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Flexibility Focused Decision and Information Sharing Model for Product Recovery System

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Abstract

As a result of rapid progress in technology and the shrinking product lifecycles faster than ever before, has led creeping realization of additional profits by performing the effective and efficient product recovery operations at a world-class level quintessential. Realization of these motives is complex due to the multidimensional relationships associated with the quality, variety, timeliness, demand changes, and logical processing of product returns and inherent complexity of recovery process. Therefore an Enterprise System (ES) perspective will give us a scope to develop a profit oriented recovery process as a flexible system that can handle products with various options and greater return volume and structural variability. This paper proposes generic model to enterprises engaged in or to be engaged in product recovery processes. A semi or partially flexible decision process model that facilitates flexible decision and information sharing (DIS) functions in product returns. This DIS model leads us to conceptualize the evolution of information associated with a product returns and how it might be encapsulated by Reverse Enterprise System (RES) to improve its profit and system performance.

Keywords: decision information sharing (DIS), enterprise system (ES), flexibility, product recovery, reverse logistics

Introduction

As residential and industrial solid waste generation continues to grow, alternatives like extended product recovery systems are sought to deal with end-of-life products. Also Mail-order, online purchases and after-sales services, such as the maintenance of guaranteed products, are all situations which contribute to the increase of returns within an organization. Environmental regulations require them to gradually reduce their consumption of non-renewable resources and to decrease the amount of waste materials produced. Traditionally -with the exception of warranties or guarantees - producer responsibility rarely extended into the consumer-use phase of a product's life cycle. Once a product reached its end-of-life, sometimes after being owned and used by different consumers, its disposal was the responsibility of either the last owner or often the municipal government. Sustainability theories, however, increasingly challenge that viewpoint (Porter & van der Linde 1995, Scarlett 1999), leading to the need of conceptualization for a flexible and robust product recovery system.

Given the previously mentioned economic and environmental contexts, some organizations are becoming aware of the importance of focusing their efforts on activities surrounding the return and processing of unused products. They seek to structure, organize, support and plan these activities so as to make the present day supply chain systems more flexible and efficient. With an adequate integration of flexible product recovery activities, in an economic or environmental context, organizations will be able to notice a double effect with their reverse supply chain. First, while focusing efforts on returns of products and their processing, competitive strategies will be set up which, at various levels, will contribute to a better performance of current activities of the supply chain, concentrated until now primarily on the distribution of new products. Secondly, the new supply chain system, which integrates product recovery management, will orient itself to ensure an efficient operation of any additional activities. The aim of this new supply chain system is to ensure clean and adequate distribution of recovered products along with the normal operation of the forward flow of products as shown in Figure1.

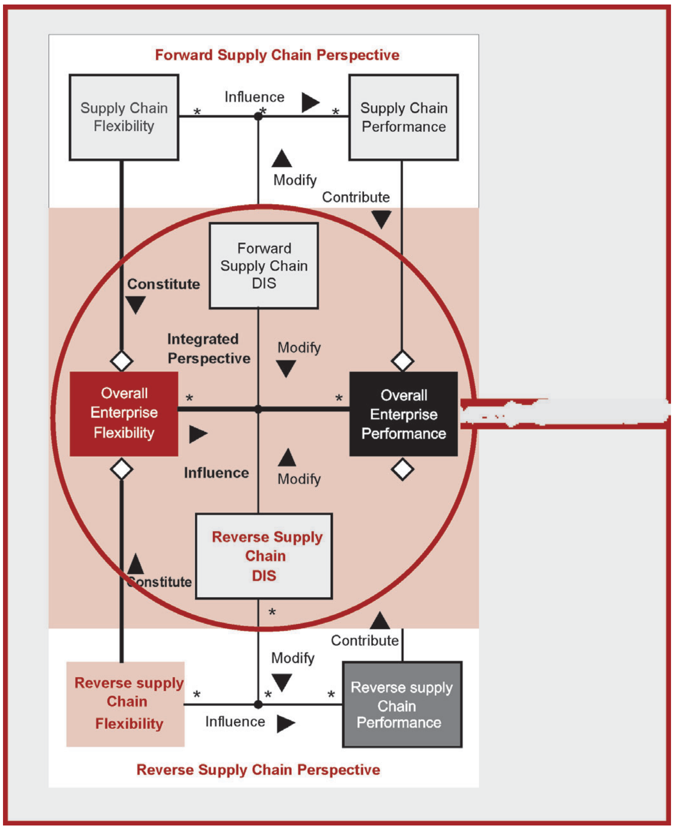

Figure 1: Focus of Studies on the Influence of Information and Decision Flexibility on Enterprise System Performance

Opposite to the forward supply chain logistics, Reverse Enterprise System supplies with the process of efficient planning, managing and controlling for raw materials, in-process stock, final products and relevant information from consuming point to starting point, so as to counter the overall cost production of the supply chain environment (Daniel & Guide 2000). This paper presents a systematic approach for modelling product recovery decisions, and in particular, investigates the role of product information (availability and quality) in improving the effectiveness of decisions in RES. The key motivating factor for this research is to propose a flexible product recovery supply chain model that can be used to manage product information and decisions in RES (Wadhwa & Madaan 2004, 2007).

Requirement for Flexible Decision and Information Model for Reverse Supply Chain Systems

One of the most serious problems that the enterprises face in execution of a RES is the dearth of flexible and robust decision and information systems. RES is typically a boundary-spanning process taking care of returns between enterprises or of the same enterprise, thus proposing model that have to work across system boundaries adds additional complexity to the problem. Therefore, DIS in a RES seems much more important. Returns information captured should be integrated with forward supply chain information to achieve optimum planning and reduction of costs. The whole support network can then be designed in such a way that it can serve for both forward and reverse product/ information flow efficiently. This is in line with the concept of a designing an information system with integrated product recovery decision system. The management of such information and flexibility is the foundation and prerequisite for RES that runs with high quality. Aim of this section is to qualitatively illustrate the motivation for DIS decision model to improve performance of product recovery system. The impact of information visibility is well manifested by the bull-whip effect in forward supply chains (Lee et al. 1997). Similar to forward supply chains, if decisions are well synchronized with information it can play important role in effectiveness management improving performance of product recovery process (Daugherty et al. 2002, Rogers et. al. 2004, Fleischmann 2001, Tibben and Rogers 2002).

The focus of this section is to establish requirement for DIS to improve performance of RES. We therefore categorize these requirements for a model according to the feasibility criteria proposed by Krikke et al. (1998) (i.e., technical, economic, and ecological) associated with product recovery decisions and information. This discussion leads to a product information and decision model that would help in conceptualizing the evolution of information associated with a product and how it might be encapsulated by RES (Gupta and McLean 1996).

Flexible DIS Model For RES

RES can be realized as specialized area of enterprises system and which involves handling individual incoming returns, opening and inspecting products, communicating with internal departments, customers and vendors and then directing products into disposition channels which will provide the highest value. It has already been discussed when and how decisions to be made under various level of information as shown in Figure 2. However, from a flexibility perspective, the bigger issue common to all of those activities is how the enterprise should effectively and efficiently get the products from where they are not wanted to where they can be processed, reused, and salvaged. Also, the firm must decide the final destination for products inserted through a RES.

To cater the need for this emerging field with interdisciplinary, multi-criteria decision-making complexity, designing a framework has always been a challenging issue. With a high variability in evaluation of these alternatives with respect to other alternatives (either tangible or intangible), no crisp data is available. A flexible DIS is required that can efficiently handle product recovery from the market. Also a considerable thought has to be given to reduce the overall costs in the whole process. The presence of multiple criteria (both managerial and technical (time/cost, market, legislative factor, quality, and environment impact)) and the involvement of multiple decision-makers will expand decisions from one to many dimensions, thus

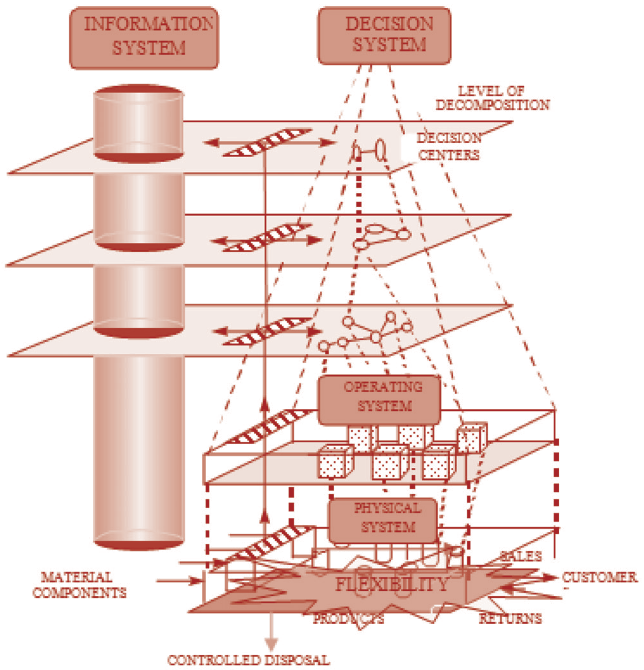

Figure 2: GRAI Model for Decisions and Information Sharing in RES (enriched from Wadhwa Brown 1989)

increasing the complexity of the product recovery process. The product recovery system so developed can help companies to prioritize and develop reverse manufacturing facilities accordingly, leading to a comprehensive reduction in overall costs.

Enterprises have to share and integrate decision and information in reverse supply chain in order to utilize correct information by correct decision in correct time, because the production, transmission, processing and utilization of information are being flexibly distributed into being all links to the system. They must integrate the RES process and design, coordinate, manage and control materials flow, information flow and fund flow among relevant entities involved in the product recovery, to improve the operation efficiency of processing returns. The flexible DIS in RES can be applied to manage and control materials flow and funds flow effectively (Dowlatshahi 2000). However, it is often seen that information associated with products is gradually lost after as product reaches to the customer, and this phenomenon is identified in the literature (Thomas et al. 1999; Tibben-Lembke and Rogers 2002) as one of the major obstacles for efficient recovery of value from returned products. According to Lund (1984) there are two different product recovery strategies to choose from: efficient and flexible. Efficient – a supply chain designed to deliver products at low cost; flexibility – a supply chain designed for speed of response. Therefore, a decentralized evaluation of recovery decision is needed to minimize delays in inspection of returns (Blackburn et al. 2004).

Thus, RES should make every effort to consider comprehensively of quick obtaining the value of returned products and capture the information of product state from the angle of overall enterprise system. Therefore, flexibility seems particularly important in the reverse supply chain as shown in Figure 3.

DIS Model for Performance Improvement in RES

While every system owns features of aggregation and dependency, integration is to assemble several units together

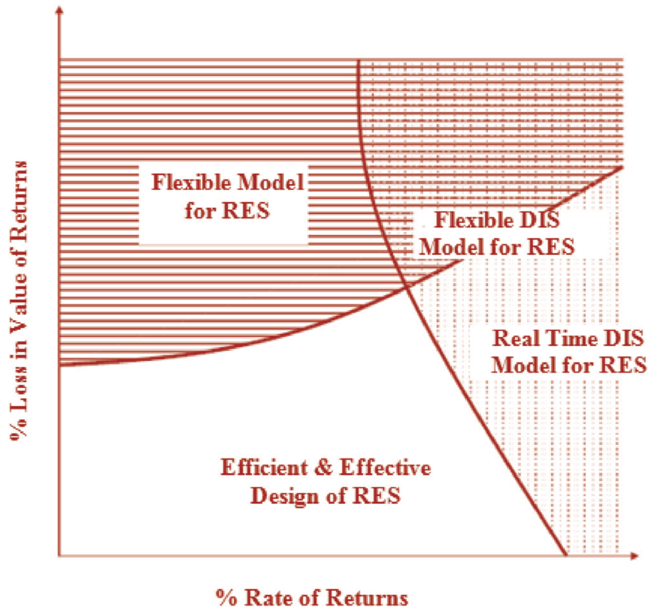

Figure 3: Trade off Between Flexibility and Efficiency in Building DIS for RES

according to a certain purpose, then make them become a system with a certain function. Supply chain is exactly the integration of a lot of enterprises including upstream enterprises (i.e. FSC) and downstream enterprise (i.e. RSC) regarding core enterprise(s) as the centre. Therefore, aim of DIS (i.e. sharing of transformed actionable information between the nodes like flow) is to improve the appreciation of the value flow by means of effective integration and support between supply chain partners, in order that all people, technology, organization, information and other resources related with enterprise's business activities be integrated effectively to form the overall competitive advantage (Wadhwa and Rao 2003).

In this section, we examine how availability of information associated with a returned product affects the decisions associated with the product's state. Then we analyze the manner in which product recovery decisions are made and study the mechanics of the decision and information sharing process. The outcome of this analysis is combined with the concept of strength of evidence developed in to understand how information and decision shared with and without delay could result in a change in the optimal recovery option for the returned product as shown in Figure 4. Furthermore, we derive the set of conditions under which a positive benefit from observing a product parameter can be achieved.

Figure 5 plots the actual benefits of the decision process against the percentage of parts processed under with and

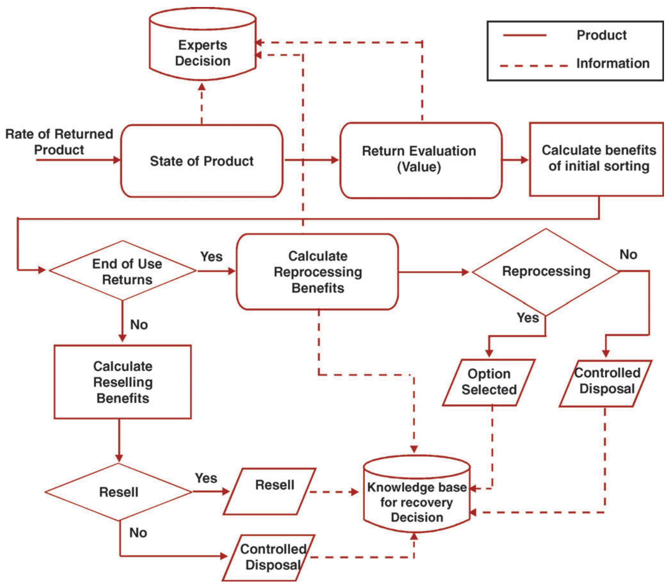

Figure 4: Illustrates the Basic Building Blocks of the Proposed Model and Shows the Various Stages of the Decision Process

without DIS delays. Evidently, there is a consistent substantial performance improvement obtained by reducing the DIS delay and improved decision-making at the initial nodes of recovery process considering time value of the returned products (Blackburn et al. 2004). Therefore, the DIS seems particularly important in the RES.

Time sensitive products, can lose value at rates in excess of percent per week, and the rate marginally increases as these products near the end of their life cycles. At these rates, returned products can lose up to 10-20 percent of their value simply due to delays in the information and decision process. The differences in Marginal Value of Time (MVT) for returns are illustrated in Figure 5.

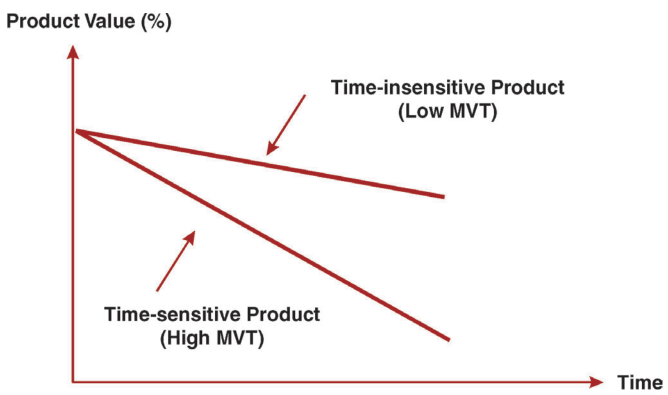

Figure 5: Marginal Value of Time for Returns (Adapted Blackburn et al. 2004)

We focus on the value of a DIS delay reduction between the evaluating facility and reprocessing facility, since this segment has the largest delays. Additional analyses were performed for the other segments of the RES (e.g., customer and evaluating facility) and the results were similar to the ones discussed here and therefore omitted.

Figure 6 depicts the value of DIS delay reduction between the evaluating facility and re-manufacturing completion as a function of the return rate and the time sensitivity parameter of product. Importance of delay reduction becomes important for higher values of the return rate. In automobile industry case, there are substantial benefits to be gained from considering a DIS based RES design. Conversely, when return rates are low a cost-efficient RES is favoured, even when the time value sensitivity of the product is high. Enterprises should find out the flexible flow direction affecting products reclaim within a certain period. Since both returns and the time/value sensitivity are increasing at a rapid pace globally and across industries, decision makers need to be aware of the growing potential benefits of adopting a DIS and flexibility focused RES design.

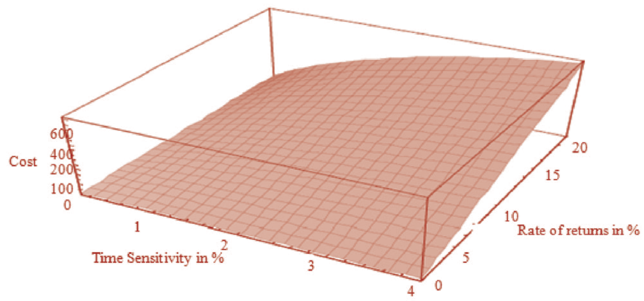

Figure 6: Impact of DIS Delay Reduction Between Nodes of RES

Figure 7 shows that, for those enterprises where both return rates and time/value reduction are considerable (e.g. 5% return rate), the proportion of new returns has a negative linear impact on the value of a DIS delay reduction between re-manufacturing and sales at the secondary market; this is a result of a lower flow of products that are remanufactured as the no. of new returns increases. However, as mentioned previously, the proportion of new returns is a driver to make real time DIS system to enable decision making at the retailer end of a RES network.

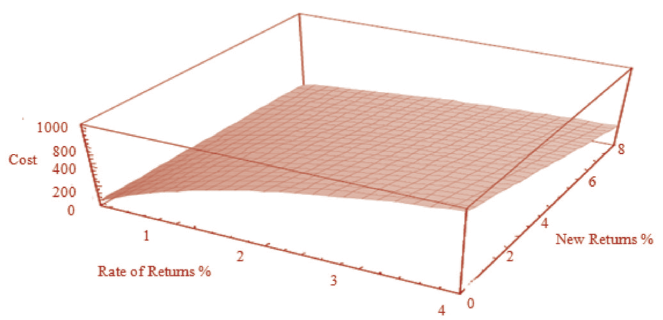

Figure 7: Impact of DIS Delay Reduction as a Function Rate of Returns and Rate of New Returns

Finally, Figure 8 depicts the value of DIS delays as a function of the proportion of new returns. The value is more sensitive to the number of new returns because approximately 80% of the value of DIS delay reduction is derived from savings in transportation costs for new returns as compared to 20% derived from the time value—mostly from variable cost savings in new returns—captured by the

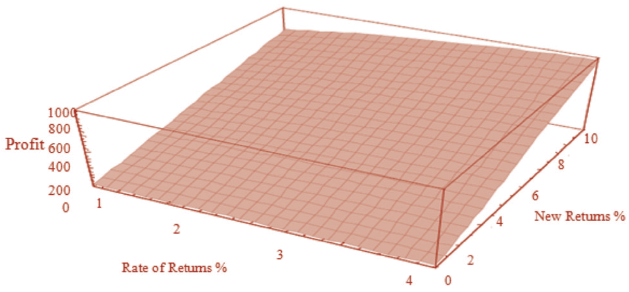

Figure 8: Pattern of Profit from DIS Delay Reduction as a Function Rate of Returns and Rate New Returns

time/value sensitivity of product parameter. This figure also illustrates, if return policies become even more lenient, i.e. both return rate and percentage new returns increase, and time/value sensitivity continues to increase as well, involving close information and decision sharing with channel partners may become imperative to maintain profitability in small and medium enterprises (SME). Therefore, it is necessary for enterprises to make intact and accurate records with all kinds of detailed information as the time, batch, prescription, materials in use for production, and the kind, the flexible flow direction. Therefore information should be highly sharable, to achieve recovery system flexibility. In other words, return handling networks is required to be re-engineered in the near future. These results demonstrate that DIS across the chain is a critical factor for ensuring success of the recovery process. The series of studies presented in the following section shows the influence of DIS delays in various stages of flexible RES scenarios.

A Comparative Study of DIS Delays on Flexibility Levels of RES

DIS proves to be a competitive method based on key ability integration. To improve performance, every member can obtain the advantages of the flexibility and benefits-sharing.This means the information intensive activities depending on the level of flexibility and delays in a given flow systems; may also entail significant decision and information sharing. Since real time DIS is almost unattainable due to high investment, delays are bound to occur between transformations from information to action. These delays refer to delay in information transfer among nodes which may increase the overall cost. This typically can be a case for short life cycle, time-sensitive products where these losses can exceed 30% of the product value. Unlike FSC system, not much has been done for decision and information sharing strategy for returns processing. Therefore, we consider the challenge in designing and managing integrated reverse supply chain and an enterprise system to maximize net asset value recovered from the flow of returned products. It is not quite easy for a lot of enterprises to get the information to correctly analyze the handling problems of retrieved products. Although Blackburn et al. (2004) hypothesize that the marginal values of time that can be used to design and measure DIS reverse supply chain. Their hypothesis was supported by case studies of several reverse supply chains.

Impact of DIS Delays on Flexibility Stages of RES

A number of researchers have contributed to the development of flexible design strategy for SC and our models are motivated by these works (Liu 2004, Wadhwa & Rao 2003, Swaminathan and Tayur 2003, Wadhwa & Bhagwat 1999). We are able to confirm a set of flexibility types and levels for reverse supply chains and observe that flexibility at various stages equates to a decentralized DIS structures. Here we limit our studies to products with high time value decay. However, flexible reverse enterprise system design, it is early product differentiation that determines profitability which requires level effective and efficient DIS delays at various flexibility stages. For the purpose of this study, impact of DIS delays on various flexibility stages is measured. Figure 9 shows the pattern of variation of cost with increasing level of stages and measure the performance with DIS delays. The results indicate that; (a) the DIS delays influence is more on higher stages and in case of DIS 4 and 5 performance is counterproductive for stage 5, (b) DIS delay effects is very high in DIS Delay = 5 and stage 4 (c) this influence is not uniform at all the stages of the flexibility, (d) DIS Delay 4 and 5 gives more significant impact and reduce the befit drastically, (f) Cost increment is low in stage 2 for all DIS delay types and subsequently increases as stage increases, (g) DIS delays impact drastically on rise of cost after stage 4, (h) SC stage 2 and 3 produces close results. The results suggest the judicious level of DIS delays and stages in product return flow network for practitioner and researchers.

A significant difference between our model and previous research on DIS in forward supply chains is that we

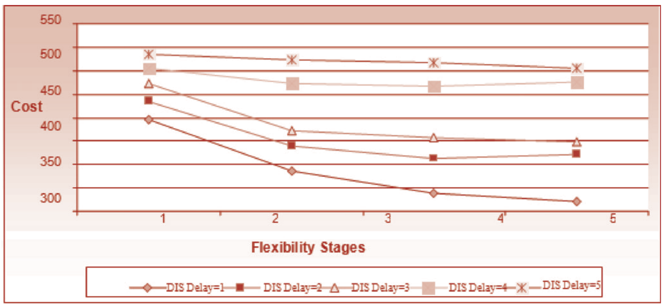

Figure 9: Impact of DIS Delays on at Various Flexibility Stages in a RES

explicitly capture the cost of lost product value due to DIS delays at each stage of the returns process. Some studies of Wadhwa and Rao (2004) DIS delays in supply chain have demonstrated that faster response in business processes can be a source of competitive advantage, and other studies have shown how to quantify the effect of time delays in traditional make-to-stock flexible flow system (Wadhwa S. and Bhagwat R 1999, Fine 1998). These earlier work provides the motivation for this models that specifically incorporate the cost of DIS delays and types of flexibility on asset recovery.

Figure 10 shows the pattern of variation of cost with increasing level of stages to measure the impact of DIS

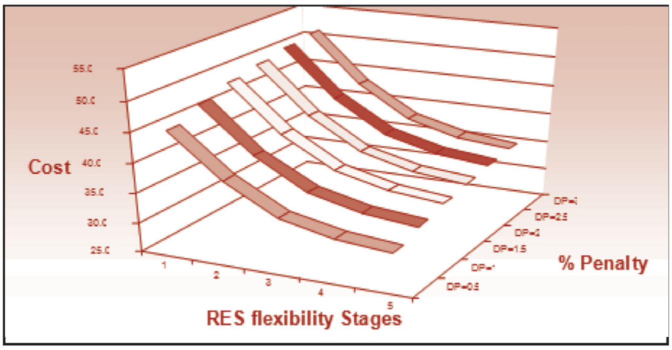

Figure 10: Impact of DIS Penalty on RES Stages

penalty. The results indicate that; (a) the results indicate that the benefit from DIS is reduced from 47.62% to 30.38%, in recovery stage 5 (b) In the case of DP = 0.5 benefit is reduced up to 6.5% and then 4.3%, 3.2%, 1.96%, and 1.86% at subsequent levels for DIS penalty, (c) maximum cost increases at stage 3 with DP = 1.5, (d) this influence is not uniform at all the stages of the flexibility in product recovery system. The simulation analysis showed that decrease in the amount of DIS could lead to an increase in the reuse of faulty products, due to potentially misleading information and decision further. However, this depends on the penalty associated with reusing faulty products, and by increasing this penalty; this can be avoided to some extent.

Studies on DIS Delays with RF of RES

In this section, impact of DIS delays on resource type flexibility (RF) is measured. Figure 11 shows the pattern of variation of cost with increasing level of RF to measure the performance of DIS delays.

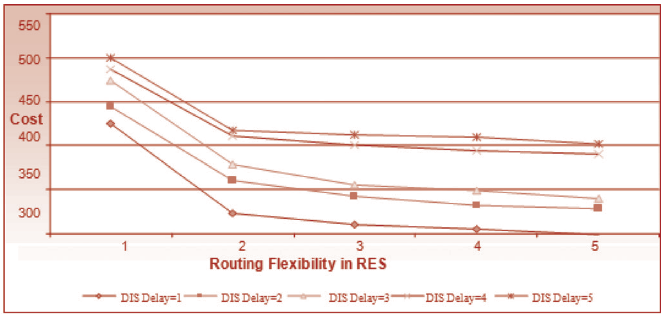

Figure 11: Impact of Increase in Routing Flexibility on Cost at Varying DIS Delays

The results indicate that; (a)up to stage 2 influence of RF is more on DIS delays, (b) RF gives beneficial results up to DIS delay 4, (c) DIS delay 5 gives counterproductive results in stage 5 due to more effects of delays on performance of enterprise system, (d) DIS delay 4 and 5 gives more impact compared to other delays, (e) Stage 3 is the stage where DIS delays effects more especially DIS 4 and 5, (e) this influence is not uniform at all the stages of the flexibility. The results are useful to select the judicious level of RF with DIS delays in RES. Table 1 shows the summary of all results. The results depicts that the DIS delay 5 reduces the total improvement up to 5.59% compared to routing flexibility 1.

Table 1: Summary of DIS delays on RF in RES

	DIS = 1	DIS = 2	DIS = 3	DIS = 4	DIS = 5	
RF = 1						-15.004
RF = 2	31.390	23.290	25.385	18.342	19.855	-22.466
RF = 3	4.154	5.427	6.218	2.735	1.314	-24.580
RF = 4	1.563	2.845	2.152	1.461	0.677	-25.238
RF = 5	2.415	1.134	2.557	1.139	1.618	-25.821
	8.338	9.655	11.279	5.423	3.650	5.591

Figure 12 shows the pattern of variation of cost with increasing level of RTF to measure the impact of DIS penalty. The results indicate that; (a) the results indicate that the benefit from DIS is reduced from 5.77% to -7.97%, in stage 5 (b) DP = 2 gives maximum significance (c) maximum cost increases at stage 3 with DP = 2, (d) this influence is not uniform at all the stages of the flexibility.

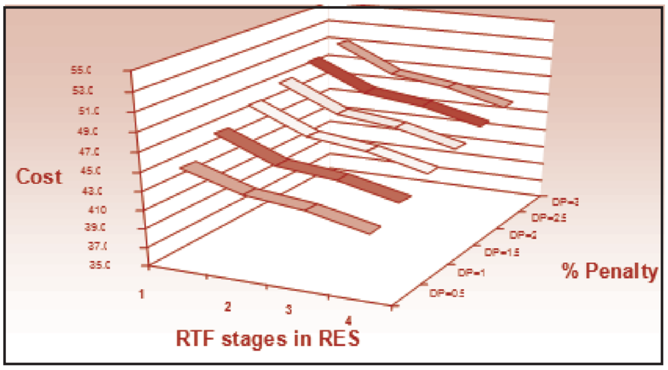

Figure 12: Impact of DIS Penalty on RTF

Studies on DIS Delays on RTF in RES

In this section, impact of DIS delays on Resource Type Flexibility (RTF) is measured. Figure 13 shows the pattern of variation of total cost with increasing level of RTF to measure the performance of DIS delays. The results indicate that; (a) DIS delay influence is more and greater cost increment is observed, (b) RTF stage 3 produces counterproductive results in DIS delay 2 to 5 due to delay effects, (c) maximum impact of DIS is observed in the stage 2 to 5, (d) this influence is not uniform at all the stages of the flexibility.

Table 2 shows the summary of all results. The results depicts that the DIS delay 5 gives the counter productive results i.e. -0.85% compared to RF 1.This analysis demonstrates the cost based performance improvement by decreasing DIS delays by flexible routing in the product recovery network. It allows for a DIS-cost analysis of at various level of routing flexible network designs.

Aforementioned deterministic model with DIS delays demonstrates routing and resource type flexibility that captures the congestion effects observed in practice for the relevant processing facilities and is similar to Toktay et al. (2000).Since DIS never comes for free it requires more investments, therefore considering these investments as penalties, a set of studies further required to be conducted.

Table 2: Summary of DIS delays on RTF in RES

	DIS = 1	DIS = 2	DIS = 3	DIS = 4	DIS = 5	
RTF = 1						-15.004
RTF = 2	0.558	1.002	4.872	5.991	6.520	-9.965
RTF = 3	1.697	0.193	0.812	1.962	3.935	-7.983
RTF = 4	3.430	6.538	6.068	5.497	5.362	-6.265
	5.772	7.814	12.139	14.011	16.648	-0.854

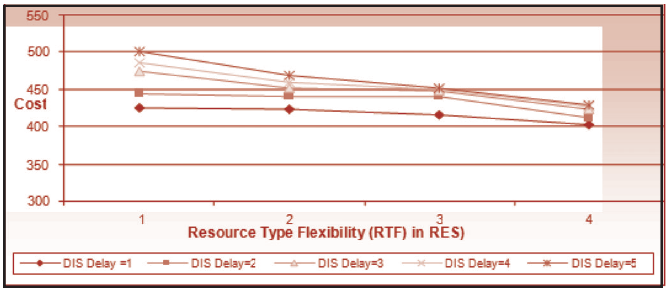

Figure 13: Impact of DIS delays on RTF in RES

Next section will discuss this issue where DIS penalties are considered in tradeoff with flexibility level of RES.

Conclusion

This paper demonstrates the impact of different levels of information sharing, timeliness of decision sharing impact of flexibility and the role of DIS delays and penalties on overall system cost performance. We found that different nodes act in a relatively autonomous fashion to decide what flexibility to use, what and when information required to be shared for improving decision performance and obtaining benefits from recovery process. Reverse Enterprise System can be looked as an extended enterprises situation with coordinated nodes willing to share more information with good timeliness and flexibility can generate cost reduction up to 45% from recovery process.

Similarly, looking at RES with the virtual enterprise perspective one expects still further decrease in information sharing but a greater use for flexibility for dynamic product recovery conditions. This study examines the product recovery operations of a manufacturer supply chain where there is a dominant node such as the final manufacturer (OEM) often plays a supervisory role and DIS delays are enforced to be minimized. Here, we show how ready availability of information regarding the critical product parameters indicating the extent of usage can improve the effectiveness of decision in product recovery process. This indicates that the decision integration across the chain is a critical factor for ensuring effectiveness of the recovery process. The series of studies presented in this section shows the influence of DIS delays in various flexibility types scenarios. This study has illustrated importance of DIS which in turn affects the efficiency of product recovery operations. The low margins and increasing volatility of returned products make timely information and decision a high priority.

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