jr. & Wassenhove 2003 has reported that, these uncertainties or complexity in return handling is extremely detrimental to develop comprehensive inventory model. Wadhwa & Madaan, 2007, Samar et al., 2013, suggested initial model to manage intricacy of return management in terms of its components and features by developing flexible recovery systems (FRS). These references has motivated us to explicitly model and study product returns under various product recovery scenarios. Further, simulation model can be utilized to verify and compare the performance of the FRS and make real time decisions (Mangla et al. 2013). To proceed for FRS firstly we will understand flexibility in supply chains context and later product recovery system. These two understanding will pave a way for FRS. To evaluate performance literature on usage simulation in recovery system can be evaluated (Bottani, 2010). Proposed approach categorize a supply chain from two in to operational domain: environmental aspect and business aspect in term of profit, cost and benefit to an enterprise. Torres (2004) initially used simulation and demonstrated efficiency-driven centralized approach to returns flow and proved quantitatively its ineffectiveness and suggested future scope to develop flexible framework with when return percentages are high and product values are considerable.

Multidimensional framework integrated recovery system

There has been considerable research in measuring performance of a flexible manufacturing (Stecke and Solberg, 1981, Cho et al. 1996). Performance measures for a flexible reverse supply chain still needs to be developed. To develop these performance parameters a standard framework will assisted researchers to evaluate flexible reverse supply chain (Wadhwa and Bhagwat, 1999). This generic framework through performance parameters can facilitate development of simulation model that can demonstrate decision-making improvements.

Pragmatically, this return processing station may decide for various recovery options e.g. repair resell, remanufacture etc. After the "Recovery" station and suitable decision returns are further conveyed to the suitable option for value recovery. This results in Recovery focused Integrated Supply Chains operation. With this framework it is possible to model an integrated forward and reverse supply chain as Reverse Enterprise System, including the value recapturing chain for different products on manifold levels.

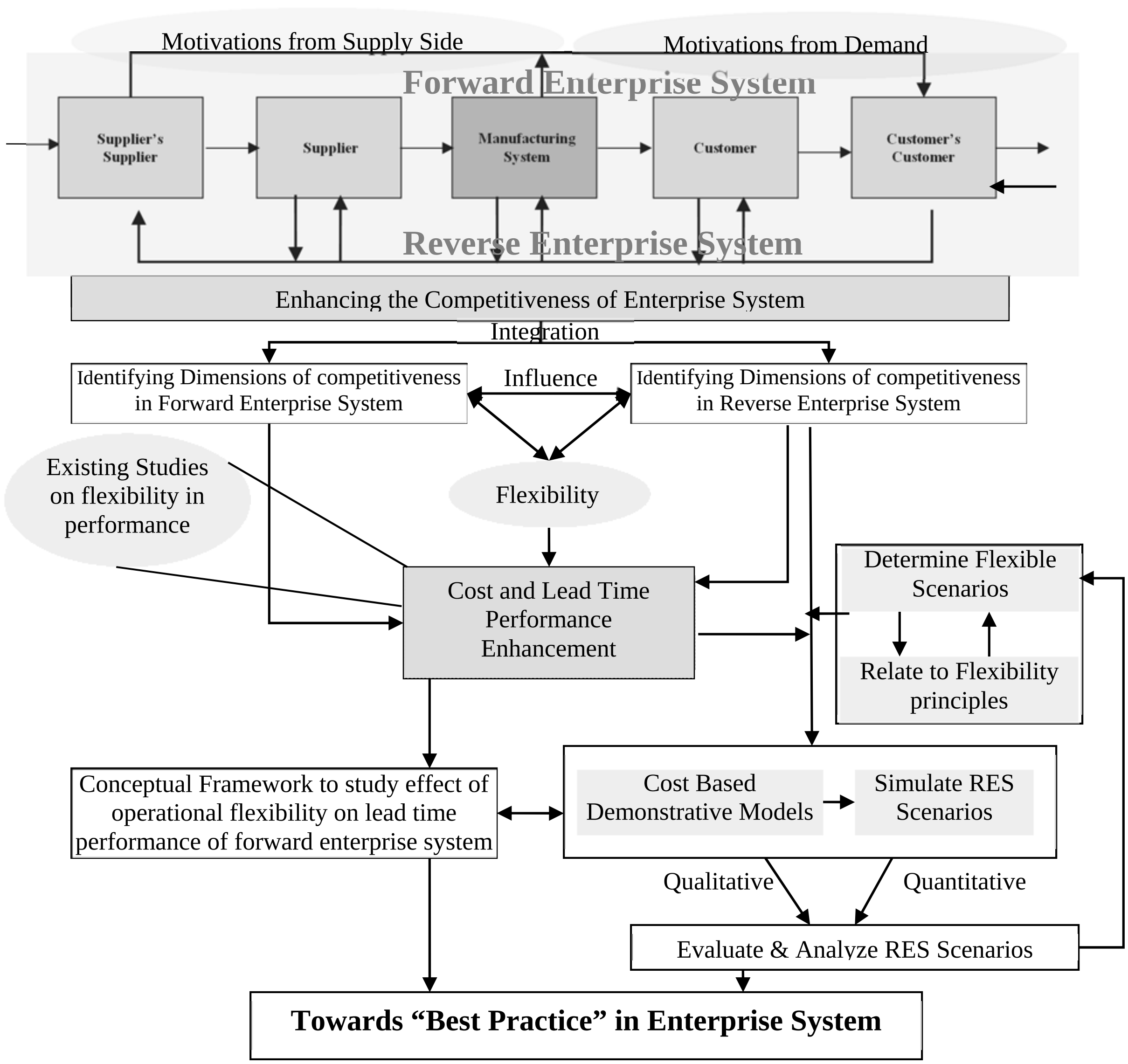

Figure 1 Multidimensional framework integrated recovery system

This proposed framework assisted us to establish models that determines vitality decision and information synergy and scenarios for simulating performance impact by returns. It is seen that an enterprise continually strives for achieving cost savings in their production processes. To study business impact from return processing we can categorize to direct gains and indirect gains. Direct gains results in requirement of new products and raw material into forward chain, and indirect gains are results in countering regulation, marketing benefits like green image and building customer/supplier relations.

Business impact of return processing or recovery operations was quantitatively demonstrated (Blackburn, 2003). The mindset of industry has been evolved from considering product recovery as waste management to asset management or investment recovery.

Flexible recovery system can fetch financial benefits to enterprises by highlighting on role of flexibility in decreasing delay in allocation of resource for reprocessing. Flexible reprocessing options and faster decision in selecting them can gain value from returns effectively. Thus, a proposed Flexible Recovery Focused Model consider efficiently and flexibly obtain the value of returned products and to gather information on the product utilization from the enterprise system perspective. It has got multilevel implication i.e. at conceptual level, where accepting; describing, capturing and assigning flexibility in a standardized way so that experts can easily recognise the models and implement effectively.

A comparative study of flexibility on recovery focused supply chains

It is both interesting and challenging to study the forward and reverse flows as flexible systems operating under varied decision scenarios and operational design levels. The proposed context is built on the forward flows and reverse flows of an enterprise system. Figure 1.2. shows overall improvement in competitive performance of an enterprise system and develops best practices for establishing a flexible enterprise system with a specific focus on product returns. Several dimensions of performance and its measurement have been identified. The main focus of this paper would be on enhancing cost/time based performance initially through studies on FSC and then extending these key performance measures towards RES.

The paper focuses on flexibility at operational level and reengineering type of innovation to understand the time and cost based performance of RES. With the knowledge of performance improvement under different operating scenarios, this paper illustrates demonstrative models which compare operational level decisions. Simulation models have been prepared using ARENA simulation software for dynamic decision modelling and which also aids in understanding the interesting ‘what if’ effect of decisions regarding reverse flow of products.

The study of flexibility in the RES offers greater scope to understand performance improvement under different return scenarios and further addresses the need to study RES from static & dynamic decision modelling perspective.

Impact of flexibility on product recovery

The focus of this section is to see the influence of flexibility especially routing flexibility with individual resources on product recovery system cost and make span with various return scenarios. The performance measure make span refers the time span by the returned product into reprocessing system. Our proposed simulation model for RES provides the opportunity to check the inventory level of various member of product recovery system and its cost based performance.

In the analysis that we have considered model for product recovery without any consideration of alternatives in recovery or Model for RES without flexibility, then we had considered partial or medium level flexibility in RES model and finally a highly flexible product recovery model (Samar et al. 2012). Details regarding considering routing flexibility as flexibility have already been described in the previous section.

The simulation is run for 10000 single products for all scenarios. The operational flexibility varies from Resource Flexibility level 1 to 3. Before explaining various scenarios and its effects on overall system cost we will consider a various cost elements in our product recovery process.

Once the strategy is fixed the decision level is condensed to selecting an suitable order size Or. As for conventional models, finding most advantageous factor by means of a Markovian analysis does find to be appealing in a pragmatic sense. Therefore, we improve by following heuristics, which can be applied to simulation model. We specifically, set Or and determine the cost using the ARENA simulation. The annotation which we will use to calculate of this analysis of costs will be the following one:

Co: Unit cost of acquisition of new or virgin products, CRSC: Unit cost of reprocessing of the returns which include the transportation, Cp, FSC: Cost of releasing new product order, CP, RSC: Cost of releasing of a order for reprocessed products, Cm, FSC: Unit cost of holding of marketable new products, Cm, RSC: Unit cost of holding returned products, CF: Unit cost penalty for not satisfying the existing demand. In general, we observe three stages product life relating to recovery operations. Early in initial phase, few units are with customer, and therefore no of units returned will be few. This is captured by the case when returns are Rt = 0. In the growth phase, and development and maturity phase that the longest stage of the life cycle, demand exceeds returns and the firm must process and reprocess to satisfy customers. Finally, in the decay phase, demand drops and returns surge, implying that the firm will not reprocess all returns. A new factor must be presented—the percentage of returns to disposed. This paper limit itself from this condition and can be proposed for future work. From the functions the total costs for the proposed flexible RES models will be defined by the following expressions:

$$TC = \frac{C_{P,FSC}}{P_{FSC,t}} + \frac{C_{P,RSC}}{P_{RSC,t}} + C_o O_t + C_{RSC} RSC_t + C_{m,FSC} S_{FSC,t} + C_{m,RSC} S_{RSC,t} + C_F F_T$$

Regulating Or and find the total cost value, examining for the most promising value of Or. To narrow down this search simulation can help to determine limits. We have objective to consider the performance of the system using push policy under periodic review and to gain awareness about influence of rate of return, cost of backorder and lead time in remanufacturing on performance.

Results obtained from this costs based simulation seems to reasonable when we suppose the cost of acquisition or processing of returns (CRSC) is lesser to the one of acquisition of the new or virgin products (CO), since these are directly marketable, i.e., they incorporate an added value greater then returns since it allows us to directly satisfy the consumers demand, whereas the returns still require the accomplishment of a series of activities that confer the quality as good as new.

In that case, we have decided that the cost of acquisition of returns to be represent a significant percentage (75%) of the value of acquisition of new products, although this value can be easily debatable. As far as the cost of emission of orders (CPFSC and CPRSC) we assume that a new product passes through an efficient forward supply chain, whereas the reprocessing operation and returned product orders are done by OEM. Due to this OEM has an expertise to reprocess products effectively. This differentiation allows us to justify a greater cost of order and processing of new products (CP FSC) in relation to the reprocessing product orders (CP RSC).

Results of simulation has been analysed to measure the performance of RES based Resource Flexibility from level 1 to 3. Figure 3 shows the pattern of deviation cost with increasing flexibility level. The results demonstrate; (a) by changing order size the total cost radically decrease in first stage for both conditions with and without flexibility (b) cost benefit is high as compared to the forward supply chain where the value is considered to be lost if product goes for uncontrolled disposal (c) performance improvement due to returns is quite significant with partial or lower flexible level in recovery chain followed by lower benefits at subsequent levels. Since in a fully flexible chain due to high cost involved of flexibility itself (since flexibility does not come for free) raise the cost up-to the level of forward supply chain system.

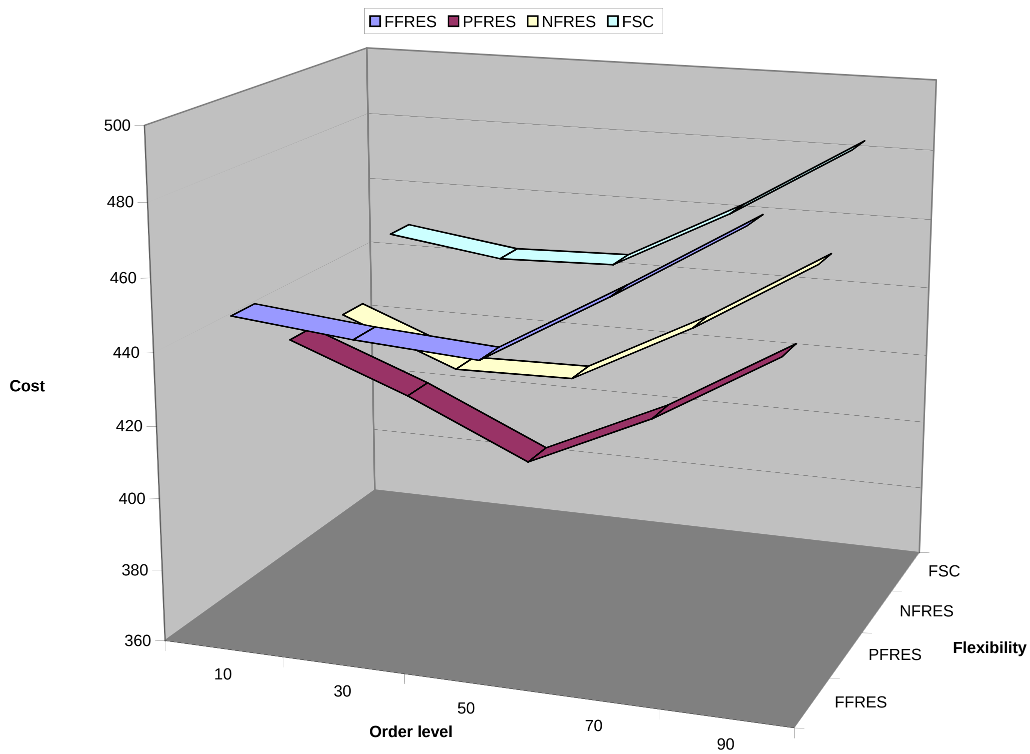

Figure 3: The pattern of variation in cost based on order level (1-3 stages FRES)

Considering our inventory based recovery models with flexibility level which is further extended by the varying batch size will demonstrate the variation of total costs. This will give the results different from model shown in the previous section, since we do not to pay much attention to how they affect to model parametric variations, but that we will focus our attention on analyzing competitiveness of our model, in terms of costs of management of inventories.

This figure can become a good exhibit to demonstrate the possibility of obtaining competitive cost advantages that can be brought through the flexibility in RES. Further, variation in the batch size of forward chain (QFSC) with order level will produce a variation in costs structure. In the first exhibit we consider the forward batch size QFSC =200 units for forward supply chain system. The results indicate that; (a) inventory is the leading dynamic control parameters to decide whether supplier is having sufficient inventory or not to fulfil orders. (b) the inventory cost drastically increases with the increasing order size and shows the very strong influence (c) the benefit of cost reduction decreases with increasing stages of flexibility in recovery chain as in the case of supply chain stage 3 and 4, (d) the PFRES provides the greatest benefit followed by lower and lower benefits at subsequent levels, (e) The total cost benefit is when order size is in the range of 30-50 units which is further reduced when we move further.

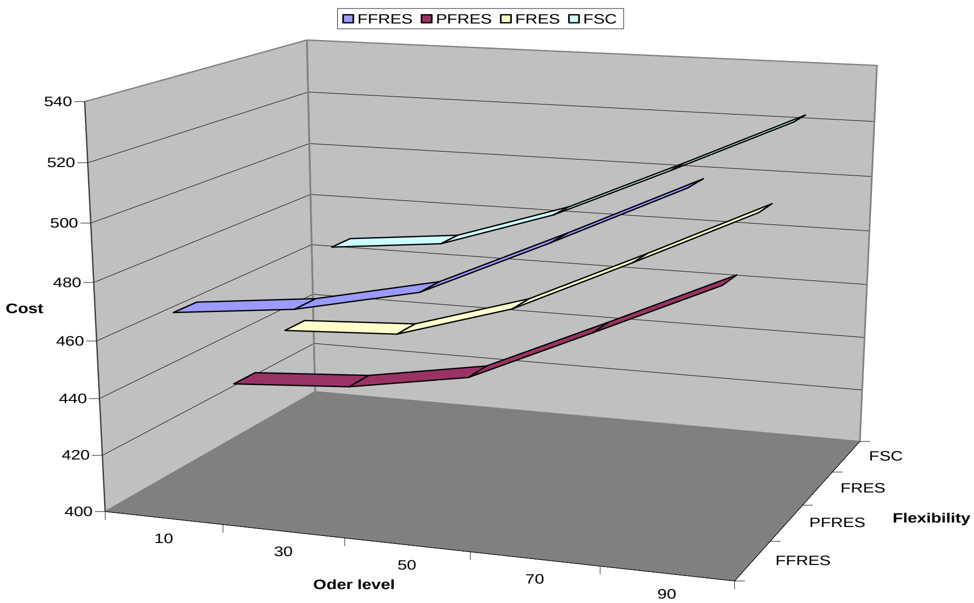

Figure 4: Pattern of variation in cost based on order level (1-3 stages FRES) with QFSC =200

From the above exhibit we observe that for particular level of flexibility and batch size in forward supply chain will produce a cost benefits for RES. From Fig. 4 it is demonstrated that the cost function is quasi-convex or even convex with Or. Therefore, increase in batch size improves the performance of both the flexibility drastically at all stages of RES. Nevertheless, the magnitude of the cost reduction with flexibility is substantial when we have better decision information sharing.

Conclusion

The results are graphically plotted to discuss and highlight the key implications. Simulation experiments were conducted with a focus on one factor at a time, these graphically plots are also useful to understand the scope of future research. The relative contribution of the factors and their interactions in the RES are analyzed and discussed. An important methodological contribution that we envisaged here is the development of relatively more verifiable conclusions and also if different research sets indicate certain contradictions then these should also be identified and analyzed. It is also important to identify counter intuitive cases and study the trace reports to improve our own understanding of the domain. Finally, it is important to relate the results to their industrial implications, for the benefit of the industrial end users.

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