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ORIGINAL RESEARCH

Barriers to Reverse Logistics in the Computer Supply Chain Using Interpretive Structural Model

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Abstract *Researchers and practitioners are paying attention to reverse logistics (RL) issues due to growing environmental concerns, competitive advantage, promising financial potential, legislative reasons and social responsibility. This study aims to examine the contextual relationship and interactions among barriers to implement RL practices in the computer supply chain of Bangladesh. We applied Interpretive Structural Modeling (ISM) technique to diagnose significant barriers and proposed a hierarchical framework for investigating the relationships among them. We also used MICMAC (Matriced' Impacts Croisés Multiplication Appliquée á unClassement) analysis to classify the barriers based on the driving power and dependence among them. Seven barriers were finalized in the Bangladesh context based on the previous literature and professional feedback. The findings reveal that financial constraints along with the lack of interest from top management are the most influential barriers to RL for the computer supply chains of Bangladesh. The ISM-based analysis can provide managers with insights for developing strategies for implementing RL practices in the computer supply chain of Bangladesh.*

Keywords Barrier analysis · Bangladesh · Computer supply chain · ISM · Reverse logistics

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Introduction

Over the past few years, businesses are facing huge competition due to technological changes, innovation, and globalization (Sharma et al. 2011; Venkatesh et al. 2015). Environmental concerns are gaining more attention recently. Companies nowadays need to manage issues such as the flow of returns of products, confirm returns, product recalls, end product returns, the end of utilization returns as well as service returns (Ravi et al. 2005). Managers are facing pressure to adopt RL practices as a part of greening the supply chain.

RL encompasses the recuperation of items once they are never again wanted or can never again be utilized by consumers, with the aim of maximizing value from the recovered products through activities of recycling, reusing, remanufacturing (Paper and Rubio 2014). In this sense, RL starts when the traditional supply chain comes to a conclusion. Companies need to have attention into the reuse or recycling or remanufacturing of the discarded product, its parts, and materials (Sharma et al. 2011).

A good RL program has a competitive advantage and can be a "differentiator" providing a market advantage or competitive advantages, whereas lack of it may damage customer relations and seriously jeopardize brand image and reputation (Fleischmann et al. 2005; Hsu et al. 2016). Not only that the practices of RL have environmental benefits (Tibben-lembke and Rogers 2002). Some renowned companies of the world like Dell, Canon, General Motors, Xerox, Hewlett-Packard, and IBM have gained benefits through the implementation of RL (Ravi et al. 2005; Jayaraman and Luo 2003; Dhanda and Peters 2005; Grenchus and Johnson 2001).

The idea of RL has not yet been popularized in Bangladesh. There exist numerous barriers to RL implementation in Bangladesh. Computers are not manufactured in this country. People who are involved in computer business are either importers or retailers or assemblers or repairers. The availability of personal computers has started to increase during the last part of the eighties. The durability of a computer is 3–5 years. In Bangladesh, during the period 1980–1990, about 50% of total computers used was said to be rejected and the volume of e-waste from used computers up to the current time is estimated to be around 21,03,687 in numbers (Hossain et al. 2010). With the possibility of maximizing return, RL implementation in the computer supply chain of Bangladesh seems appropriate and meaningful. However, there are some significant barriers to RL in the Bangladesh context.

Barriers to RL were studied by some researchers (Sorker and Shukla 2009; Zhu et al. 2014; Prakash and Barua 2015; Rameezdeen et al. 2016; Bouzon et al. 2016a, b; Prakash and Barua 2016). Most of these works did not examine the relationship among barriers. This study fills this research gap by implementing and developing a hierarchical ISM framework.

ISM is a powerful tool for examining interactive relationships and interdependencies among selected barriers (Sushil 2012; Attri et al. 2013a; Giridhar 2015; Rick and Liu 2007). This study applied the ISM methodology in examining the interactions and contextual relationships among selected barriers, followed by a MICMAC analysis to categorize the barriers. This paper contributes to the RL literature in the following ways:

1. To identify the most influential barriers to RL implementation in the computer supply chain of Bangladesh.
2. To examine the interaction and convergent relationships among the selected RL barriers through the development of an ISM framework.

The remaining of the article is prepared as follows: The next section contains a survey of the literature on RL. Section 3 illustrates the steps for ISM-based framework development. Section 4 describes an example application of the ISM framework to a company. Section 5 clarifies the results and discussion. Section 6 concludes this paper.

Literature Review

Reverse Logistics

The idea of RL dated back a long time ago, but its knowledge has been expanded over time (Kokkinaki et al. 2001; Ravi 2014). The term like “reverse distribution channel” for recycling already exists in the literature from the 1970s (Guiltinan and Nwokoye 1975; Ginter and Starling 1978). The term “reverse logistics” was first introduced by Stock (1992). Rogers and Tibben-Lembke (1998) defined RL as “The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.”

Related Studies on Reverse Logistics

Over the past few years, closed-loop supply chains and RL have enticed the attention to industrial managers and researchers (Fleischmann et al. 2000; Dekker et al. 2004; Prahinski and Kocabasoglu 2006; Rubio et al. 2008; Flapper et al. 2012; Nikolaou et al. 2013). Researchers and practitioners are now paying attention to RL-related issues due to growing environmental concerns, competitive advantage, promising financial potential, legislative reasons and social responsibility. As a result, the scope of RL has been widening (Sasikumar and Kannan 2008).

Huscroft et al. (2014) investigated the complex relationship among factors affecting RL for the pharmaceuticals industry in India. Taylor et al. (2014) examined barriers to RL practices in the manufacturing industries of China. Bouzon et al. (2016a) evaluated barriers to RL implementation in the Brazilian context using gray decision-making approach. Ponce-Cueto et al. (2010) studied and proposed a design for RL for recovering mobile phones in Spain including collection and recycling system. Wang et al. (2014) assessed economies of scale for reusing lithium-ion battery in the USA. Çetin et al. (2014) researched on RL network infrastructure of a third party logistics (3PL) under supply uncertainty.

Kumar and Putnam (2008) explored RL opportunities and strategies in different industries. Ngadiman et al. (2016) detailed RL in food and beverage industries in Malaysia. Bing et al. (2014) proposed a framework for infrastructure development for RL network for household plastic waste to make the network more sustainable and energy efficient. Prakash and Barua (2015) investigated barriers to RL in the Indian electronics industry. Kara and Onut (2010) designed a reverse supply chain network for paper recycling. Zhang et al. (2011) proposed a framework to develop existing systems of automotive remanufacturing industry in the context of China. Sharma et al. (2011) evaluated RL implementing barriers in the context of India. Some other examples of RL studies are summed up in Table 1.

Barriers to Reverse Logistics

RL is gaining momentum across the globe. Despite the importance of RL for environmental protection as well as environmental sustainability, practicing the needed RL practices and approaches is constrained by several barriers. According to Khor et al. (2016), companies are unwilling to implement RL for the reason that its economic benefits are ambiguous compared to forwarding logistics. Nagel and Meyer (1999) mentioned that RL requires substantial investments. We identified barriers based on the previous extant literature. Some of the barriers, among others, are lack of interest from top management (Ravi et al. 2005; Sharma et al. 2011; Abdulrahman et al. 2014), lack of appropriate company policies (Starostka-patyk et al. 2013; Prakash and Barua 2015; Laribi and Dhouib 2016), information gap and lack of technological infrastructure (Sharma et al. 2011, Starostka-patyk et al. 2013), financial constrains (Rameezdeen et al. 2016). A summary of the identified barriers is registered in Table 9 in Appendix.

RL research in the context of developing countries is lacking in the literature. To the best of our knowledge, barriers to RL in the computer supply chain of Bangladesh have not yet been studied. This study fills this research gap.

ISM-Based Framework Development

ISM was introduced by John N. Warfield in 1973 (Sharma et al. 2011; Debata et al. 2013; Verma 2014; Poduval and Pramod 2015). It is an interactive approach where multi-faceted factors are constructed into a powerful well-organized model. ISM can include multiple factors in a structural way (Soti et al. 2011; Talib et al. 2011; Shibin et al. 2016; Ertas et al. 2016). The purpose behind applying ISM approach is to get a collective understanding of complex relationships among barriers by imposing order as well as direction (Jindal and Sangwan 2011; Jakhar 2014; Mangla et al. 2012).

However, there are some limitations to ISM approach. ISM methodology can deal with what and how theory is built but fails to give any logical solution to why the theory is built in that way. It cannot consider transitive linkage in the digraph. Such limitations lead to the development of total interpretive structural model (TISM) (Sushil 2012; Mohanty and Shankar 2017; Sindhwani et al. 2017). TISM determines how the elements are connected and why they are connected that way. Transitive linkages are well depicted in the digraph (Rajesh 2017; Jena et al. 2017). This research uses ISM method to assess the barriers to RL in the computer supply chain of Bangladesh. The authors of this paper recommend that future researchers explore this research using TISM and compare results.

The opinion of experts who have practical experience is encouraged for the ISM approach (Govindan et al. 2013), though Jindal and Sangwan (2011) have applied ISM only based on literature review. The steps for establishing the ISM framework can be visualized in Fig. 1. The steps are explained below (Attri et al. 2013a):

Table 1 Some examples of RL studies

Source	Contributions	Method/approach used
Agrawal et al. (2015)	Reviewed literature on RL	Systematic literature review
Ongondo et al. (2011)	Reviewed electrical and electronics waste management	Systematic literature review
Abdulrahman et al. (2014)	Examined barriers to RL in the Chinese manufacturing context	Empirical
Bernon et al. (2010)	Developed a conceptual framework for implementing RL in the retail business	Empirical and literature review
Prakash and Barua (2016)	Prioritized RL barriers in the context of Indian electronics industry	Fuzzy-based MCDA
Govindan et al. (2012)	Evaluated the third party RL service provider for a tire manufacturing company	ISM
Raci and Shankar (2005)	Examined RL barriers for Indian automobile industry	Literature review and experts' opinions
Jindal and Sangwan (2011)	Evaluated barriers to RL implementation in Indian industry	Literature review

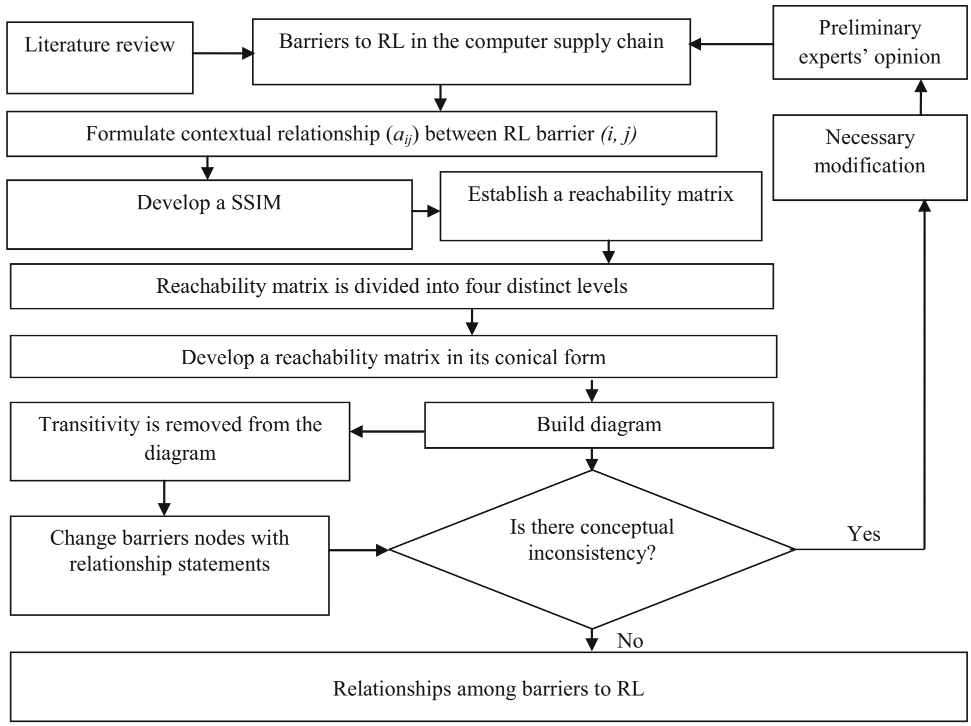


Fig. 1 Steps involved in ISM-based framework development (modified from Poduval and Pramod 2015)

Step 1 The barriers to RL practices are listed through the literature review and industrial experts' feedback.

Step 2 A matrix of the contextual relationship and interaction among a set of listed RL barriers is established.

Step 3 A structural self-interaction matrix (SSIM) of RL barriers is built; this denotes a pairwise relationship among barriers to RL practices in the computer supply chain. For making SSIM, following notations are utilized to show the contextual relationship among RL barrier (i, j).

- V means that the barrier in the row listed i will facilitate to reach the barrier in the column listed j;
- A means that the barrier i can be obtained by barrier j;
- X means that the listed barrier i and listed barrier j will help to reach each other;
- O means that the listed barrier i in row and listed barriers j in column are unconnected.

Step 4 From the SSIM, a reachability matrix is built and then a transitive relationship is checked (i.e., if a barrier A is linked to barrier B and barrier B is linked to barrier C, then barrier A is linked to barrier C). For reachability matrix formulation, following binary digit is utilized (i.e., for V, a_{ij} will be 1, whereas a_{ji} will be 0, for X, if a_{ij} is 1, then a_{ji} will be 1, for A, if a_{ij} is 0, then a_{ji} will be 1, for O, if a_{ij} is 0, then a_{ji} will be 0.)

Step 5 The final reachability matrix is divided into four levels.

Step 6 A directed graph is established based on the final reachability matrix, and then the transitive relations are checked.

Step 7 The obtained digraph is converted to an ISM model.

Step 8 Finally, the obtained ISM model in Step 7 is checked for logical inconsistencies, and if any, the corrections are made.

An Example Application

The proposed framework was applied to "ABC" company in Bangladesh. This company started their business in 1993. This company provides the nation full IT hardware and software support. It has 30 branches and service centers across the country. "ABC" IT company also provides various global-branded computer like Apple, Dell, HP, Intel, Microsoft and more nationwide. This company is well established in the country. Recently, the company aims to minimize electronic waste and implement RL in the computer supply chain. Therefore, "ABC" IT Company wants to evaluate RL barrier. Experts from five departments namely supply chain manager, IT specialist, logistics manager, customer manager, sells executives from the company were selected to identify and evaluate barriers to RL. Seven barriers were selected from the experts' feedback. Then, the ISM methodology was applied for examining interrelationship among the selected RL barriers, which are detailed below:

Table 2 Selected RL barriers with identification code

Identification code	Barriers
RB1	Lack of interest from top management
RB2	Company policies
RB3	Information gap and lack of technological infrastructure
RB4	Financial constraints
RB5	Uncertainty of demand and return
RB6	Lack of facility for marketing of remanufactured product
RB7	Lack of interest in investment

Identifying the Most Common RL Barriers in the Computer Supply Chain of Bangladesh

Based on the summary of expert opinion (Table 10 in Appendix), seven significant RL barriers were finalized as explained below.

- Lack of interest from top management
  Top management is unwilling and less interested in applying RL. To provide a clear vision and value to RL, efficient and dynamic leadership is a must. Low commitment is found to be the most important management barrier.
- Company policies
  Company policies act as significant barriers to RL. Bangladeshi companies are lacking appropriate polices to implement RL in place.
- Information gap and lack of technological infrastructure
  Information and technological capacity are found to be essential for tracking and tracing the product return.
- Financial constraints
  Financial constraints can be a significant barrier to RL. High costs were associated with the implementation of RL. More funds are required for adequate information and technology systems for enabling RL-based practices.
- Uncertainty of demand and return
  Stochastic demand and return have been identified as a barrier to RL in the Bangladeshi computer supply chain.
- Lack of facility for marketing of remanufactured product
  Remanufactured products are hard to market due to competition from new products. Due to the uncertainty of demand and return, the pricing issue of remanufactured products is a complex and challenging task as opined by industry experts.
- Lack of interest in investment
  Due to high start-up cost and slow return rate, RL is getting less investment compared to forward supply chain and logistics sectors in the computer sector.

The selected barriers are codenamed as shown in Table 2.

Development of Self-interaction Matrix

The SSIM is formulated based on experts' opinion. The process is given in step 2 (Ravi et al. 2005; Charan et al. 2008; Khalid et al. 2016). The obtained SSIM is given in Table 3.

Establishment of Reachability Matrix

This section presents the initial reachability matrix, which is established from the SSIM. The initial reachability matrix is given in Table 4. In Table 5, the final reachability matrix is shown which is formulated by checking transitivity. In Table 5, some cells carry "0" values which are replaced with "1" by taking into account the transitivity rule. The replacing value is indicated by "*" besides the value 1. The driving power and dependence of each barrier are evaluated and achieved from the final

Table 3 Structural self-interaction matrix (SSIM)

Barriers *i*	Barriers *j*						
	RB1	RB2	RB3	RB4	RB5	RB6	RB7
RB1	X	V	V	A	V	V	V
RB2		X	V	A	A	A	X
RB3			X	A	A	A	V
RB4				X	V	V	V
RB5					X	X	V
RB6						X	V
RB7							X

Table 4 Initial reachability matrix

Barriers *i*	Barriers *j*						
	RB1	RB2	RB3	RB4	RB5	RB6	RB7
RB1	1	1	1	0	1	1	1
RB2	0	1	1	0	0	0	1
RB3	0	0	1	0	0	0	1
RB4	1	1	1	1	1	1	1
RB5	0	1	1	0	1	1	1
RB6	0	1	1	0	1	1	1
RB7	0	1	0	0	0	0	1

Table 5 Final reachability matrix

Barriers *i*	Barriers *j*							
	RB1	RB2	RB3	RB4	RB5	RB6	RB7	Driving power
RB1	1	1	1	0	1	1	1	6
RB2	0	1	1	0	0	0	1	3
RB3	0	1*	1	0	0	0	1	3
RB4	1	1	1	1	1	1	1	7
RB5	0	1	1	0	1	1	1	5
RB6	0	1	1	0	1	1	1	5
RB7	0	1	1*	0	0	0	1	3
Dependence	2	7	7	1	4	4	7	32

*Values obtained after considering transitivity

reachability matrix. In MICMAC analysis, the obtained driving and dependence power is used. The driving power means the strength of the variable that can drive other variables. The dependence indicates the dependency on the other variable, and it is easily influenced by the driven variable.

Level Partitions

Level partitioning is performed by finding the reachability set, antecedent set, and interaction set (Khalid et al. 2016). The reachability set is constructed of the barrier to RL itself for a particular barrier and for all those barriers which it may assist reach. The antecedent set for a specific barrier to RL comprises the barrier itself and those barriers which may alleviate them. The intersection of these two types of RL barriers was also derived for all RL barriers. Those barriers will be at the top level (level I) in the hierarchy of the ISM framework whose reachability set and the antecedent set are alike. The levels are determined from iteration process (see Table 6). Once we have obtained level I, we tried to find the next level by omitting the level I. The level II would be positioned in second from the top. Similarly, other levels were evaluated (Table 7).

Conical Matrix

Conical Matrix is developed by clustering together the variables in the same level, across rows and columns of the final reachability matrix (Attri et al. 2013a, b). It is similar to the reachability matrix with the exception that the variables in the conical matrix are positioned along the rows and columns based on their levels. The relationships between the variables are similar to the reachability matrix. The conical matrix for these selected barriers is given in Table 8.

Building Digraph

The initial digraph is built from the conical form of reachability matrix, including transitive links. It is a set of nodes representing the barriers in the conical matrix, which are interlinked together based on their relationship in the matrix and all the links are represented as arrows indicating the direction from one node to the other. The final digraph

Table 6 Levels of barriers to RL

Barriers	Reachability set	Antecedent set	Intersection set	Level
Iteration-1				
RB2	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB3	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB7	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB5	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	
RB6	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	
RB1	RB1	RB1, RB4	RB1	
RB4	RB4	RB4	RB4	
Iteration-2				
RB5	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	II
RB6	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	II
RB1	RB1	RB1, RB4	RB1	
RB4	RB4	RB4	RB4	
Iteration-3				
RB1	RB1	RB1, RB4	RB1	III
RB4	RB4	RB4	RB4	
Iteration-4				
RB4	RB4	RB4	RB4	IV

Table 7 Final levels of barriers to RL

Barriers	Reachability set	Antecedent set	Intersection set	Level
RB2	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB3	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB7	RB2, RB3, RB7	RB1, RB2, RB3, RB4, RB5, RB6, RB7	RB2, RB3, RB7	I
RB5	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	II
RB6	RB5, RB6	RB1, RB4, RB5, RB6	RB5, RB6	II
RB1	RB1	RB1, RB4	RB1	III
RB4	RB4	RB4	RB4	IV

is developed by removing the transitivity links. The final digraph is shown in Fig. 2.

Development of the ISM Model

The final digraph is converted to an ISM framework by means of replacing the nodes of the variables. The proposed ISM framework for barriers to RL in the computer supply chain is established, which is shown in Fig. 3.

MICMAC Analysis of Obtained Results

The ISM only helps to map inter-relationships among the variables. The MICMAC analysis determines the degree of influence a particular variable holds over others and vice versa (Purohit et al. 2016). MICMAC analyzes the strength or weakness of driving power and dependence of the variables in question.

MICMAC analysis was used here to categorize all the barriers identified into four types of boundaries namely, independent barriers, autonomous barriers, linkage barriers and dependent barriers based on their driving and dependence power.

Cluster A Autonomous barriers indicate that they are weak in both driving power and dependence. In this research, no autonomous barrier was found. This indicates that implementing RL practices in the computer supply chain is free from autonomous barriers. In addition, managers should give proper attention to other cluster of barriers. Due to weak driving power and dependence,

Table 8 Conical matrix

Barriers *i*	Barriers *j*						
	RB2	RB3	RB7	RB5	RB6	RB1	RB4
RB2	1	1	1	0	0	0	0
RB3	1*	1	1	0	0	0	0
RB7	1	1*	1	0	0	0	0
RB5	1	1	1	1	1	0	0
RB6	1	1	1	1	1	0	0
RB1	1	1	1	1	1	1	0
RB4	1	1	1	1	1	1	1

*Values obtained after considering transitivity

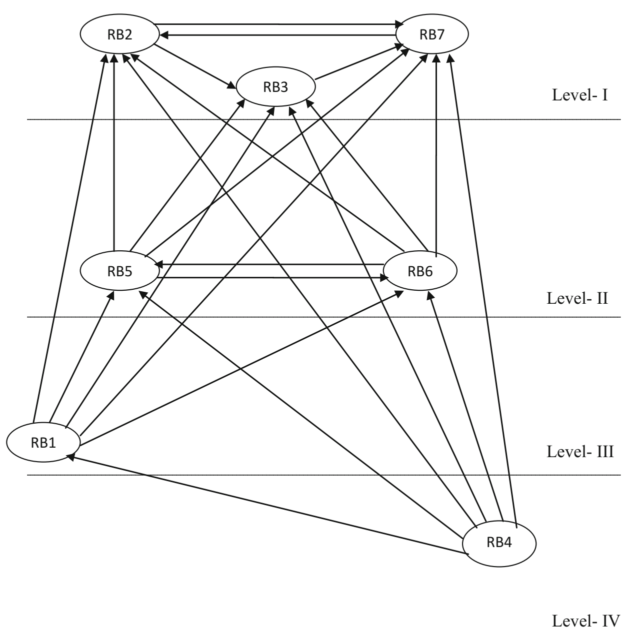


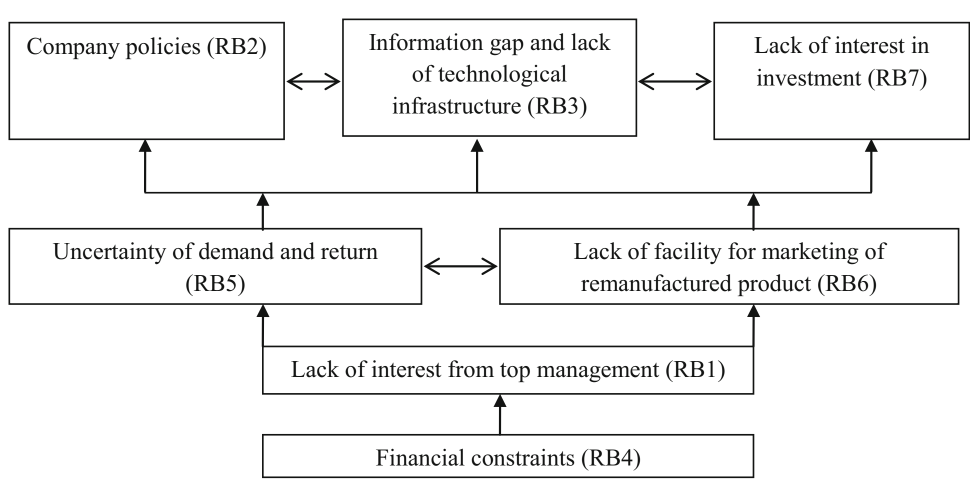
Fig. 2 Final digraph

autonomous barriers do not have significant effect on RL practices. Therefore, managers do not need to pay more attention to autonomous RL barriers.

Cluster B Dependent barriers are those barriers which have low and weak driving power but high and strong dependence. Dependent barriers are influenced by independent or linkage barriers. Here, company policies (RB2), information gap and lack of technological infrastructure (RB3) and lack of interest in investment (RB7) have been found as dependent barriers. These barriers are strongly dependent on the barriers present in Cluster D. Therefore, industrial mangers should give proper attention to the barriers present in Cluster D.

Cluster C Linkage barriers indicate that these are strong in both driving power and dependence. Linkage barriers are unstable in nature. Any operations on these barriers have a reaction effect on the other barriers as well as on themselves. The uncertainty of demand and return (RB5) and marketing of remanufactured product (RB6) were identified as linkage barriers.

Fig. 3 The proposed ISM framework for barriers to RL in the computer supply chain



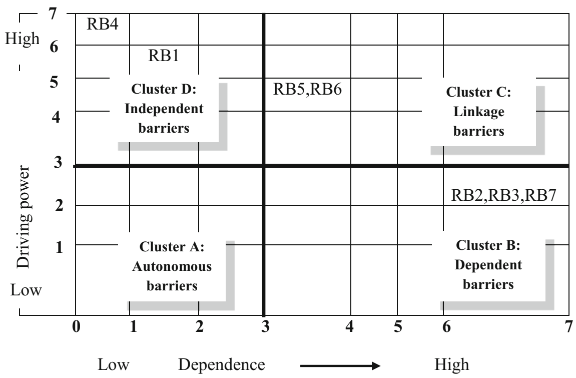


Fig. 4 Driving power and dependency diagram

Cluster D Independent barriers indicate that these have high and strong driving power and low and weak dependence (Ravi et al. 2005). Independent barriers will affect others which are dependent on them. In this research, lack of interest from top management (RB1) and financial constraints (RB4) have been found as independent barriers. Figure 4 gives the obtained values of driving power and dependence power with cluster region. These independent barriers can potentially hamper the RL implementation process. Decision makers should pay careful attention to these barriers.

Results and Discussion

Understanding the levels of barriers in the ISM framework is important for successful implementation of RL. Financial constraints (RB4) were found to be the most crucial barrier among all the selected barriers. Financial constraints (RB4) showed high driving and low dependence power. Therefore, this barrier was leveled at the bottom of the hierarchical structure of the ISM framework. Financial constraints (RB4) along with lack of interest from top management (RB1) was positioned in level III and could play the role of key variables for implementation of RL in the computer supply chain of Bangladesh. These two barriers need to be addressed in the first place to implement RL.

The next two barriers placed in the level II are the uncertainty of demand and return (RB5) and lack of facility for marketing of remanufactured product (RB6). These barriers may hinder the implementation of RL system. Finally, the top level reveals that three barriers company policies (RB2), information gap and lack of technological infrastructure (RB3) and lack of interest in investment (RB7) are found as least influential barriers as compared to other barriers that needs least attention to industrial manager to implement RL in the computer supply chains. The MICMAC analysis was useful for providing more insights about the nature of barriers. In the MICMAC analysis, the barriers have been examined on the four boundaries based on driving power and dependence. We found the uncertainty of demand and return (RB5) and marketing of remanufactured product (RB6) as linkage category. These two linkage barriers are linking between dependent and independent barriers and are positioned in the middle of the ISM-based hierarchy model. There was no autonomous barrier in the system. The absence of autonomous barrier indicates that all the considered barriers play a significant role during adaptation of RL practices in the computer supply chain. There are two barriers (RB1, RB4) found under the independent barrier. These barriers should be given utmost attention to implement RL practices because the independent barriers have high and strong driving power and low and weak dependence power. There are three barriers (RB2, RB3, RB7) found under dependent barriers. These barriers are generated because of the independent drivers as dependent barrier have high and strong dependence and low and weak driving power. If the barriers with high driving powers can be eradicated, then these barriers with high dependence will not be in place. The proposed ISM model in this research work will help decision makers have a clear understanding about the barriers obstructing successful implementation of RL in the computer supply chain of Bangladesh.

Conclusions, Managerial Implications and Direction for Future Research

This paper aimed to examine the relationships among barriers to RL in the computer supply chain of Bangladesh. To achieve this aim, an ISM-based hierarchical framework was proposed to explore the relationships among the barriers. This paper also performed MICMC analysis of the barriers to categorize them based on their driving power and dependence.

The findings show that the financial constraints are at the bottom of the hierarchy, whereas company policies, information gap and lack of technological infrastructure and lack of interest in investment are simultaneously at the top of the hierarchy of the proposed ISM model. It means "financial constraints" will impose hurdles in implementing RL practices because of information gap and lack of technological infrastructure for RL and thus will create unfavorable company policy which will lead to lack of interest in investment. So, financial constraints should be given utmost attention. The Bangladeshi computer supply chain decision makers may implement RL practices in their organizations by eradicating the mentioned barriers successfully and make a profit by improving social and environmental sustainability.

This research will assist industrial mangers to have an understanding of barriers to RL. We propose some practical implications of this research as follows:

- *Policy setting to implement RL practices* Setting strategy to RL implementation is important for the computer supply chain. However, understanding the barriers is a prerequisite to RL implementation. This research can guide managers on such aspect by recognizing the significant barriers.
- *Motivating managers to RL implementation* Top management support can act as a key driving force for RL implementation. This research may motivate top management for RL practices by realizing the actual nature of each barrier.
- *Building awareness on sustainability* Companies should adopt RL practices in supply chains to achieve environmental sustainability. RL practices can reduce the energy consumptions, waste generation and can help gain competitive advantages in the market. This research may create awareness among stakeholders for building a sustainable computer supply chain in Bangladesh.

This research has some limitations. The ISM is highly dependent on the judgment of experts which may be biased. Some significant barriers may be overlooked by experts. Also, the ISM only explains the nodes in a digraph. Further research can be conducted to refine the model using total interpretive structural modeling (TISM), which explains both nodes and links in a digraph. TISM can help for a better conceptualization of related factors and the theory building (Singh and Sushil 2013; Dubey et al. 2015; Sushil 2016, 2017).

Besides refining the ISM framework using TISM, it may be worth exploring to investigate barriers to RL with an emphasis on logistics and supply chain disruptions. Examining disruptions in forward logistics and supply chains have become a popular topic of discussion over some years (Paul et al. 2014; 2017; Ali and Nakade 2017; Ali et al. 2018). However, few researchers have explored RL with a focus on disruptions (Hatefi and Jolai 2014, 2015). It may be exciting to investigate RL barriers in the computer supply chain considering supply disruptions of used products or demand disruptions of the remanufactured/recycled products.

Compliance with Ethical Standards

Conflict of interest No potential conflict of interest was reported by the authors.

Appendix

See Tables 9 and 10.

Table 9 Some articles with RL barriers

Barriers	Authors and year										
	(Sharma et al. 2011)	(Lehmann 2015)	(Jindal and Sangwan 2011)	(Laribi and Dhouib 2016)	(Rameezdeen et al. 2016)	(Ravi et al. 2005)	(Abdulrahman et al. 2014)	(Starostka-patyk et al. 2013)	(Garg et al. 2016)	(Zhu et al. 2014)	(Prakash and Barua 2015)
Absence of knowledge about reverse logistics	√		√	√	√	√		√			√
Lack of interest from top management	√	√	√	√		√	√	√	√		√
Absence of proper performance management facility	√						√				
Company policies	√	√	√	√		√	√	√	√		√
Lack of proper strategic planning for reverse logistics			√	√		√	√	√	√		√
No interest to modify existing process		√	√	√		√		√	√		√
Competitive issues				√			√				
Lack of interest in investment		√					√				
Difficulties in marketing recycled product across countries							√				
Personal resources	√						√				√
Lack of skilled human resource		√	√	√		√	√	√	√		√
Information gap and lack of technological infrastructure	√	√	√	√		√		√	√		√
Lack of appropriate performance metrics			√	√		√		√			√
Lack of facility to shared best practices		√					√				√
Financial constraints	√	√	√	√	√	√	√	√	√	√	√
Lack of economic benefits			√	√				√			√
Lack of economy of scale			√					√			√
Administrative and financial burden of tax	√						√			√	
Legal Issues	√	√	√	√			√	√	√		√

Table 9 continued

Barriers	Authors and year										
	(Sharma et al. 2011)	(Lehmann 2015)	(Jindal and Sangwan 2011)	(Laribi and Dhouib 2016)	(Rameezdeen et al. 2016)	(Ravi et al. 2005)	(Abdulrahman et al. 2014)	(Starostka-patyk et al. 2013)	(Garg et al. 2016)	(Zhu et al. 2014)	(Prakash and Barua 2015)
Broad informal waste sector			√	√			√	√			√
Lack of supportive economy policies			√	√				√		√	√
Perception about the low quality of recycled products	√	√		√		√				√	√
Uncertainty of demand and return			√	√				√		√	√
Lack of interest in supply chain partners	√	√	√	√		√	√	√			√
Lack of facility for marketing of remanufactured product			√					√	√		√
Lack of facility to collect and store the products from end customer				√	√		√				√
Limited forecasting and planning	√						√				√

Table 10 Experts' feedback on barriers to RL

Barriers	Supply chain manager	IT specialist	Logistics manager	Customer manager	Sells executives
Lack of interest from top management	√	√	√	√	√
Company policies	√	X	X	√	√
Lack of skilled human resources	√	√	X	X	X
Information gap and lack of technological infrastructure	√	√	√	X	X
Financial constraints	√	√	X	√	X
Uncertainty of demand and return	√	√	√	X	X
Limited forecasting and planning	√	X	X	X	√
Lack of economic benefits	X	√	√	X	X
Administrative and financial burden of tax	X	√	X	X	X
Legal issues	X	√	X	X	√
Lack of economy of scale	X	√	X	X	√
Perception about the low quality of recycled products	X	√	√	X	X
Lack of facility for marketing of remanufactured product	X	√	√	X	√
Lack of interest in supply chain partners	X	√	X	X	√
Difficulties in marketing recycled product across countries	X	√	X	X	√
No interest to modify existing process	X	√	X	X	X
Lack of interest in investment	X	√	√	√	X

Table 10 continued

Barriers	Supply chain manager	IT specialist	Logistics manager	Customer manager	Sells executives
Lack of facility to shared best practices	X	X	√	X	√
Competitive issues	X	X	X	√	X
Lack of facility to collect and store the products from end customer	X	X	X	√	X
Broad informal waste sector	X	X	X	√	X
Lack of appropriate performance metrics	X	X	X	√	X
Lack of strategic planning	X	X	X	X	√

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Key Questions

1. What are the significant barriers to reverse logistics implementation in the computer supply chain of Bangladesh?
2. What are the contextual relationships among the significant barriers to reverse logistics implementation?

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