Proceedings of GLOGIFT 12
July 30 – August 1, 2012
University of Vienna, Austria
pp. 630-646

Innovations and Reverse Supply Chain: A Multi Objective Decision Approach Using ISM Methodology

Sachin Mangla[1] and Jitendra Madaan[2]

Abstract

Over the past few years, increasing attentions have been paid on the "reverse supply chain", mostly due to government pressures, environmental concerns and economic benefits. This emerging area involves the activities in the returned product flows, beginning from ultimate consumers upwards along the forward supply chain till the manufacturers or vendors. Innovation is the first use of a new product, process and system in a commercial context. Reverse supply chain perspective, innovations come into being when a new or better product and process for return is in the market and fulfill their objectives. Moreover, determining key variables, which an organization can opt for initiate and regulate innovative activities in a reverse supply chain, is a dare. Therefore, this paper utilizes the Interpretive Structural Modeling (ISM) methodology to understand the mutual influences among the variables drives innovations in reverse supply chain. These variables have been categorized under "enablers" and "result outcomes". The enablers are the variables that drive other driving variables, while results variables are the outcome of good innovative practices. By analyzing the variables using this model, we may extract crucial enablers that drive innovative activities. Finally, followed by an actual example of case automobile sector provided some managerial insights into this methodology.

Keywords*: Innovations, Reverse supply chain (RSC), Reverse logistics (RL), Interpretive Structural Modeling (ISM)*

Introduction

Innovation is the creation of better or more effective products, processes, services, technologies, or ideas that are accepted by markets, governments, and society. In today's business environment integrating and organizing the supply chain is a crucial element to gain competitive advantage. Within a reverse supply chain, innovation may be linked to positive changes in efficiency, productivity, quality, competitiveness, market share, and others. The main focus in supply chain management is on the management and integration of the 'traditional' flows going upward to the consumer market. Contrary, reverse supply chain management is rarely viewed as a separate business process and organizations often approach these activities passively (Guide, Harrison and van Wassenhove, 2003). Reverse supply chain management said as the

1. Department of Mechanical Engineering,
Ganpati Institute of Technology & Management, Bilaspur, Haryana, India
Email: sachinmangl@gmail.com

2. Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee, India
Mob: +91-1332-285726, Email: jmadaaniitd@gmail

managing the reverse supply chains and involves smooth flow of goods going back up the supply chain. This includes: product returns, repairs, maintenance, and end-of-life returns for recycling or dismantling (Harrison and van Hoek, 2007).

Moreover, Research on reverse supply chain is not mew and research on strategies and models on reverse logistics (RL) can be seen in the publications in and after the Eighties. However, efforts to synthesize the research in an integrated broad-based body of knowledge have been limited (Shaligram *et al.*, 2009). Most research focuses only on a small area of RL systems, such as network design, production planning or environmental issues. Fleischmann *et al.*, (1997) studied reverse logistics from the perspectives of distribution planning, inventory control and production planning. Carter and Ellram, (1998) focused on the transportation and packaging, purchasing and environmental aspects in their RSC study. Linton *et al.*, (2003) studied the relations between sustainability and supply chains by considering environmental issues regarding product design, product life extension and product recovery at end-of-life. Realff *et al.*, (2004) have also reviewed the literature on reverse supply chain published between 1995 and 2005 by focusing on management of the recovery, distribution of end-of-life products, production planning and inventory management, and supply chain management issues. Certain keywords such as product returns, product recovery, reverse logistics, end-of-life products, closed-loop supply chains, recycling, remanufacturing all are associated with the reverse channel and may be termed as creations/innovations with time. As growing consumer pressure for environmentally friendly operations intensifies, managers must choose from a daunting array of possible alternatives that develop new capabilities, change interactions with customers and suppliers, and require adjustments in existing supply chain partnerships, which, in turn, affect firm performance. Time has come when to create/innovate something feasible and supply chain management must expand from its traditional focus on the forward flow of materials, components and products to explicitly address the some new creative processes like disposal, recycling, reconditioning and remanufacturing of used products. In this work, we study recent creations in reverse supply chain and analysis of various variables affecting these innovations that led a sustainable behavior with consideration of environmental issues.

Motivation for Research

Motivation means to drive/steer or intentions of doing something. There are numerous literature available on desirable characteristic of RSC and demonstrated by several authors; i.e. economical, strategic, and environmental (Carter and Ellram, 1998; De Brito, *et al.*, 2003; De Brito and de Koster, 2003). Innovation creates an environment for better quality and reliability of existing products, reduce costs (including wages, raw materials, and energy consumption), and improve the performance of the various product linked services. Among these, the key goal of an organization's innovation is to produce competitive advantage in order to make it possible for the company to survive in future. Innovation differs from invention in that innovation refers to the use of a new idea or method, whereas invention refers more directly to the creation of the idea or method itself. System thinking and collaborative methods are replacing information and operations silos of traditional supply chain. This has motivated research in the fields of supply chain management both in forward as well as reverse direction with innovative technologies that promotes overall coordination of value added networks for integrated supply chain. Finally, the environment has become a key issue for RL system. The increase in innovation makes it possible to reduce environmental damage and satisfy regulations, standards, and government legislation. Innovation is certainly a combination of activities as shown in Figure 1. It basically represents opportunities existing in market, corresponds to the suitable and right use of technology and last but not the least depends upon the user's requirements.

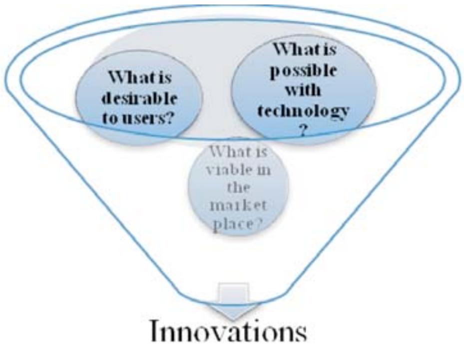


Figure 1: An Illustration of Innovation

Innovation varies according to degrees and types, but the ultimate reverse supply chain innovation goal is that the supply chain management must expand from its traditional focus on the forward flow of materials, components and products to explicitly address the disposal, recycling, reconditioning and remanufacturing of used products. The objective of reverse or closed loop supply chain is to minimize waste and close the flow of material. Therefore, to get better economic and strategic benefits, reverse supply chain network needs to innovate and better manage its process of value extraction from the product after return. Still knowledge management practices are not yet fully developed, therefore it is required to pull out information from customers and business partners, who pushes products in to the return chain. All these factors, leads to development of innovation based approach that suggests mechanisms for effectively managing innovative change in a reverse supply chain system.

This paper begins with a description on innovation and reverse supply chain in general. It goes ahead to describe a suitable framework to study the variables those drives innovations in reverse supply chain to maximize their value in the automotive sector. On that note, an ISM hierarchy is being developed on the account of importance of variables, followed by Micmac analysis to analyze the driving and dependence power of variables. Finally, the paper ends with conclusions and necessary managerial insights to achieve desired objectives.

Reverse Supply Chain

Principally, the reverse supply chain (RSC) refers to the series of activities necessary to retrieve a product from a customer and either dispose of it or recover value (both information and physical goods). Getting products to the end customer means the end of the forward supply chain processes. It is just the starting point of the 'new era' of challenges for the reverse supply chain that requires to apply the appropriate reverse supply chain strategy, design and procedures to enable the optimization of flows of product returns (Dowlatshahi, 2000; Sahyouni *et al*., 2007). Due to the economic, competitive and political factors, reverse supply chains are becoming essential for survival (Guide and Wassenhove, 2002). Reverse supply chains represent an opportunity to generate a value for companies. Thus, reverse supply chains require as much or even more attention than forward supply chains (Blackburn *et al*., 2004).

Definitions

Reverse supply chain system promises to be a broad area of research. Most of the articles are practitioner-oriented and published in the industrial rather than academic journals, thus even the term 'reverse supply chain' is not clearly defined and widely accepted by academia researchers (Dowlatshahi, 2000; Prahinski and Kocabasoglu, 2006).

Guide and van Wassenhove (2002) defined reverse supply chain (further - RSC) as - 'the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it.

Further, Guide and van Wassenhove (2002) studied the reverse supply chain with five key processes: product acquisition, reverse logistics, inspection and disposition, reconditioning, distributions and sales. This definition was applied in a number of studies (e.g. Blackburn *et al.*, 2004).

Whereas, (Prahinski and Kocabasoglu, 2006) defined reverse supply chain management as – 'the effective and efficient management of the series of activities required to retrieve a product from a customer and either dispose of it or recover value.'

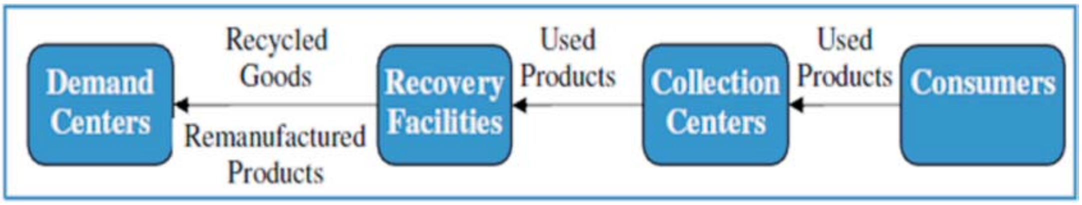


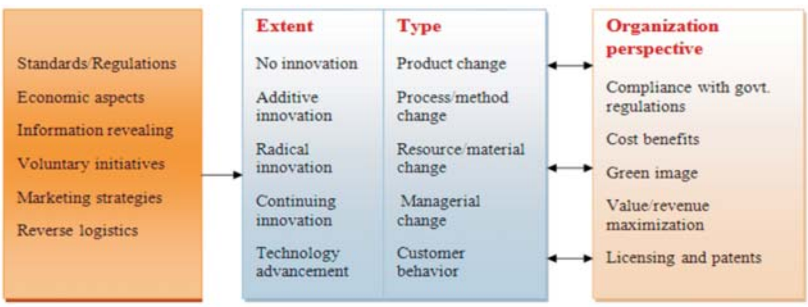
Figure 2: The Generic Reverse Supply Chain (Pochampally *et al.*, 2009)

It is important to note that in the reverse supply chain literature besides the term reverse supply chain the reader may meet other terms such as reverse chain, reverse logistics or reverse distribution that are referring to approximately the same research area. For instance, Rogers and Tibben-Lembke (1999) defined reverse logistics (RL) – 'the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal.' RL includes various activities such as return products to supplier, resell, sell-via-outlet, reconditioning etc. Note that in this paper we use the terms reverse logistics and reverse supply chains interchangeably. The simplified model of reverse supply chain is presented in the Figure 2. The used products after being used by the consumers shipped to collection centers for inspection. In next echelon, various recovery facilities to recover product/material in form of various re's (recycling, reuse and remanufacturing) finally, transported to demand centers to enter in the market.

Generic Framework

During generic framework, it has been observed that the innovative actions of firms are influenced by pressure of government rules & regulations and other policy instruments. Firms undertake

Table 1: General Representation for Studying Innovations Associated with Reverse Supply Chain



Envrionmental Policy instruments in reverse supplychain	Innovative Responses	Contexual parametres

environmental investments for a variety of drives relating to finances, markets, image and other factors. A generic framework for studying the innovations in reverse supply chain is illustrated in Table 1. The general representation consists of three components: i) the effect of environmental policy, which can take a variety of forms; ii) a range of possible innovative responses; and iii) organization-level contextual parameters which shows the effects of environmental policies on innovation in reverse supply chain.

Here, environmental policy instruments encompass a number of approaches and product standards are regulatory requirements that specify the environmental and/or safety characteristics of industrial products. These regulations/standards are stated by government and generally, such standards are imposed on products already in the marketplace taking account of economic aspects (deposit/refund schemes; advance disposal fees, materials taxes etc.). Information revealing covers a range of initiatives pertaining to public disclosures of environmental performance and also monitoring requirements. While, assign the initiative for specifying change to the party with the knowledge to design it and the means to implement it - i.e. the firm is termed as voluntary initiatives (OECD, 2001). Therefore, for an organization it is crucial to share and reuse various kinds of knowledge involved in a product life cycle from-cradle-to-grave. Moreover, reverse logistics stands for all operations related to the recycle/reuse/remanufacturing of products and materials. Of course, these instruments overlap in their classifications and their effects and are usually combined in policy implementation.

The goal of study of innovations in reverse supply chain is to encourage manufacturers to recapture the value of products after their usage so that they will lead to reduced or less polluting waste streams and disposed off easily. With regard to different re's (recycling, repair, reuse, remanufacturing and reduce etc.), various reverse supply chain approaches could lead to no innovation, incremental innovation or radical innovation. Both incremental and radical innovation may decrease energy and materials consumption as producers work hard to make less wasteful and more recyclable products (OECD, 1992). It is difficult to distinguish between what constitutes incremental or radical innovation in terms of product design. RSC-related innovation could include product simplification, standardization of components, modifying components for reuse, standardization of material types, easily detachable parts, reduction in number of pieces requiring dismantling, etc. Separately, all of these could lead to less waste and lower costs of waste management and proper disposal of used product, but would probably be termed incremental innovation. More radical innovation may be understood as “design for the environment”. Green product design includes a variety of techniques and strategies which aim to increase a product’s recycled content, eliminate problematic ingredients, or create a system to take-back a product or its packaging for reuse, or recycling at the end of its useful life. This includes designing products in their entirety that can be easily upgraded, rather than replaced when they become outmoded. RSC-driven radical innovation can have far-reaching effects on firms which invest in product-oriented environmental management systems. Moreover, these innovations could prompt changes in the behavior of reverse supply chain, which would base their purchases to some degree on environmental criteria relating to a product’s waste effects (OECD, 2001).

The innovative responses of firms differ in both in degree and type. In some cases, environmental policy may produce no innovative changes at all, results in a type of product change. Radical and incremental innovations represent different degrees of change; the latter denoting smaller improvements along a given trajectory involve changes in resources, and the former, major departures from the technical status quo. The need for innovation to satisfy environmental policy may be continuing or it may be satisfied by a single technological modification. Technology advancement succeeds innovation, as subsequent users adopt, often with adaptations, the technology pioneered elsewhere. To bring changes at managerial level there should be continuation in innovation process (OECD, 1992). These degrees of innovation can take different forms. Most often, they are changes to either products or production processes to incorporate environment-related improvements. Innovation may or may not be embodied in a change in the type or level of resource inputs. More far-reaching innovations relate to both the organization and management of enterprises and to customer behavior, which can become more oriented to environmental considerations as an integral part of operational thinking.

The contextual parameters show the set of boundary conditions which can limit the innovative responses to environmental policy. Organizations have varying motivations for making environmental investments and introducing environment-related innovations in reverse supply chain. These include the desire to be in regulatory compliance as stated by government, to realize cost savings and reduce wastages and efficiency gains to maximize their value, to enhance their green image considering environmental issues while expand their consumer base, and/or to patent and sell a new technology. Lastly, the innovative response of an organization will depend to a large degree on the various driving forces in RSC and particular product in question. The dynamics of these and other linked factors with the innovation in reverse supply chain are analyzed.

Case Study

Twenty-years ago, supply chains were busy fine-tuning the logistics of products from raw material to the end customer. Products are moving at a very high rate to the end customer as compared to their reverse flow. This is the case for majority of industries, covering electronic goods, pharmaceuticals, beverages and so on. Here, we focus on the automobile sector industries and for instance, the automobile industries are busy changing the physical and virtual supply chain to facilitate end-of life recovery (Boon *et al*., 2001; Ferguson and Browne, 2001). According to world statistics, the automobile industry is world's largest single manufacturing sector and the automotive industry leads in research and development activities in response to the negative environmental developments (Lettice, *et al*., 2010). The growth in the world's population has also heightened the demand for the vehicles (Olugu *et al*., 2010). Increasing trend of demand of automobiles such as bikes, cars and commercial vehicles in India has been noticed in last few years, therefore leading international and domestic automobile manufacturers (like Maruti Suzuki, Hyundai, Tata Motors, General Motors, Honda, Fiat, Bajaj Auto, Hero Honda etc.) are either setting up their new manufacturing plants or increasing their production capacity in existing plants. Due to globalization and modernization, Environmental issues are becoming very important these days. So companies need to focus on energy consumption and resources for making environmentally sound supply chain. By virtue of the effect of environmental legislation & competitiveness a great need to implement product/material recovery operations to receive a product in a reverse supply chain. Because vehicles are already among the most highly recycled products, the innovation goal here is to recapture their value after ending of usage life. About 75% of vehicles by weight consist of metals which are usually recycled. The target is the remaining 25% consisting of mixed materials such as plastic, rubber, glass, textiles, paint, etc. which are difficult to recycle, may be contaminated with hazardous substances, and are usually land filled. The major variables affecting the innovations in reverse supply chain in sector understudy are described ahead.

Interpretative Structural Modeling(ISM) as Multi Criteria Decision Modeling Tool

ISM provides an ordered, directional framework for complex problems, and gives decision makers a realistic picture of their situation and the variables involved. In this research, we are interested in the innovations in reverse supply chain management which further depends on a number of variables. A model depicting those key variables that should be focused on such that desired results could be achieved would be of great intentioned for management. ISM can rightly be employed under such circumstances because on the basis of relationship between the variables, an overall structure can be extracted for the system under consideration. ISM is primarily intended as a group learning process, but can also used individually. The ISM process transforms poorly articulated mental models of systems into visible, well-defined models useful for many purposes. ISM is an interactive learning process in which a set of different and directly related elements are structured into a comprehensive systemic model Warfield (1974) & Sage (1977). ISM can be used extensively in identifying and analyzing interactions among the elements of a system. The model so formed portrays the structure of a complex issue or problem, a system or a field of study, in a carefully designed pattern implying graphics as well as words. The method is interpretive as the judgment of the group decides whether and how the variables are related. In this paper, interpretive structural modeling has been applied to develop a framework for the variables affecting innovations in reverse supply chain system concept to achieve the desired broad objectives:-

1. Deriving the interrelationships among the variables.
2. Classifying these variables according to their driving and dependence power.

On the basis of relationship among the variables, an overall structure is extracted from the complex set of variables. It is a modeling technique as the specific relationships and overall structure is portrayed in a digraph model. ISM starts with an identification of variables, which are relevant to the problem or issue and then extends with a group problem-solving technique. ISM methodology helps to impose order and direction on the complexity of relationships among elements of a system.

ISM Methodology and Model Development

The various steps involved in the execution of ISM method are given below (Kannan *et al.*, 2008). The flow chart for the ISM methodology is shown in Figure 2.

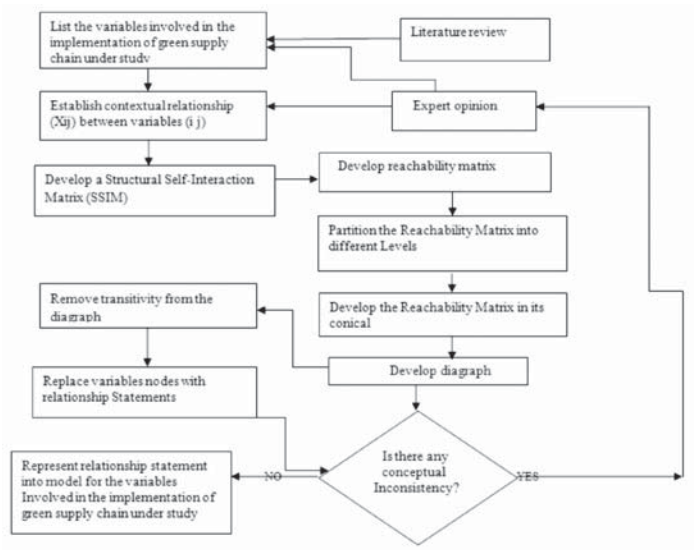


Figure 3: Flow Diagram for ISM Methodology

Step 1: The variables affecting the product recovery system for the firm under study are listed. Step 2: For each pair of variables identified in Step 1, a contextual relationship is established. Step 3: A Structural Self-Interaction Matrix (SSIM) is developed, which indicates pair wise relationships among variables of the system under consideration. Step 4: A reachability matrix, initial & followed by final is developed from the SSIM and the matrix is checked for transitivity. The transitivity rule states that if a variable 'A' is related to 'B' and 'B' is related to 'C', then 'A' is necessarily related to 'C'. Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels. Step 6: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed. Step 7: The resulting digraph is converted into an ISM by replacing the variable nodes with statements. Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistencies, and necessary modifications are made. We now apply the ISM methodology to the organization under study.

Identification of the various Variables Affecting the Innovations in Reverse Supply Chain

This step involves the identification of various variables for a problem; here some variables acted as driving forces which drive innovations in reverse supply chain and results into good performance of the system (Diabat and Kannan, 2011). ISM can be used for identifying and summarizing relationships among specific variables which define a problem or an issue (Ravi and Shankar, 2005). In this paper various variables, affecting innovations in the reverse supply chain in automobile sector have been analyzed using the ISM methodology, which shows the interrelationships of the considered variables and their levels. These variables are further categorized on the basis of their driving power and dependence. After review of literature on reverse supply chain system and the opinion of experts, both from automobile industries and the academia, 12 important variables affecting innovative activities in reverse supply chain have been identified and are discussed below. These variables have been categorized under "enablers" and "results". The enablers (Green forces, demand pattern, marketing strategies, shortening product life cycle, cost benefits and return alternatives policies etc.) are the variables that help boost the innovations in reverse supply chain system, while results variables (Customer diversity & time value, value maximization, competitive edge, the volume of returns, changes in buying behavior and product return policy etc.) are the outcome of innovative practices.

1. Green forces – This is a crucial driver of regulating innovations in RSC and environmental issues are the significant force shaping the economy, as well as one of the most critical aspect of sustainability (Murphy *et al.*, 1995). Companies have focused on reverse logistics operations because of various government pressures and environmental reasons (Rogers and Tibben Lembke, 1999) & (Wu and Dunn, 1995). Kopicki *et al.*, (1993) gave attention to environmental concerns by pointing out opportunities on reuse and recycling in reverse logistics programs. Customer's attitudes and governmental regulations regarding environmental impact of products and processes is forcing companies to explore 'greener' alternatives and implement new practices of product returns management (Prahinski and Kocabasoglu, 2006; Pochampally *et al.*, 2009).
2. Demand pattern – Changes in demand pattern is a very strong driving variable for a RSC as reflects the requirements of the users. Competitive pressure requires discovering new ways to improve customer service level. By speeding up reverse flows and increasing responsiveness through the RSC design the customer service level can be improved significantly (Blackburn *et al.*, 2004; Prahinski and Kocabasoglu, 2006).
3. Marketing strategies – These are certainly requirements to make stock adjustments increased due to unsold merchandises (Blumberg, 2005; de Brito, 2003). Also the success of a RSC depends on its marketing strategy as well as on its design, it is important that the planned marketing strategy be evaluated with respect to various other variables in the supply chain.
4. Shortening product life cycle –Product life cycle deals with the life of a product in the

market with respect to business/commercial costs and sales measures. The shorter product life cycle the faster returns have to be processed (e.g. repaired, re-manufactured, and upgraded) in the reverse chain, which leads to increasing requirement for speed and responsiveness of the RSC (Krikkle *et al*., 2004; Blackburn *et al*., 2004).

5. Cost benefits – This is paramount thrust for any business and by incorporating reverse operations no doubt that the environment will be benefited. Moreover, the practice of reverse logistics would lead to cost reduction. The companies, by reusing, remanufacturing or recycling, are striving to extract potential value of product returns (e.g. in many cases it may cost less to produce an item from reprocessed materials that from raw resources) (Pochampally *et al*., 2009). Ford Motor Company, for instance, produces tail light housings from recycled plastic bumpers (Blumberg, 2005). One more example, organizations that make use of remanufacturing in the product recovery are estimated to save nearly 50 percent of the costs compared to manufacturing a new one (Toensmeier, 1992) while requiring only 20 percent of the effort (Sturgess, 1992).
6. Return alternatives policies– Recapturing or retrieving the value of used products is called as reverse logistics (Johnson, 1998; Ravi *et al*., 2005). By means of the returned products, organizations can explore the possibility of recovering constituent material and products that can't use further as in original form. Various alternatives includes product recalls, leasing, short or long-term rents (Blumberg, 2005).
7. Customer diversity & time value – Returns flows depend on users/costumers and may require precise knowledge and understanding of specific users/customers; from cost perspective processes need to be organized in a manner to enable making returns available for reuse (especially for the returns that have high marginal time value). According to Blackburn *et al*., (2004) depending on strategic goals, the RSCs strive to focus either on the cost efficiency or on the speed of response/ time efficiency.
8. Value maximization –The ultimate objective of RSC is to maximize revenues or reduce costs by choosing the most appropriate recovery alternative. Since there are many parties involved in the reverse chain, the control and the coordination of activities is needed to maximize their value. (Blumberg, 2005).
9. Competitive edge – Globalization increased the possibility to re-distribute and re-sell products' returns to secondary markets (Meyer, 1999). Companies initiate reverse logistics programs in organization for competitive reasons (Carter and Ellram, 1998). Reverse logistics system combined with alternative product return policies can be used to gain competitive advantage in the market (Marien, 1998).
10. The volume of returns –Various driving operations affect the volume of returns of products significantly. Based on a former study, total value of the returned products in the US is worth $10 billion per year. And that's only value of products passively returned by consumers, let alone products that can be collected by manufacturers to retrieve remaining value from. Without any doubt, RSCs not only directly affect the environment, but also have profound impacts on the economic performance of each supply chain member on a chain. Return rates vary from industry to industry, in some industries (e.g. magazine publishing) returns expressing up to 50 present of turnover (Rogers & Tibben-Lembke, 1999).
11. Changes in buying behavior – Advancement in technology and inventions influencing the buying behavior taste of customers. Due to increasing e-commerce and modernization the customers are shifting towards non-store purchasing, which, in turn, raises amount of product returns including products that have never been, used (Rogers and Tibben- Lembke, 1999; Blumberg, 2005).

12. Product return policy – On the one hand, sellers' (or manufacturers') responsibility regarding product returns has increased - 'In many countries, home-shoppers are legally entitled to return the ordered merchandize' (de Brito, 2003). While, companies, in order to increase competitiveness, may apply even more liberal return policies such as extended warranties time, after-warranties services etc. (Guide *et al*., 2003).

Development of Structural Self-Interaction Matrix (SSIM)

Based on contextual relationship among identified variables, a Structural Self-Interaction Matrix was developed, shown in Table 2. This matrix indicates the pair wise relationships among the variables affecting the innovations in RSC system initiatives for the automobile sector under consideration. A detailed description of the symbols used to denote the directions of the relationship between the variables are given as below:-

Let us assume that the variables under study are i and j, then the symbol 'V' denotes that variable i will help to achieve variable j, the symbol 'A' means that variable j will be help to achieve variable i. The symbol 'X' means that variable i and j will help each other to achieve and the symbol 'O' means the variables are unrelated.

Table 2: Structural Self-interaction Matrix (SSIM)

S.N.	Variables	12	11	10	9	8	7	6	5	4	3	2	1
1	The volume of returns	V	X	V	A	X	A	A	X	X	A	X	
2	Cost benefits	V	V	V	V	A	X	V	V	V	A		
3	Green forces	V	V	V	V	V	V	V	V	V			
4	Demand behavior	V	V	V	A	A	X	A	V				
5	Changes in buying characteristics	V	A	V	A	A	V	X					
6	Shortening product life cycle	V	X	V	A	A	V						
7	Return alternatives method	V	V	V	A	A							
8	Marketing strategies		V	V	V	V							
9	Product return policies		V	V	X								
10	Customer diversity & time value		V	A									
11	Competitive edge	V											
12	Value maximization												

The following statements illustrates the use of symbols V, A, X and O in the SSIM matrix.

- Cost benefits variable will be achieved by Marketing strategies variable (A);
- Green forces variable will help to achieve Value maximization variable (V).

We derived the reachability matrix from the structural self-interaction matrix (SSIM) developed in the previous step. The initial reachability matrix is constructed from the structural self-interaction matrix, using the following rules as shown in Table 3.

- If the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 0.
- If the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 1.
- If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 1.

Table 3: Initial Reachability Matrix

S.N	Variables	1	2	3	4	5	6	7	8	9	10	11	12
1	The volume of returns	1	0	0	0	0	0	1	0	0	1	0	1
2	Cost benefits	0	1	0	1	1	1	0	0	1	1	1	1
3	Green forces	1	1	1	1	1	1	1	1	1	1	1	1
4	Demand behavior	0	0	0	1	1	0	0	0	0	1	1	1
5	Changes in buying characteristics	0	0	0	0	1	0	1	0	0	1	0	1
6	Shortening product life cycle	1	0	0	1	0	1	1	0	0	1	1	1
7	Return alternatives method	0	0	0	0	0	0	1	0	0	1	0	1
8	Marketing strategies	0	1	0	1	0	1	1	1	1	1	1	1
9	Product return policies	1	0	0	1	1	1	1	0	1	0	0	1
10	Customer diversity & time value		0	0	0	0	0	0	0	0	0	1	0
11	Competitive edge	0	0	0	0	0	0	0	0	0	0	1	1
12	Value maximization	0	0	0	0	0	0	0	0	0	0	0	1

- If the (i, j) entry in the SSIM is O, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 0.

The final reachability matrix shown below in Table 4 is constructed from the initial reachability matrix taking into account the transitivity rule, which states that if a variable ‘A’ is related to ‘B’and ‘B’ is related to ‘C’, then ‘A’ is necessarily related to ‘C’.

Level Partitions of Reachability Matrix

The reachability matrix obtained as above was partitioned into different levels. The reachability and antecedent set for each variables (Warfield, 1974) were found from the final reachability matrix as shown in, Table 5. The reachability set for an individual variable consists of itself and the other variables which it may help to achieve. The antecedent set consists of the variables themselves and the other variables which may help in achieving it. The intersection of both

Table 4: Final Reachability Matrix

S.N	Variables	1	2	3	4	5	6	7	8	9	10	11	12	Driving power
1	The volume of returns	1	0	0	0	0	0	1	0	0	1	0	1	4
2	Cost benefits	0	1	0	1	1	1	0	0	1	1	1	1	8
3	Green forces	1	1	1	1	1	1	1	1	1	1	1	1	12
4	Demand behavior	0	0	0	1	1	0	0	0	0	1	1	1	5
5	Changes in buying characteristics	0	0	0	0	1	0	1	0	0	1	0	1	4
6	Shortening product life cycle	1	0	0	1	0	1	1	0	0	1	1	1	7
7	Return alternatives method	0	0	0	0	0	0	1	0	0	1	0	1	3
8	Marketing strategies	0	1	0	1	0	1	1	1	1	1	1	1	8
9	Product return policies	1	0	0	1	1	1	1	0	1	0	0	1	7
10	Customer diversity & time value	0	0	0	0	0	0	0	0	0	1	0	1	2
11	Competitive edge	0	0	0	0	0	0	0	0	0	0	1‘	1	2
12	Value maximization	0	0	0	0	0	0	0	0	0	0	0	1	1
Net	Dependence power	4	3	1	6	5	5	7	2	4	9	6	12	

these sets was also derived for all variables. The variables for which the reachability and the intersection sets are same is assigned as the top level variables.

Table 5: Level Partition of Variables – Iteration 1

Variables	Reachability Set	Antecedent Set	Intersection set	Level
1	1,7,10,12	1,3,6,9	1	
2	2,4,5,6,9,10,11,12	2,3,8	2	
3	1,2,3,4,5,6,7,8,9,10,11,12	3	3	
4	4,5,10,11,12	2,3,4,6,8,9	4	
5	5,7,10,12	2,3,4,5,9	5	
6	1,4,6,7,10,11,12	2,3,6,8,9	6	
7	7,10,12	1,3,5,6,7,8,9,	7	
8	2,4,6,7,8,9,10,11,12	3,8,	8	
9	1,4,5,6,7,9,12	2,3,8,9	9	
10	10,12	1,2,3,4,5,6,7,8,10	10	
11	11,12	2,3,4,6,8,11	11	
12	12	1,2,3,4,5,6,7,8,9,10,11,12	12	Level 1

The ISM hierarchy as it would not help achieve any other variable above their own level. After the identification of the top level element, it is discarded from the list of remaining variables. From Table 5, it is seen that the value maximization (variable 12) is found at level 1st. thus, it would be positioned at top of ISM hierarchy. For iteration-1, value maximization variable is found to have same reachability and the intersection sets, and so qualifies to hold level 1. The identified levels aids in building the diagraph and final model of ISM. This iteration is repeated till the levels of each variable are found out. As there no common variables in intersection set so iteration-1 is sufficient to build an ISM model for the variables associated with innovations in RSC system.

Formation of ISM Model

With the help of the level partition shown in Tables 3 and 4, a model of the various variables important to study innovations in RSCs for the industries under study was developed, and is shown in Figure 4.The structural model is generated from the final reachability matrix and the digraph is drawn. Removing the transitivity's as described in the ISM methodology, the digraph is finally converted into the ISM model as shown in Figure 4. It is observed from this figure that green forces (variable 3) is a very significant factor to affect the innovations in RSC system as it forms the base of the ISM hierarchy. ISM hierarchy has been described as a relationships of various variables while moving from level 12 (green forces) towards desired outcomes level 1(value maximization) as shown in Figure 4. Value maximization at the top of the hierarchy is the desired outcome, which depicts the successful implementation of product recovery operations/methods in a RSC system. The green forces (variable 3) lead to the employment of various marketing strategies (variable 8) to recapture the value of used products and the consideration of cost (variable 2) involved in process.

Moreover, the marketing strategies opted by sector under study might increase overall cost of process and also have significant effect on the life cycle of product because to processed faster returns requires short product life cycle. Further, this cost considering variable impact significantly on various product return policies (variable 9) employed by the company to retrieve

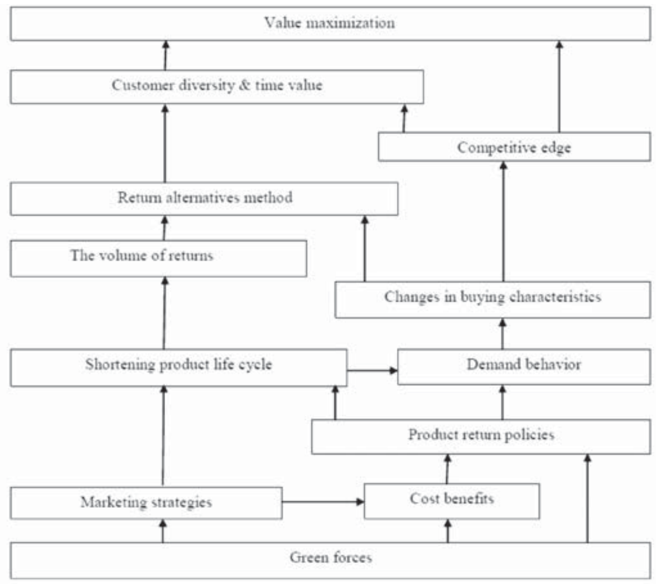


Figure 4: ISM Model for the Variables Associated with Product Recovery System

the products from customers. While, to manage competitiveness and globalization various product return policies lead to certain changes in demand behavior of products (variable 4) and shortening the product life cycle (variable 6). The shorter product life cycle the faster and volume of returns (variable 1) have to be processed (e.g. repaired, reuse, recycled re-manufactured, and upgraded) in the reverse chain for implementing a successful product recovery & reverse logistics program. This shortening product life cycle also have direct effect on changes in demand behavior of products which further results changes in buying charters tics (variable 5) of the customers. Further, the changes in buying behavior and the volume of returns collectively influences various return alternative method (variable 7) to successfully recover constituent material and components that no longer needs to be purchased/used in same quantities. These various changes in the buying taste of customers have a great effect on market share and competitive edge (variable 11) to enhance their value. Further, the selected return alternative methods within the system and competitive edge together help to achieve customer diversity & time value (variable 10) focusing on precise knowledge and understanding of specific users/customers along with a quick responsive RSC. Finally, this customer diversity & time value leads to generate maximum revenue or minimum cost i.e. value maximization (variable 12) by choosing the most suitable recovery methods in a RSC system.

MICMAC Analysis

In MICMAC analysis, the dependence power and driving power of the variables are analyzed. On the basis of the above study, the variables were classified into four sectors. The four sectors are autonomous, dependent, linkage, and independent. In the final reachability matrix, shown in Table 4, the driving power and dependence of each of the variables are calculated. The variables which we have stated like green forces, shortening product life cycle, product return policy, volume of returns, marketing strategies and return alternative methods all are environment concerning and very critical in today era. Due to the complexity of RSC practices, customer and cost pressures and regulation uncertainty, implementing product/material returns and studying innovations associated with this is considered as a thankless task that increases overall product cost. If decision maker are aware of the relative importance of the various variables and the techniques for implementing them, cumulative behavior can well be estimated. Highlighting the 12 types of variables, an ISM model was developed and the interactions between these variables were analyzed using the ISM model and MICMAC analysis as shown in Figure 5.

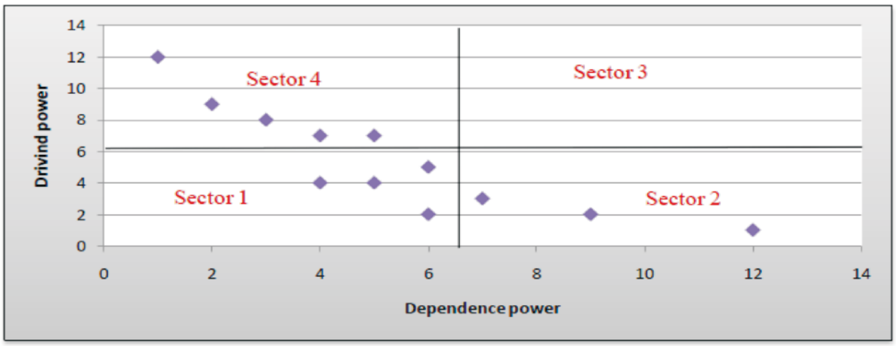


Figure 5: Driving Power and Dependence Power Diagram

Discussions

One of the primary goals of a supply chain of the companies is to increase its productivity and performance in terms of value maximization such that it is able to generates maximum revenues and satisfy its customers. Liberal return policies and growing environmental concerns have led to an increase of returned products in RSC system. These outdated products should be reused or recycled should be done to recapture value from them. If these products are not reused in any form further, they should at least be properly disposed off such that there is no harmful effect on the environment. The managerial implication for study the effect of various variables on innovations in RSC system and concluding remarks emerging from this study are as follows:-

The variables that have weak variables power as well as dependence will fall in SECTOR 1 and are called as “autonomous elements”. While variables that have weak driving along with strong dependence power will fall in SECTOR 2 and are known as “dependent elements”. Similarly other set of variables both strong driving and dependence power will fall in SECTOR 3 will be called “linkage elements”. These variables are further considered to be highly unstable and sensitive. Any action on these will affect the variables, and may also have a strong feedback. Therefore, for a stable system less number of variables is required be there in this sector (linkage elements). In our study we have no variable been found in this sector. Thus, it can be inferred that among all the variables chosen in this study, no variable is unstable. Variables that have strong driving power but weak dependence power will fall in SECTOR 4 and are called independent elements (Kannan and Haq, 2007). Because, these variables have strong driving power i.e. they strongly affect other sector variables and weak dependence power i.e. didn’t much depend on other sector variables.

Thus there is a strong need to address these variables help to achieve desired result variables, which appear at the top of the ISM hierarchy. Shortened life cycles of products and environmental consciousness, collaboration and smart use of resources in various processes are becoming more important. Therefore, sustainable development and reverse logistics are back bone for RSCs.

Conclusions

In this paper, an ISM based model has been developed to analyze the interaction among the variables regulating innovations in RSC. It identifies the hierarchy of actions to be taken for the conduct product recovery/return operations in a reverse system in order to maximize value. The variables (enablers and result outcomes) identified in the ISM model are quite generic and, with marginal adjustments, can be used for many other supply chains. It can also help top management to decide the course of action in the successful implementation of product recovery/return programs to increase the overall revenue and competitive edge. The driver power-dependence matrix (Figure 5) gives some valuable insights about the relative importance and interdependencies among the RSC variables. The recommended managerial implications required to study innovations within the reverse channel system emerging from this study are concluded as:-

- The volume of returns, demand behavior, changes in buying characteristics and competitive edge are autonomous variables for affecting innovations in RSC. These variables appear as weak driver as well as weak dependent and do not have much influence on the other variables of the system.
- Value maximization, return alternatives method and customer diversity & time value are weak drivers but strongly dependent on other variables which are, The volume of returns, cost benefits, green forces, shortening product life cycle, marketing strategies, demand behavior, changes in buying characteristics, product return policies, customer diversity & time value and competitive edge. Value maximization and customer diversity & time value are seen at the top of the ISM hierarchy; these variables represent the desired objectives of the study and should be under high attention for studying the innovations with RSC and implementing successful product recovery/return methods to recapture their value.
- Variables that have both strong driving power and dependence power will fall in SECTOR 3 and are called linkage elements. No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Due to which, within a system any action on these sector variables have strong dependence on each other and also having a great impact on other sector variables.
- The independent variables of the RSC system such as green forces, cost benefits, shortening product life cycle, marketing strategies and product return policies are at the bottom of the models strongly drives other variables. Because, these variables have strong driving power i.e. they strongly affect other sector variables and weak dependence power i.e. didn't much depend on other sector variables. Thus there is a strong need to address these variables help to achieve desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that there must be strategies to enhance the deployment of independent variables so that the desired level of results/outcome can be achieved.

References

- Boon, J. E., Isaacs J. A. and. Gupta. S. (2001) Economic Impact of Aluminum-Intensive Vehicles on the USA Automotive Recycling Infrastructure, *Journal of Industrial Ecology*, 4(2), 117–134.
- Blackburn, J. D., Guide, V. D. R., Souza, G. C. and Van Wassenhove, L. N. (2004) Reverse Supply Chains for Commercial Returns, *California Management Review*, 46(2), 6-22.
- Blumberg, D. F. (2005) Introduction to Management of Reverse Logistics and Closed Loop Supply Chain Processes, New York: CRC Press.
- Carter, C. R. and Ellram, L. M. (1998) Reverse Logistics: A Review of the Literature and Framework for Future Investigation, *Journal of Business Logistics*, 19(1), 85-103.
- De Brito, M. P. (2003) Managing Reverse Logistics or Reversing Logistics Management? ERIM PhD Series Research in Management, N. 35, Rotterdam: Erasmus University Rotterdam.
- De Brito, M. P., Dekker, R. and Flapper, S. D.P. (2003) Reverse Logistics - A Review of Case Studies, Report Series Research in Management, ERS-2003-012-LIS, Erasmus University Rotterdam, The Netherlands.

- De Brito, M. P. and de Koster. M. B. M. (2003) Product and Material Returns: Handling and Warehousing Issues, In R. Dekker, K. Inderfurth, L. van Wassenhove, and M. Fleischmann, editors, Quantitative Approaches to Reverse Logistics, chapter 6. Springer-Verlag, Berlin, Germany.
- Diabat, A. and Kannan G. (2011) An Analysis of the Drivers Affecting the Implementation of Green Supply Chain Management, *Resources, Conservation and Recycling*, 55, 659–667.
- Dowlatshahi, S. (2000) Developing a Theory of Reverse Logistics, *Interfaces*, 30(3), 143-155.
- Ferguson, N. and Browne. J. (2001) Issues in End-of-life Product Recovery and Reverse Logistics, *Production Planning and Control*, 12(5), 534–547.
- Fleischmann M., Bloemhof-Ruwaard J.M., Dekker R., van der Laan E., van Nunen JAEE and van Wassenhove L.N.(1997) Quantitative Models for Reverse Logistics: A Review, *European Journal of Operational Research*, 103(1),1–17.
- Guide, V. D. R. and van Wassenhove, L. N. (2002) The Reverse Supply Chain, *Harvard Business Review*, 80(2), 25–26.
- Guide, V., Harrison T.P. and Van Wassenhove, L.N. (2003) The Challenge of Closed-loop Supply Chains, *Interfaces*, 33(6), 3-6.
- Harrison, A. and van Hoek, R. (2007) Logistics Management and Strategy: Competing through the Supply Chain (3rd ed.), Harlow, Pearson Education Limited.
- Kannan G., Haq A.N., Kumar P.S. and Arunachalam S. (2008) Analysis and Selection of Green Suppliers Using Interpretative Structural Modeling and Analytic Hierarchy Process, *International Journal of Management and Decision Making*, 9(2), 163–82.
- Kannan, G. and Haq, N.A. (2007) Analysis of Interactions of Criteria and Sub-Criteria for the Selec-Tion of Supplier in the Built-In-Order Supply Chain Environment, *International Journal of Production Research*, 45(17), 1–22.
- Krikke, H., Blanc, I. and Velde S. (2004) Product Modularity and the Design of Closed- Loop Supply Chains, *California Management Review*, 46(2), 23-39.
- Lettice, F., Wyatt C. and Evans S. (2010) Buyer–supplier Partnerships during Product Design and Development in the Global Automotive Sector: Who Invests, in What and When?, *International Journal Production Economics*, 127, 309–319.
- OECD (1992) The Polluter Pays Principle: OECD Analysis and Recommendations, OECD, Paris, 8-9.
- OECD (2001) Extended Producer Responsibility, OECD, Paris.
- Olugu, E.U., Wong, K.Y. and Shaharoun, A.M. (2010) A Comprehensive Approach in Assessing the Performance of an Automobile closed loop Supply Chain, *Sustainability*, 2, 871-879. Doi: 10.3390/su2040871.
- Pochampally, K. K., Nukala, S. and Gupta, S. M. (2009) Strategic Planning Models for Reverse and Closed-Loop Supply Chains, CRC Press, Boca Raton, Florida, ISBN: 9781420054781.
- Prahinski, C. and Kocabasoglu, C. (2006) Empirical Research Opportunities in Reverse Supply Chain, *The International Journal of Management Science*, 34, 519-532.
- Ravi, V., Shankar, R. and Tiwari M.K. (2005) Productivity Improvement of a Computer Hardware Supply Chain, *International Journal of Productivity and Performance Management,* 54(4), 239-255.
- Ravi, V. and Shankar, R. (2005) Analysis of Interactions among the Barriers of Reverse Logistics, *International Journal of Technological Forecasting and Social change*, 72(8), 1011–29.
- Realff, M.J., Ammons, J.C. and Newton, D.J. (2004) Robust Reverse Production System Design for Carpet Recycling, *IIE Transactions*, 36(8), 767–776.
- Rogers, D. S. and Tibben-Lembke, R. S. (1999) Going Backwards: Reverse Logistics Trends and Practices, Reverse Logistics Executive Council, Nevada: Centre for Logistics Management.
- Sage, A.P. (1977) Interpretive Structural Modeling: Methodology for Large-Scale Systems, McGraw-Hill, New York NY, 91–164.
- Sahyouni, K., Savaskan, R. C. and Daskin, M. S. (2007) A Facility Location Model for Bidirectional Flows, *Transportation Science*, 41(4), 484-498.

- Shaligram, P. and Mutha, A. (2009) Perspectives in Reverse Logistics: A Review, *Resources, Conservation and Recycling*, 53,175–182
- Sturgess, S. (1992) Specifying Replacement Parts: The Buyer Beware, *World Wastes*, 35(8), 50-4.
- Marien, E.J. (1998) Reverse Logistics as Competitive Strategy, *Supply Chain Management Review,* 34(2), 43-52.
- Meyer, H. (1999) Many Happy Returns, *The Journal of Business Strategy*, 20(4), 27-31.
- Murphy, P.R., Poist, R.F. and Braunschweig, C.D. (1995) Role and Relevance of Logistics to Corporate Environmentalism, *International Journal of Physical Distribution and Logistics Management,* 25(2), 5-19.
- Toensmeier, P.A. (1992) Remanufacture does more than Just save on Investment, *Modern Plastics*, 69(4), 77-9.
- Warfield, J. W. (1974) Developing Interconnected Matrices in Structural Modeling, *IEEE Transaction Systems Man and Cybernetics*, 4(1), 51–81.
- Wu, H. and Dunn, S.C. (1995) Environmentally Responsible Logistics Systems, *International Journal of Physical Distribution & Logistics Management,* 25(2), 20-39.