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Flexibility in reverse logistics: a framework and evaluation approach

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ABSTRACT

Reverse logistics (or the reverse supply chain) features greater relative uncertainty when compared to forward logistics and supply chain flows. An effective way to manage uncertainty and variance in operational and organizational systems is by introducing greater flexibility. The literature on flexibility in reverse logistics is surprisingly sparse, with an explicit focus on flexibility in reverse logistics non-existent in the literature. To address this gap in the literature, and building upon literature in supply chain flexibility, we introduce a reverse logistics flexibility framework. The framework is separated into operational and strategic flexibilities. Operational flexibility includes a variety of dimensions such as product and volume flexibility across various reverse logistics operational functions. We have also included strategic flexibility categorized into network and organizational design flexibility dimensions. Additional sub-dimensions are also included in the framework. The framework is useful for practical managerial decision making purposes such as process improvement or programmatic evaluation. The framework is also useful as a theoretical construct for reverse logistics empirical research. To exemplify the practical utility of the framework we introduce a performance evaluation of third party reverse logistics providers model using a novel neighborhood rough set approach. Using illustrative data, sensitivity results help evaluate the neighborhood rough set technique's robustness with various reverse logistics performance factors. This paper sets the foundation for significant future research in reverse logistics flexibility.

1. Introduction

Organizations seek to implement green supply chain management in response to consumer, regulatory and governmental pressures and to improve their environmental image and performance. A critical aspect of greening the supply chain is 'closing-the-loop[2]' (Zhu et al., 2008). Forward logistics functions are critical activities in the supply chain loop, but to fully close this loop reverse logistics (RL) functions and activities are necessary. These RL functions may be more difficult to manage due to inexperience of most companies with RL functions. It was not until this past decade that reverse logistics has taken on a larger and more visible presence in the academic literature, as well as in industry practice (Meade et al., 2007; Hojas Baenas et al., 2011; Giannetti et al., 2012; Silva et al., 2013). Much of the growth in this field is due to increasing interest in sustainable supply chain management research and practice (Srivastava, 2007; Nikolaou et al., 2011).

Complicating the management of RL functions are supply and demand characteristics of products flowing through these functions. RL product and material flow is more reactive and has less visibility (Tibben-Lembke and Rogers, 2002). Rarely do organizations initiate RL activity as a result of proactive planning measures, but initiate RL activity in response to external downstream partner and stakeholder requirements. Uncertainty of supplies and timing are important factors differentiating RL from traditional logistics systems (Blumberg, 1999; Serrato et al., 2007; El korchi and Millet, 2011). In a RL environment customers of the material or product are usually suppliers of these same materials and products. This customer function duality contributes to managerial complexity and uncertainty. Managing this dual relationship requires both procurement and marketing efforts be managed jointly (Sarkis et al., 1998; Sarkis, 2003b; Hans et al., 2010).

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[2] Supply chains have typically been associated with an uni-directional linear set of activities and stages from extraction of virgin material to disposal of the end product and materials. Closing the loop means that materials and goods are brought back into the supply chain set of activities in a cyclical way, extending the life of materials and products. Reverse logistics is critical to re-introduction of these materials and products into the supply chain.

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RL channels for most product supply chains are relatively immature. Remanufacturing, disassembly, and other environmentally oriented extended producer responsibility activities dependent on RL suffer from this lack of development (Subramoniam et al., 2013). Developmental barriers include infrastructural, demand and supply based, and operational weaknesses. The lack of development greatly increases uncertainty in the RL environment.

Flexibility of the organization and its reverse supply chain/logistics channels is needed to handle uncertainty and the greater probabilities of disruption in these channels (Tang and Tomlin, 2008). Research on reverse logistics flexibility has seen virtually no study when compared to other aspects of supply chain and reverse logistics research. In this paper we build upon the study of flexibility in traditional (forward) supply chains (Duclos et al., 2003; More and Babu, 2009) extending it to reverse logistics. We make it very clear that no research or publication has provided a solid understanding, review, and application of flexibility in reverse logistics. The framework introduced in this paper seeks to fill this gap, building on research from forward supply chain management flexibility.

In our paper we initially introduce a flexibility framework for RL utilizing operations and supply chain management flexibility research as a foundation. The framework is represented in tabular format focusing on operational and strategic dimensions of flexibility. The framework is useful for practical application such as managerial decision making, e.g. evaluating reverse logistics performance or planning and design for flexibility. The framework is also useful for research purposes such as scale construct development for empirical studies investigating theoretical relationships amongst reverse logistics flexibility and other organizational initiatives.

To exemplify the managerial utility of this framework we introduce a methodology to help organizations evaluate and/or monitor third party reverse logistics providers (3PRLP). We use a novel rough set approach to complete this analysis. The reverse logistics flexibility framework and the rough set formal modeling technique set the stage for significant development and application to a variety of managerial practices and research into reverse logistics in general and management of 3PRLP specifically. Additional research streams are also identified.

Our contribution is three-fold: (1) Introducing an RL systems flexibility framework; (2) apply rough set to flexibility evaluation for management of 3PRLP; and (3) identification of additional RL flexibility research streams.

2. Background

2.1. Reverse logistics and uncertainty

RL is not simply reversing the forward logistics or supply chain (Meade et al., 2007). Many companies, even successful forward logistics operators, are not able to efficiently and effectively handle the flow of materials in the reverse direction (Genchev et al., 2011; Hojas Baenas et al., 2011). Most logistics systems are not equipped to handle product movement in the reverse channel (Jayaraman et al., 1999). Returned goods cannot always be transported, stored, or handled in the same manner as in the regular forward channel (Guide et al., 2003; Meade et al., 2007). For example managers have put management of returned cores in remanufacturing processes as one of the most important issues facing effective remanufacturing (Subramoniam et al., 2013).

Certain events can trigger RL actions and these events can either be planned or unplanned. The unplanned transactions are expenditures to avoid and planned transactions are expenditures that must be incurred (Giuntini, 2004). For example the return of a defective good would be unplanned and the expiration of an operating lease resulting in returned equipment would be a planned expenditure. Indeed, the differing reasons for RL (warranty returns, end of life disposition, recycling, etc.) all may result in varying RL channel implementations and approaches for managing RL functions (Gehin et al., 2008). This variance leads many companies to treat returns on an ad hoc basis with few standardized processes in place (Herold and Kämäräinen, 2004; Sietz, 2007).

Other factors that complicate the management of RL systems include the multi-company and multifunctional contextual environment of many RL processes. Often this situation includes third and fourth party logistics providers. Companies may play both a supplier and customer role. Companies can act as both a customer (for the material) and supplier (of the reclaimed material) in the process (Dhanda and Hill, 2005). These dual relationships for companies tend to vary depending on the recovery costs of the material versus their benefits.

The net result of RL networks differing nature in many cases include more difficult coordination of processes and companies, increased information management needs, and generally more complex management and system requirements. This complexity leads to additional reverse distribution costs which may be several times higher than moving the product forward (Jayaraman et al., 1999). Similar to the unpredictable dynamics of the forward supply chain, uncertainty may derive from a variety of internal and external sources, including partners, operating systems, customers, and competitors (Yi et al., 2011; Silva et al., 2013).

To help manage these issues and uncertainties, flexibility needs to be built into the RL system. Flexibility can be built into an RL system, for example, by having larger safety stocks or materials, contracting with a broader set of suppliers/RL providers, investing in modular product technology, multiskilling employees on various RL operations, vendor collaboration, and investing in flexible automation to name a few measures. The frameworks introduced will provide additional examples and relationships to additional measures for RL flexibility. First an overview of RL functions and activities is presented.

2.2. Functions and activities within reverse logistics channels

Table 1 summarizes various definitions of unique RL functions and activities from the past couple decades. These activities can be traced from procurement (collection) to managing the inventory and storage, to transformation processes, and eventually to redistribution. Planning and control activities may also be considered as broader support activities for RL function management.

Not all RL functions will be similar and generic. For example a warranty return RL network would not have the same functions as a recycling RL network (Meade et al., 2007). The availability of each of RL function services will also be dependent on the product life cycle, industry, and design of the RL network. Mature product environments may be more focused on processing stages, while less mature products will develop networks for initial aggregation and collection. An example set of functions that takes into consideration various activities, inputs, outputs, and mechanisms (and overall system) perspective of RL is shown in Fig. 1. This figure is only one example of activities and may vary across industries, materials, and product types.

In summary, the major RL functional phases can include Collection, Separation, Disassembly, Compaction and Outbound Logistics (El korshi and Millet, 2011). Collection is the accumulation of materials from the waste stream for eventual introduction back into the forward manufacturing and supply chain. Collection accumulation may include curbside collection, drop-off centers, and buy-back centers. Separation is the sorting of materials from