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Decisions Variables Within Reverse Logistics

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ABSTRACT

This paper addresses a gap in the Lambert model of supply chain management through refining the link between the returns management process and the overall strategy of a supply chain firm by addressing the decision as to which reverse logistics activity to pursue. Current literature is sparse in this area and existing decision support systems (DSS) do not specifically address this problem. In order to determine what variables should be considered in such a DSS, recent DSS and simulation literature that addresses decision making within reverse logistics was reviewed. The author compiled a listing of 60 different variables spanning six broad categories, which identify areas for further research, gives researchers a comprehensive listing of variables to consider, and that can be analyzed in further studies to create a disposition decision framework and corresponding DSS.

The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

Keywords

Reverse logistics, decision support system, simulation, variable, remanufacturing, closed loop supply chain

INTRODUCTION

Reverse logistics (RL) is a multi-billion dollar business in the United States (Stock, Speh, & Shear, 2002). Accordingly, the decisions made within this area can significantly affect a firm's bottom line. In order to assist industry decision makers and academics alike, researchers continue to create decision support systems (DSS) and simulations in order to quantitatively measure the implications of the rather unstructured decisions presented by reverse logistics. The goal of such research is to create standardized, optimized, programmed decisions in areas that have received little attention until recent years. One such decision involves how to recover the greatest amount of value from a returned product. This decision explores which disposition option will generate the most value for the firm, given its environment and circumstances. Research suggests that end-of-life product disposition can take four forms: a product can be reused, upgraded (remanufactured, refurbished), recycled, or disposed of (Prahinski & Kocabasoglu, 2006; Rogers, Lambert, Croxton, & Garcia-Dastugue, 2002; Staikos & Rahimifard, 2007).

The disposition decision is significant and has the opportunity to generate (or cede) sizeable profits. It is estimated that companies spend over $35 billion on reverse logistics activities in the United States each year (Pogorelec, 2000). Accordingly, initiating a disposition option without understanding the potential pitfalls and second-order ramifications can be detrimental. For example, supply chain capacities must be evaluated and market analysis must be completed to determine if the activity is not only profitable, but feasible. However, making an informed disposition decision can create competitive advantage through differentiation, thus maximizing profits.

The Lambert model of supply chain management conceptually integrates many business processes across the supply chain (Croxton, Garcia-Dastugue, Lambert, & Rogers, 2001; Lambert, Cooper, & Pagh, 1998). At the center of the model is the manufacturing organization, which is dissected into six basic departments found within such a firm: logistics, purchasing, production, research and development, finance, and marketing and sales. Products flow from initial suppliers, through the manufacturer, and then to the end user. The processes that are managed throughout this entire supply chain are: customer relationship management, supplier relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, product development and commercialization, and returns management. Research which ties the returns management process into the strategic objectives of the supply chain is limited. Although some research investigates strategic and operational considerations for pursuing returns management activities (Rogers et al., 2002), the actual framework outlining these considerations has not been comprehensively investigated. Furthermore, decision frameworks in the literature are sparse and the factors considered vary considerably (Carter & Ellram, 1998; Dowlatshahi, 2005; Jayaraman & Yadong, 2007; Mollenkopf, Russo, & Frankel, 2007; Rogers et al., 2002; Skinner, Bryant,

& Richey, 2008; Tan & Kumar, 2006). Research is needed in this area to determine what factors must be evaluated from a strategic perspective when deciding whether or not to pursue a certain reverse logistics process.

The author did not find any DSS which specifically addresses support of the disposition decision at the strategic level. Such a DSS would be valuable to practitioners as it would provide a working tool that would aid in making this important decision. Academics would benefit from a strategic DSS as it would undoubtedly lead to further exploration of the variables and processes involved. However, before assimilating the strategic-level considerations into a framework and then creating a DSS in accordance with the framework, the operational variables which affect reverse logistics decisions must be evaluated in order to better understand the underlying factors involved. Finding and analyzing these variables will facilitate further research and lay the foundation for building a strategic framework.

This review investigates DSS and simulation literature as it applies to the product disposition decision within RL. The purpose of this review is to identify and assimilate the decision variables considered in the contemporary literature in order to create better understanding of the factors that affect the decision while identifying areas for future research. The output quality of any decision tool is a function of both its inputs and the methodology and accuracy of calculation. The published research in the emerging field of reverse logistics includes sound simulation and decision support methodologies and techniques. Correspondingly, the precision of these models require use of limited assumptions yet several variables. Inadvertently omitting any pertinent variable or holding incorrect assumptions (because of limited research within that assumption) can adversely affect the accuracy of such models, which may lead to inaccurate decisions. The outcome of this review identifies all variables considered within the scope of the literature. This provides future researchers a checklist of variables while highlighting assumptions that may deserve additional consideration. This also provides a platform for recognizing the absence or underutilization of variables that may require further investigation. Finally, this will provide insight into what variables should be included in a strategic disposition framework and, subsequently, a strategic DSS to facilitate disposition decisions.

METHODOLOGY AND SCOPE

The scope of this review was limited to articles that design, develop, test, or otherwise utilize a DSS or simulation in regard to facilitating a decision within reverse logistics. The literature from the top eight journals in Supply Chain Management, Management Information Systems, and Operations Management, as identified by Gibson and Hanna (2003), Rainer and Miller (2005), and Gorman and Kanet (2005) was first considered. The author originally began to review the top five in each discipline, but in order to incorporate the journals most applicable to the topic, the top eight in each field were included. In rank order by discipline, these journals are noted in Table 1, below:

Supply Chain Management	**Management Information Systems**	**Operations Management**
Journal of Business Logistics	MIS Quarterly	Transportation Science
Harvard Business Review	Communications of the ACM	Mathematics of Operations Research
Supply Chain Mgt Review	Information Systems Research	Operations Research
Transportation Journal	Mgt Science	Manufacturing/Service Operations Mgt
Intl Journal of Logistics Mgt	Journal of Mgt Information Systems	Mgt Science
Traffic World	Harvard Business Review	IIE Transactions
Intl Journal of Phys Dist/Log Mgt	Decision Sciences	Production and Operations Mgt
Journal of Supply Chain Mgt	Decision Support Systems	Journal of Scheduling

Table 1: Top Journals by Field

The top eight journals in each of these three fields yielded a total of 22 journals because of the interdisciplinary nature of both Management Science and Harvard Business Review. Logistics research spans a multitude of disciplines (Stock, 1997). However, the three selected disciplines encompass the vast majority of literature on the specific topic of disposition decision making in reverse logistics and are therefore thought to appropriately limit the scope of the search. Although searching only the top journals in a field may not render exhaustive results (Webster & Watson, 2002) a comprehensive interdisciplinary analysis of this nature requires a limited scope in the preliminary search of literature. Furthermore, this listing served more as a beginning reference than as a definitive boundary. Investigation into the literature revealed additional journal titles that pertain to this topic and were subsequently explored. These additional journals are discussed later in this section.

This review examined all applicable literature from 2000 through 2008. In their review of reverse logistics literature, Carter and Ellram (1998) propose that the first truly academic work (as opposed to practitioner-based work) in the field was not published until the early 1990s (Kopicki, Berg, Legg, Dasappa, & Maggioni, 1993; Stock, 1992). Their review also notes that the majority of literature throughout the 1990s was exploratory in nature, offering little theoretical grounding or quantitative study. Accordingly, the vast majority of quantitative reverse logistics literature is published after the year 2000, thus presenting a logical limit to the scope of this review. Furthermore, the author's objective was to determine which variables are currently being utilized in the literature. This dictated that the review reach back far enough to provide an appropriate number of articles, but not so far as to lose contemporary relevance. The year 2008 was chosen as an upper limit so as to facilitate a comprehensive search of a selected period, thus limiting the possibility of accidently omitting newly published literature within the stated scope of the review.

Each selected journal was searched via electronic database for the time period between January 1, 2000 and December 31, 2008. Broad keyword searches specific to each genre of journal reduced the risk of overlooking an article that meets the criteria. Keyword searches were tailored to each genre of journal in order to maximize effectiveness. For example, searching MIS literature for "logistics" helped to generate relevant results. Conversely, searching SCM literature for such a broadly-used term in the field produced thousands of hits. The keywords used for searching Supply Chain Management journals were: closed loop supply chain, end of life, return, disposition, reverse logistic, decision, model, simulation. The keywords used for searching Management Information Systems articles were: supply chain, logistic, decision, model, simulation. The keywords used for searching Operations Management journals were: reverse logistic, closed loop supply chain, return, decision, model, simulation. The initial keywords used for each genre of journal were broad in scope. The additional keywords were included after reviewing relevant keywords noted in the articles that were discovered using the broad terms. Of the many articles yielded in the search, titles, abstracts, and introductions were reviewed to find any literature that may build a DSS or simulation within reverse logistics. Articles not available in electronic format were requested through the university library. This process yielded 63 results – of which, the author was able to thoroughly read and make a final determination regarding adherence to established criteria of utilizing a DSS or simulation within reverse logistics for the purpose of decision making. Furthermore, rudimentary citation analysis directed the author toward other journals which, although not within the original scope, were deemed to be highly applicable to this review.

Much of the literature in this area seems to be in the Operations Management field, which prompted further exploration into more of these top journals. These journals are: Journal of Operations Management, International Journal of Production Economics, International Journal of Production Research, and Naval Research Logistics. In addition, the preliminary search in the Management Information Systems literature did not contribute many results. Therefore, the author searched the digital library within the Association for Computing Machinery portal in search of other relevant journal titles or conference proceedings within MIS. The same search procedure was performed on the additional journals and conference papers, which yielded a total of 15 additional articles. In sum, 79 articles were found, but only 45 articles met the specific criteria and were reviewed. The other 34 articles were dismissed because of various reasons, such as not being specific to reverse logistics, being qualitative in nature, not actually utilizing a DSS or simulation, or otherwise not being within the scope of this review. Because of the space limitations, a listing of all 45 articles used is not included in this manuscript. However, the reference list can be obtained from the author by request.

This paper serves to assimilate the work of each individual author in regard to searching for relevant decision variables. This documentation of variables will be available for use in future analyses while also identifying variables that may be under-utilized, omitted entirely, or requiring further research in order to include. The author investigated model explanations, discussion of variables, parameters, assumptions, and other applicable areas of the selected literature to extract and tabulate all variables that are considered in the respective article.

Limitations

This review includes only articles that develop, test, or otherwise utilize a DSS or simulation within reverse logistics for the purpose of facilitating a disposition decision or optimizing the disposition process. Although most reverse logistics articles include discussion of pertinent decision variables and considerations, unless the author creates a functional DSS or simulation, such articles are not considered. In short, quantitative articles were reviewed in lieu of qualitative or conceptual work because this author's goal is to discover what variables are actually being used in quantitative research. Further, articles which meet the criteria of this review may have been missed in the initial keyword search. Of the articles discovered, some variables may have been overlooked or inadvertently omitted by the author in the review of the article and transcription and coding of the variables. The author assumes that all variables used in the respective research article are documented within the article. However, the sufficient number of articles and the large number of variables suggest that the limitations presented by this review do not affect its usefulness.

FINDINGS

A total of 60 variables are found within the literature. For ease of assimilation and to facilitate usefulness, the variables are listed in Table 1, in order of most utilized (top left) to least utilized (bottom right).

Variable	Times Used	Ratio	Variable	Times Used	Ratio
Customer Demand	34	75.56%	New Item Inventory Level	6	13.33%
Product Return Volume/Rate	28	62.22%	Delays	6	13.33%
Remanufacturing Costs	28	62.22%	Recycling Costs	5	11.11%
Cost of Acquiring Returned Product	27	60.00%	Demand for Remanufactured Part	4	8.89%
Management Strategy/Policy	23	51.11%	Revenue from Recycling	4	8.89%
Inventory Costs	22	48.89%	Lot/Batch Size	4	8.89%
Disposal Considerations/Scrap Costs	21	46.67%	Labor Cost	3	6.67%
Leadtime	17	37.78%	Quantity Recycled	3	6.67%
Retail Price (New)	16	35.56%	Pattern of Recovery (Quantity and Type of Collection Location)	3	6.67%
Transportation Costs	16	35.56%	Legal Considerations	3	6.67%
Manufacturing Costs	16	35.56%	Outsourcing (3PL/4PL)	3	6.67%
Inspection Costs	14	31.11%	Environmental Considerations	3	6.67%
Remanufacturing Capacity	13	28.89%	Length of Time Customer Holds Product	3	6.67%
Sales Lost/Backorder Costs	13	28.89%	Cost of Capital	2	4.44%
Remanufactured Item Sales Price	13	28.89%	Safety stock	2	4.44%
Profit Margin of Remanufacturing	13	28.89%	Stocking points	2	4.44%
Product Lifecycle	13	28.89%	Service Level	2	4.44%
Fixed Costs	12	26.67%	Factory Location	2	4.44%
Return Quality	11	24.44%	Number of Remanufacturers	1	2.22%
Total Servicible Item Levels/Net Inventory	10	22.22%	Reverse Logistic Administrative Program Costs	1	2.22%
Manufacturing Capacity	10	22.22%	Processing Times (Remanufacturing/Manufacturing)	1	2.22%
Wholesale Price	9	20.00%	Packaging	1	2.22%
Number of OEMs (Monopoly, etc.)	9	20.00%	Discontinuation Price	1	2.22%
Existing Logistics Infastructure	9	20.00%	Customer Segment (First Time or Replacement Customer)	1	2.22%
Salvage Value	8	17.78%	Value of Time	1	2.22%
Supply of Parts required for Remanufacture (Cost/Capacity)	8	17.78%	Penalty Costs of Uncollected Returns	1	2.22%
Market Size	8	17.78%	Sorting Policy	1	2.22%
Quality of Remanufactured Item	8	17.78%	Total Quantity of Items in Supply Chain	1	2.22%
Disassembly (Cost/Time)	8	17.78%	Total Cost of Reverse Logistics	1	2.22%
Remanufactured Item Inventory Level	7	15.56%	Forecast	1	2.22%

Table 2: Variables Used in Quantitative Reverse Logistics Literature

Close review of these variables suggests that the 60 individual variables can be grouped into six broad categories for consideration. In descending order of number of variables accounted for in each category, these are: supply chain and manufacturing (28), costs (15), market (7), customer (6), profits (2), and environmental/regulatory (2). Because of space limitations and lack of inter-rater reliability inherent in a single-author study, further discussion of these variables is not prudent for the purpose of this paper. Regardless, the inductive discovery of these six broad categories satisfies the purpose of this study. Further discussion of the findings will be included in a forthcoming study.

DISCUSSION AND RECOMMENDATIONS

As the findings suggest, very little literature was noted in regard to product reuse, recycling, or waste management. Investigation into what considerations are presented by these reverse logistics options is encouraged. In fact, most of the models reviewed are focused upon optimizing remanufacturing in some way; therefore, the variables concerning

remanufacturing issues are utilized more frequently. Although useful, this serves to only expand the knowledge base regarding one of the four disposition alternatives, leaving the other three behind in terms of academic development. Accordingly, the first recommendation for future research is to further develop areas of reuse, recycling, and waste management as they pertain to the reverse logistics process. This can be accomplished through the development of simulations or DSS and will lead to greater understanding of these disposition options while likely uncovering additional variables to be considered.

The results demonstrate a number of variables that are rarely used within simulations and DSS research in reverse logistics. This may be because these variables are not critical to RL. However, this may suggest that the implications of the variable within reverse logistics are not understood well enough and require further investigation. The second recommendation for future research is to take any variable with a low use rate and investigate it further by testing the effect of the variable on various reverse logistics processes. Specifically, quality in remanufacturing, 3PL/4PL considerations, legal considerations, and environmental considerations are research streams that have been previously identified as requiring more empirical study (Prahinski & Kocabasoglu, 2006). However, as this research suggests, there are many other variables within reverse logistics which may require further investigation.

The third recommendation is to conduct a similar study to this with a change in scope in order to discover what considerations exist within conceptual models and frameworks, qualitative research, or case studies. The author suspects that one may find additional variables that have been conceptually investigated but have yet to be included in empirical work. This information would provide researchers with a quantitative focus with additional variables to consider while providing researchers with a conceptual focus a better understanding of the variables being discussed in current research. Whether using the method described here or an unrelated methodology, further study is recommended to determine if any variables exist which are not addressed in this review.

Finally, the purpose of this study is to identify variables to consider when making strategic-level disposition decisions. This study identified 60 variables utilized as the operational considerations of recent DSS and simulation studies in RL. Further analysis of these operational considerations may suggest possible areas for strategic consideration. The author proposes that the most frequently used operational variables as determined by this study are also the most likely to be considered in a strategic framework. For example, the variable found to be used the most by this study, customer demand, will surely be a primary consideration within a strategic framework. However, in order to quantify these results and consider the use of all 60 variables, current decision frameworks and strategy-oriented reverse logistics literature must be reviewed to not only investigate whether or not these variables fit current models, but to determine if any of these variables can fill the gaps and/or expand upon existing literature in this area.

Future Work

This study is the first step toward a more broad research effort. In accordance with the recommendations above and in order to build upon this study, the author will validate the usefulness of the operational variable categories identified in the findings by reviewing literature of a strategic nature to determine if these categories are considered in strategic supply chain management literature. Upon validation and modification of these six general categories, the author plans to build a generalizable DSS to be used by supply chain professionals which will guide toward making the most advantageous RL disposition situation for their organization. The final outcome of the larger study is twofold. First, a gap in the Lambert theory will be filled which links organizational strategy to RL disposition decision making. Second, a useful tool (DSS) will be fashioned to assist practitioners in their decision making efforts.

CONCLUSION

Decision support systems and simulations require the inclusion of all relevant parameter variables if they are to produce accurate results. This paper identified 60 variables derived from the 45 articles reviewed. The articles reviewed offer complete, relevant simulations and DSS. Future authors will now have a depository of possible variables to consider – thus reducing workload and facilitating consistency. Recommendations for future research were suggested, which essentially call for searching for more variables and creating better understanding of the variables reviewed in this research. Although operational in nature, the articles encompass the many variables considered in reverse logistics processes. This provides insight into the possible considerations that may be taken into account when making strategic-level disposition decisions. Using the data gathered in this study in conjunction with existing frameworks, one could begin to hone a strategic framework with regard to strategic-level disposition decisions in an attempt to fill the gap presented by current understanding of the Lambert model of supply chain management.

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