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REVERSE LOGISTICS AND SUPPLY CHAINS: A STRUCTURAL EQUATION MODELING INVESTIGATION

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The process of transforming raw materials into final products and delivering those products to customers, known as supply chain (SC) management, is becoming increasingly complex. Most of SC management research has been concerned with procurement and production. However, recently, it has become increasingly important to extend SC issues beyond the point of sale to reverse logistic (RL) where the flow of returned products is processed from the customers back to the collection centers for repair, remanufacturing or disposal. We propose a conceptual framework and empirically investigate the relationship between the key factors in RL and SC performance measurement using a series of hypotheses. Structural equation modeling (SEM) is used to test the hypotheses. The results reveal insightful information about the effects of RL factors on the SC performance.

Keywords: supply chain performance; reverse logistic; structural equation modeling

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1. INTRODUCTION

Competition in the manufacturing environment has shifted from simple and uni-directional supply chains (SCs) to sophisticated and bi-directional SCs and only firms with agile and versatile SCs can sustain an effective competitive edge (Ohara, 2002; Chan et al., 2003; Li et al., 2006; Lin et al., 2006; Vonderembse et al., 2006). Most of SC management research has been concerned with procurement and production. However, recently, it has become increasingly important to extend SC issues beyond the point of sale to reverse logistic (RL) and the product utilization phase (e.g., service, maintenance and others) and to the end-of-life phase (e.g., product recovery, refurbishing or recycling) (Schultmann et al., 2006).

A forward SC is concerned with the flow of materials, products and information from suppliers through the production and distribution processes to the final users (Schary, 2001). A RL is 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 or creating value or for proper disposal (Rogers and Tibben-Lembke, 1999, p. 2). The majority of the SC performance measurement studies in the literature are devoted to forward logistics performance measurement. However, a comprehensive SC performance management system should collectively consider the performance of the RL and the performance of the SC in an integrated framework.

In spite of the fact that RL happens frequently for many reasons such as the rise of electronic retailing, the increase in catalogue purchases, more self-service stores, and a lower tolerance among buyers for imperfection, few companies understand the effects of RL on their SC and know how to deal with it properly (Stock et al., 2002). One reason could be because RL operations are considered significantly more complex than a traditional manufacturing SC due to uncertainty of return timing, quantities of return, and the quality of used products returned by customers (Fleischmann et al., 1997; Tibben-Lembke and Rogers, 2002).

Prahinski and Kocabasoglu (2006) reviewed the literature and showed that most research in RL has relied on case studies and optimization models. They proposed using survey-based research methods to explain the predominant issues in RL and developed 10 research propositions to be studied using empirical research methods. Their first proposition was to study the effects of RL on operational performance. They argue that although the relationship between RL and organizational performance is implied in several studies (Guintini and Andel, 1995; Minahan, 1998; Autry et al., 2001; Trebilcock, 2002), the direct impact of RL on the SC performance has not been investigated through empirical studies.

In this study, we present a comprehensive conceptual framework for measuring the performance of the SC components including the RL and SC. A suitable performance evaluation model of the SC is selected to further investigate the relationship between the RL and the SC using factor analysis and SEM. We empirically investigate the relationship between the key factors in RL and SC performance measurement through a series of hypotheses. Structural equation modeling (SEM) is used to test the accuracy and the power of the hypotheses. The data used in this research are collected from a large number of respondents from academia and industry. The results reveal insightful information into the effects of RL factors on the SC performance.

The remainder of this paper is organized as follows. In Section 2, we review the relevant SC performance management literature. In Section 3, we develop the conceptual model for RL and SC performance measurement and formulate the main and subsidiary hypotheses considered in this research. In Section 4, we test the hypotheses and present the results of the fitness test and statistical analysis. Finally, we conclude the paper in Section 5 with our conclusion and future research directions.

2. LITERATURE REVIEW

Dowlatshahi (2000) categorized articles related to RL by topic into five groups: concept of RL (De Brito and Dekker, 2004), quantitative models (Fleischmann et al. 1997; Ravi and Shankar, 2005; Schultmann et al., 2006), studies of logistics (Pokharel and Mutha, 2009), company profiles (Thierry et al., 1995; Kim et al., 2012), and RL application (Govindan and Murugesan, 2011). Table 1 presents a selected group of SC and RL performance measurement studies in the literature.

Table 1. Selected supply chain and reverse logistic performance measurement literature

Supply chain (SC) performance	
Researcher(s)	**Description: Theme/aim/methodology/application**
Cadden et al. (2013)	Conceptual framework.
Jraisat and Sawalha (2013)	Conceptual framework/explore the factors of quality control (QC) among key members of a supply chain - five firms in the fresh fruit and vegetable supply chain in Jordan.
Chang et al. (2013)	The theoretical/discuss the relationship between e-procurement and supply chain performance/108 Taiwanese enterprises.
Bai et al. (2012)	SCOR model/to introduce a methodology to help evaluate, select, and monitor sustainable supply chain performance measurement.
Gligor and Holcomb (2012)	Conceptual framework/Understanding the role of logistics capabilities in achieving supply chain agility/a systematic literature review.
Kim et al. (2012)	Framework/to develop a framework for assessing the comprehensive performance of supply chain partnership/self-assessment dimensions and approaches of the business excellence model (EFQM).
Giannakis (2011)	Framework/ to explore the utility of the manufacturing biased supply chain operations reference (SCOR) tool in services and develops a reference model for use in service organizations.
Reverse logistic (RL) performance	
Mondragon et al. (2011)	Measures for auditing performance and integration in closed-loop supply chains.
Erol et al. (2010)	Exploring reverse supply chain management practices/ Top-500 Industrial Enterprises List of The Assembly of the Istanbul Chamber of Industry.

Pokharel and Mutha (2009) investigated the development in research and practice in RL through content analysis of the published literature. They found that research and practice in RL are focused on all facets of RL - from collection of used products and their processing to the outputs of processing (i.e., recycled materials, spare parts, remanufactured products and waste material disposal). They also showed that mathematical modeling in RL research is mainly focused on deterministic methods and there is limited research in stochastic methods.

3. CONCEPTUAL MODEL

In this Section we propose a comprehensive conceptual model which includes a set of criteria for the RL and SC performance measurement. SEM is used to analyze this conceptual model by constructing a hypothetical structure based on the literature review.

3.1 Supply chain performance evaluation model

Estampe et al. (2013) analyzed and compared 16 different models according to eight criteria: decision level, type of flows, level of SC maturity, type of benchmarking, contextualization, quality factors, Human capital, and Sustainability. They showed that some models are oriented toward an internal analysis of companies which mainly incorporate organizational performance measurements (i.e., ASLOG,ABC, SCM/SME) while others have a sweeping overview of the SC, viewing it as something ranging from suppliers' suppliers to customers' customers and incorporating the financial, organizational and societal aspects of performance (i.e., SCOR, WCL, SCALE). We chose the SCOR as a SC performance evaluation model in this study because of its expanded overview of the SC and its compatibility with organizational maturity as well as its implementation of several concepts such as continuous improvements, benchmarking and total quality management which is used in our case study (Stewart, 1997; Giannakis, 2011; Bai et al., 2012).

3.2 Reverse logistic performance metrics

A wide range of models have been proposed for RL performance measurement. These models generally use a number of criteria and indicators in a specific domain such as IT Infrastructure or resource commitment. Nizaroyani (2010) carried out field studies to investigate how companies measure and manage performance of their RL operations. One of the key questions in this study was to find out whether there are differences between performance measurement in forward SCs and in RLs. Nizaroyani (2010) proposed a three-level framework for measuring the performance of SCs and RLs. The proposed framework allows the decision makers to identify meaningful performance attributes and performance metrics through a systematic view of the strategic objectives and characteristics of the whole RL and SC. A set of performance attributes is proposed in this study to address all the issues which might govern RL and SC performance management. Nizaroyani (2010) also discussed the need for testing these performance attributes in case studies to assure their applicability and usefulness in real world SC performance measurement problems. In this study, we use the method proposed by Nizaroyani (2010) to gather the relevant performance measurement attributes and further select the most useful indicators for inclusion in our RL and SC performance measurement model.

3.3 Structural equation modeling

SEM refers to sets of statistical methods (i.e., path analysis, confirmatory factor analysis, structural regression models, latent change models) used for analyzing multivariate data. SEM consists of two components: a measurement model and a structural model. The measurement model considers the relationship between the latent factors and the observed variables in the questionnaire items while the structural model represents the path direction and strengths of the relationships between the latent variables. The latter is used to evaluate the hypothesized relationships among the latent factors (Hair et al., 2009). SEM has been widely used in a number of disciplines. Table 2 presents some recent applications of SEM in SC management.

In this case study, we use SEM to validate the primary model for the RL and SC performance measurement and to study the cause and effect between the RL and SC. In the first step, we apply SEM to determine how much the observed variables explain the relevant latent variables in the RL and SC. In the second step, we test the hypotheses in the validated model developed in the first step for measuring the performance of the RL and SC.

Table 2. Recent applications of SEM in the supply chain field

Researcher(s)	Field application
Zhao et al. (2013)	Conceptual framework to Empirically explore the relationships among supply chain risks (SCRs), supply chain integration (SCI), and company performance in a global context in manufacturing plants in ten countries and three representative industries.
Barnes and Liao (2012)	The effect of individual, network, and collaborative competencies on the supply chain management system.
Fayard et al. (2012)	Effect of internal cost management, information systems integration, and absorptive capacity on inter-organizational cost management in supply chains.
Giovanni et al. (2012)	Covariance versus component-based estimations of performance in green supply chain management.
Green et al. (2012)	Aligning marketing strategies throughout the supply chain to enhance performance.
Huo (2012)	The impact of supply chain integration on company performance: an organizational capability perspective in 617 companies in China.
Prajogo et al. (2012)	The effects of different aspects of ISO 9000 implementation on key supply chain management practices and operational performance in 321 middle and senior managers of ISO 9001 certified firms in Australia.
Ramanathan and Gunasekaran (2014)	Supply chain collaboration: Impact of success in long-term partnerships.
Teller et al. (2012)	Improving the execution of supply chain management in organization.
Cao and Zhang (2011)	Supply chain collaboration: Impact on collaborative advantage and firm performance.
Merschmann and Thonemann (2011)	Supply chain flexibility, uncertainty and firm performance.
Ramanathan and Muyldermans (2011)	Identifying the underlying structure of demand during promotions.
Su and Yang (2010)	Why are enterprise resources planning systems indispensable to supply chain management?
Lin et al. (2005)	The effect of supply chain quality management on organizational performance.

3.4 Hypotheses

The literature review has identified several criteria and sub-criteria that have direct effects on the performance of the RL and SC. Table 3 presents the latent and the observed variables related to the RL and SC performance found in the SC performance management literature.

Table 3. Latent and observed variables related to reverse logistic and supply chain performance models

Latent variables	Observed variables	Reference	Description
Supply chain performance (SC)	Reliability (Y1)	Stewart (1997); Giannakis (2011); Bai et al. (2012); Estampe et al. (2013)	The ability to perform tasks as expected.
	Responsiveness (Y2)	Stewart (1997); Giannakis (2011); Bai et al. (2012); Estampe et al. (2013)	The speed at which tasks are performed.
	Agility (Y3)	Stewart (1997); Giannakis (2011); Bai et al. (2012); Estampe et al. (2013)	The ability to respond to external influences and the ability to change.
	Operating costs (Y4)	Stewart (1997); Giannakis (2011); Bai et al. (2012); Estampe et al. (2013)	The cost of operating the process. It includes labor costs, material costs, and transportation costs.
	Asset utilization (Y5)	Stewart (1997); Giannakis (2011); Bai et al. (2012); Estampe et al. (2013)	The ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs.

			outsourcing.
Reverse logistic performance (RL)	Green image (X1)	Nizaroyani (2010); Estampe et al. (2013)	Environmental performance and sustainability.
	Flexibility (X2)	Nizaroyani (2010); Estampe et al. (2013)	Product/component durability.
	Quality (X3)	Nizaroyani (2010); Estampe et al. (2013)	Quality related measures (reliability and accuracy).
	Responsiveness (X4)	Nizaroyani (2010); Estampe et al. (2013)	Flow and time related measures.
	Expenses (X5)	Nizaroyani (2010); Estampe et al. (2013	Costs of the whole process including overall direct cost, indirect costs and cost of obsolescence.
	Value recovered (X6)	Nizaroyani (2010); Estampe et al. (2013)	Value recovered from reverse flow.

We then formulate the following primary and subsidiary hypotheses with regards to the RL and SC performance measurement:

Primary hypothesis:

Hypothesis 1. The RL performance has a direct effect on the overall performance of the SC (Daugherty et al., 2011).

Subsidiary hypotheses:

Hypothesis 2. The RL performance has an indirect effect on the reliability (RE) of the SC (Mondragon et al., 2011; Erol et al., 2010; Chang et al., 2013; Gligor and Holcomb, 2012; Zhao et al., 2013).

Hypothesis 3. The RL performance has an indirect effect on the responsiveness (RSC) of the SC (Mondragon et al., 2011; Erol et al., 2010; Chang et al., 2013; Gligor and Holcomb, 2012; Zhao et al., 2013).

Hypothesis 4. The RL performance has an indirect effect on the agility (AG) of the SC (Mondragon et al., 2011; Erol et al., 2010; Chang et al., 2013; Gligor and Holcomb, 2012; Zhao et al., 2013).

Hypothesis 5. The RL performance has an indirect effect on the operating costs (CO) of the SC (Mondragon et al., 2011; Erol et al., 2010; Chang et al., 2013; Gligor and Holcomb, 2012; Zhao et al., 2013).

Hypothesis 6. The RL performance has an indirect effect on the asset utilization (AS) in the SC (Mondragon et al., 2011; Erol et al., 2010; Chang et al., 2013; Gligor and Holcomb, 2012; Zhao et al., 2013).

The model presented in Figure 1 illustrates the relationship between the observed variables and the latent factors.

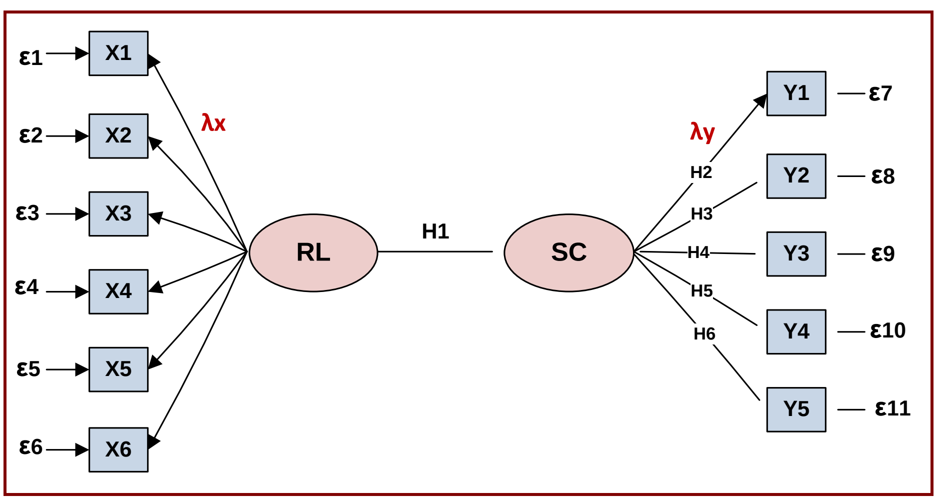

Figure 1. Conceptual model

4. RESULTS

In this section we briefly discuss data gathering, questionnaire validation, factor analysis and the test of hypotheses results.

4.1 Data gathering

The sample is this research is composed of two segments: academic and industrial. The academic segment included 100 academics with at least five years of experience teaching SC management and logistics courses in various universities throughout the United States, Europe and Asia. The industrial segment included 100 operations managers with at least five years of experience with a SC company in the United States, Europe and Asia. Each participants received two questionnaires: the first questionnaire (presented in Appendix A) was used to evaluate the SC performance and the second (presented in Appendix B) was used to evaluate the RL performance. A total of 163 completed questionnaires (79.5% response rate) were returned by the participants.

4.2 Questionnaire validation

The validity of the questionnaire was determined by pre-testing the questionnaire with a population of a group of 20 randomly selected academic and industry experts. The reliability of the questionnaire was tested with the Cronbach α using SPSS 19.0. The results showed that the Cronbach α for the SC performance questionnaire was 0.745 and for the RL questionnaire was 0.891. A value for the Cronbach α larger than 0.7 in the RL and SC questionnaires confirmed the reliability of the relationships among the observed and the latent variables. In order to evaluate the suitability of the data for factor analysis, KMO significance and Bartlett's test were applied with SPSS 19.0. In the Bartlett's test we were looking for the significance less than 0.5 and in KMO we needed the significance more than 0.5. The results in Table 4 show that the data has passed the required adequacy level and therefore we can apply factor analysis.

Table 4. Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity results

	Reverse logistic	Supply chain
KMO	.897	.891
Bartlett		
Approx. Chi-Square	1396.476	740.774
df	153	45
Sig.	.000	.000

4.3 Factor analysis

A confirmatory factor analysis was conducted for the RL to determine how well the questionnaire items (identified as observed variables) were able to explain the relevant attributes (identified as latent variables). The LISREL 8.50 software was used to perform this analysis. Table 5 shows the factor loadings in the standard solution along with the t-values.

Table 5. Confirmatory factor analysis for reverse logistic performance

Latent variables	Observed variables	Primary model		Revised model	
		Factor loadings	t-value	Factor loadings	t-value
Green image (GI)	% of reduction of consumption of rare material/ non-renewable energy (GI1)	0.93	13.92	0.93	13.92
	% of reduction in the use of hazardous materials/ products / process (GI2)	0.76	10.68	0.76	10.69
	No. of environmental certifications/ awards achieved (GI3)	0.06	0.08	-	-
Flexibility (FL)	Feasibility in recycling/ repair options (FL1)	0.77	10.96	0.77	10.94
	Number of outlets (market segments) for selling returned or refurbished products (Fl2)	0.03	0.25	-	-
	Reusability of parts/ products (product modularity/ durability) (FL3)	0.74	10.34	0.74	10.31

Quality (QL)	Number of faulty/ badly damaged returns (QL1)	0.80	11.83	0.80	11.83
	Percentage of defects (QL2)	0.79	11.69	0.79	11.69
	Customer complaints resolved (QL3)	0.62	8.53	0.62	8.53
Responsiveness (RL)	Return rates by returns' reason (RL1)	0.57	7.80	0.57	7.80
	Return rates by quality (RL2)	0.72	10.18	0.72	10.18
	Total lead time (RL3)	0.71	10.10	0.74	10.10
Expenses (EX)	Reverse distribution/ transportation cost (EX1)	0.79	11.50	0.79	11.50
	Total cost for testing/ sorting/ repair/ refurbishment/ remarketing/ redistribution inventory/ land filling/ scrapping (EX2)	0.80	11.72	0.80	11.74
	Cost of information and communication technology (ICT) support installed (EX3)	0.74	10.46	0.74	10.46
Value recovered (VR)	Revenue from reselling repaired products in value-recovery (VR1)	0.66	7.71	0.66	7.71
	Cost avoidance by reusing refurbished parts/products in the forward supply chain (VR2)	0.63	7.46	0.63	7.46
	Cost avoidance by recycling materials (VR3)	0.75	8.65	0.75	8.64

As shown in this table, the factor loadings for items GI3 and FL2 are less than 0.5 implying that they cannot represent their relevant attributes. Therefore, these factors were removed from the model and confirmatory factor analysis was repeated. The results for the revised model are also presented in Table 5.

Next, the confirmatory factor analysis was carried out to determine which attributes had the most effect on the RL performance. Table 6 and Figure 2 show the factor loadings in the standard solution, the t-values and the fitness indicators. The results indicated that the *value recovered* attribute should be removed from the model due to its low factor loading.

Table 6. Confirmatory factor analysis for reverse logistic performance

Latent variables	**Observed variables**	**Factor loadings**	**t-value**
Reverse logistic performance	Green image (GI)	0.79	10.73
	Flexibility (FL)	1.00	11.55
	Quality (QL)	0.98	11.85
	Responsiveness (RRL)	1.05	8.02
	Expenses (EX)	0.87	9.72
	Value recovered (VR)	0.08	0.85

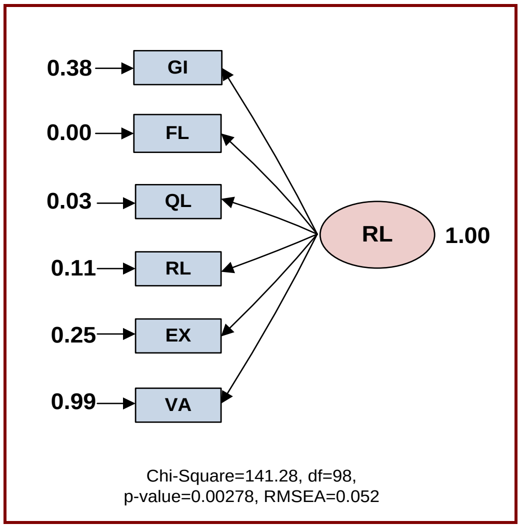

Figure 2. Confirmatory factor analysis for the reverse logistic performance model

A confirmatory factor analysis was conducted for the SC to determine how well the questionnaire items (identified as observed variables) were able to explain the relevant attributes (identified as latent variables). The LISREL 8.50 software was used to perform this analysis. Table 7 shows the factor loadings in the standard solution along with the t-values.

Table 7. Confirmatory factor analysis for supply chain performance

Latent variables	Observed variables	Factor loadings	t-value
Reliability (RE)	On-time delivery (RE1)	0.70	8.76
	The right quality and quantity (RE2)	0.67	8.45
Responsiveness (RS)	Customer order promised cycle time (RS1)	0.56	7.12
	Supply chain cycle time (RS2)	0.76	9.60
Agility (AG)	Flexibility (AG1)	0.84	12.20
	Adaptability (AG2)	0.86	12.61
Operating costs (CO)	Cost of goods sold (CO1)	0.80	11.20
	Supply chain management cost (CO2)	0.79	11.11
Asset utilization (AS)	Cash-to-cash cycle time (AS1)	0.78	10.58
	Return on fixed assets (AS2)	0.63	8.42

As shown in this table, the factor loadings are all in an acceptable region and the model is confirmed.

Next, the confirmatory factor analysis was conducted to determine which attributes had the most effect on the SC performance. Table 8 and Figure 3 show the factor loadings in the standard solution, the t-values and the fitness indicators. The results indicated that all the values are in acceptable region, the model is confirmed.

Table 8. Confirmatory factor analysis for supply chain performance

Latent variables	Observed variables	Factor loadings	t-value
Supply chain performance	Reliability (RE)	0.86	7.85
	Responsiveness (RSC)	0.98	7.19
	Agility (AG)	0.81	9.35
	Operating costs (CO)	0.88	9.41
	Asset utilization (AS)	1.03	11.42

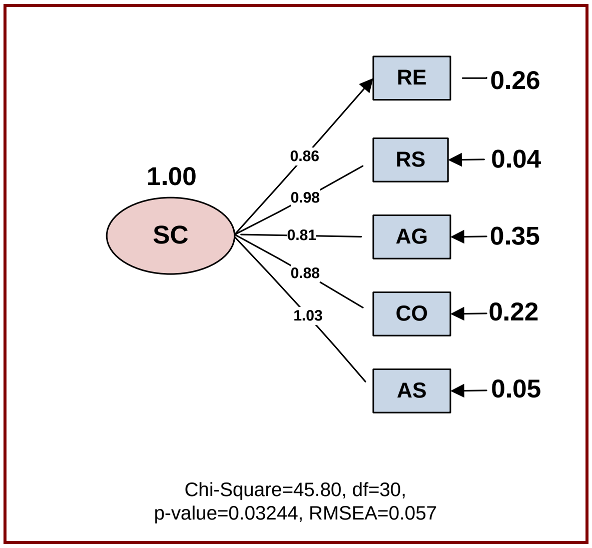

Figure 3. Confirmatory factor analysis for the supply chain performance model

4.4 Test of hypotheses results

SEM was used next to test the hypotheses. The loading factors and the t-values for the final model are presented in Figures 4(a) and 4(b).

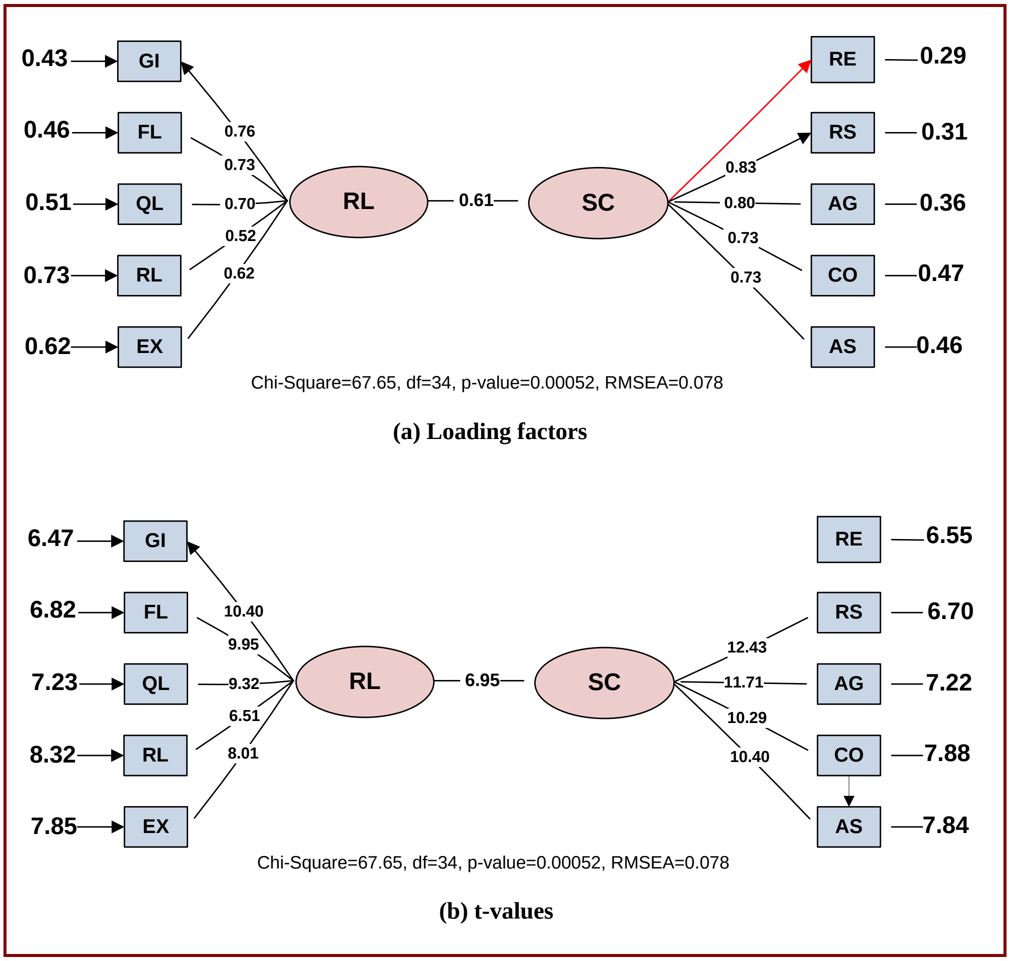

Figure 4. Loading factors and t-values for the final model

SEM investigated the relationship among the latent variables. The results of the structural analysis are supplied in Table 9 and Figure 5.

Table 9. Hypotheses testing results

Path	Hypothesis	Factor loading	Result
RL → SC	H1	0.61	☑
RL → RE	H2	0.51	☑
RL → RSC	H3	0.51	☑
RL → AG	H4	0.50	☑
RL → CO	H5	0.45	☑
RL → AS	H6	0.45	☑

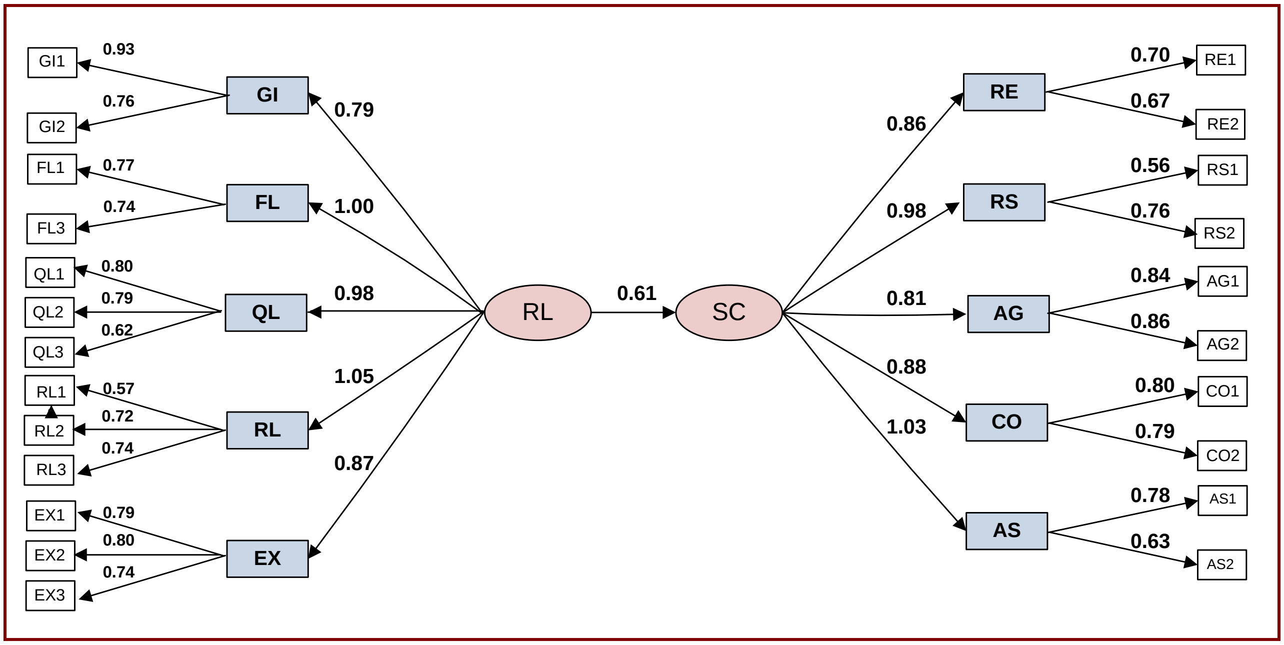

Figure 5. Structural equation modeling results

It can be concluded from Table 9 that all hypotheses in our study are confirmed. The results show that RL has a considerable effect on the supply chain performance. Moreover, the structural modeling results shown in Figure 5 highlight the directed dependencies among the RL criteria and their effect on the SC performance through path analysis and the associated loading factors.

5. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

The traditional SCs were driven by manufacturers who managed and controlled the pace at which products were manufactured and delivered to customers (Stewart, 1997). Generally, the performance measurement in traditional SCs was measured by taking the ratio of revenue over the total SC operational costs (Mishra, 2012). However, in recent years, the rise of multiple measures has rendered the performance measurement task difficult and challenging (Xu et al., 2008). In addition, most of the traditional SC performance measurement research has focused on the analysis of forward SC flows, from suppliers to end customers, providing the transformation of raw materials into final products (Prahinski and Kocabasoglu, 2006; Li and Olorunniwo, 2008). The RL flows (i.e., material movement from end customers to suppliers) have traditionally received much less attention (Rogers and Tibben-Lembke, 2001; Stock et al., 2002; Lambert et al., 2011).

In this paper, we developed a conceptual framework to study the relationship between RL and SC performance. The proposed framework consisted of two main modules with several unique attributes and related indicators. The first module, a SC performance measurement system based on the SCOR model version 10.0, was composed of five attributes including reliability, responsiveness, agility, costs and asset utilization. Each attribute was identified by indicators. The second module, a RL performance measurement, was composed of six attributes including green image, flexibility, quality, responsiveness, expenses and value recovered. Each attributes in the RL module was identified by three indicators. The entire framework included eleven attributes and twenty eight indicators.

SEM was used to conduct a confirmatory factor analysis of the overall structure. The results showed that one attribute (value recovered) and two indicators had negligible effects in the RL module and were removed from the study. The results also showed that responsiveness was the most influential factor on the RL performance. Other factors including flexibility, quality, cost and green image had less effect, respectively. Also, in the SC performance module asset utilization was the most effective factor and other factors including responsiveness, cost, reliability and agility had less effect, respectively. Finally, testing the main hypothesis showed that the RL performance has a direct effect on the SC performance.

The conceptual and practical contributions of the framework proposed in this study are threefold: (1) a comprehensive framework was proposed to study RL and SC performance based on a set of attributes and their associated indicators; (2) the loading factors for different segments of the proposed framework were determined and tested with an empirical study using SEM; and (3) The proposed framework could be used by practicing SC managers to isolate the significant and insignificant factors in their SC and RL flows for the purpose of allocating scarce resources..

The proposed framework can be used to investigate the relationship between RL and SC in other service and production industries such as dairy, food, garment and clothing, petroleum, steel, cement, electronic tools, computers and laptop, and furniture. Moreover, it would be interesting to incorporate other criteria such as just in time and/or agility in the proposed framework.

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APPENDIX A – SUPPLY CHAIN PERFORMANCE MEASUREMENT QUESTIONNAIRE (SIMPLIFIED VERSION)

Attribute	Criteria/Measure	Level of Importance				
Reliability (RE)	On-time delivery (RE1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	The right quality and quantity (RE2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Responsiveness (RS)	Customer order promised cycle time (RS1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Supply chain cycle time (RS2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Agility (AG)	Flexibility (AG1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Adaptability (AG2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Operating costs (CO)	Cost of goods sold (CO1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Supply chain management cost (CO2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Asset utilization (AS)	Cash-to-cash cycle time (AS1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Return on fixed assets (AS2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐

APPENDIX B – REVERSE LOGISTIC PERORMANCE MEASUREMENT QUESTIONNAIRE (SIMPLIFIED VERSION)

Attribute	Criteria/Measure	Level of Importance				
Green image (GI)	% of reduction of consumption of rare material/ non-renewable energy (GI1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	% of reduction in the use of hazardous materials/ products / process (GI2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	No. of environmental certifications/ awards achieved (GI3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Flexibility (FL)	Feasibility in recycling/ repair options (FL1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Number of outlets (market segments) for selling returned or refurbished products (Fl2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Reusability of parts/ products (product modularity/ durability) (FL3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Quality (QL)	Number of faulty/ badly damaged returns (QL1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Percentage of defects (QL2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Customer complaints resolved (QL3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Responsiveness (RL)	Return rates by returns' reason (RL1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Return rates by quality (RL2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Total lead time (RL3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Expenses (EX)	Reverse distribution/ transportation cost (EX1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Total cost for testing/ sorting/ repair/ refurbishment/ remarketing/ redistribution inventory/ land filling/ scrapping (EX2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Cost of information and communication technology (ICT) support installed (EX3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
Value recovered (VR)	Revenue from reselling repaired products in value-recovery (VR1)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Cost avoidance by reusing refurbished parts/products in the forward supply chain (VR2)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐
	Cost avoidance by recycling materials (VR3)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
		☐	☐	☐	☐	☐