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Assessing sustainable supply chain enablers using total interpretive structural modeling approach and fuzzy-MICMAC analysis

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Abstract

Purpose – The purpose of this paper is to model the enablers of an integrated logistics. The integration is accounted for incorporating sustainability, thereby aiming in its theory building. Existing models have focused on enablers of sustainable supply chain independently which lacks a holistic view in understanding the integrated logistics for sustainable supply chain.
Design/methodology/approach – An extensive literature review, expert opinion from both industry and academia based on questionnaire survey, is conducted to find the relevant enablers. The modeling of these enablers is done using total interpretive structural modeling (TISM). Finally, TISM along with its respective fuzzy-matriced impact croises multiplication applique (fuzzy-MICMAC) analysis is depicted.
Findings – The result of the survey and TISM model with its respective fuzzy-MICMAC has been used to evolve the mutual relationships among the important enablers of integrated logistics of consumer durables. The strategic factors obtained from TISM are integration and collaboration in the supply chain, vehicle type, and capacity; reduction in average length of haul; and real-time information system. Route selection and scheduling, reduction of fuel consumption, customer relationship management, green technology, cost reduction, etc., are some of the operational factors. Sustainable environment performance is obtained as the performance factor. Fuzzy-MICMAC is more responsive than the traditional MICMAC analysis.
Research limitations/implications – The study has limitation for the development of a conceptual framework for integrated logistics in uncertain environments. So it can be extended by combining soft computing methodologies. There is a lack of mathematical quantification of the proposed model where the enablers of sustainability can be measured.
Practical implications – The study on integrated logistics for sustainable supply chain is itself a new area to be explored, as very few studies on this relevant topic exist. The research concentrates on TISM for the integrated logistics and the movement of consumer durables through different distribution channels of a supply chain. The study has implications for practitioners, academicians, and policy makers. For practitioners, it provides a list of strategic factors, operational factors, and performance factors. For academicians, this methodology can be opted to conduct an exploratory study by identifying the essential enablers. For policy makers, the regulations can be developed using the above model.
Originality/value – It is an effort to model the important enablers and establish sustainability in integrated logistics of consumer durables.

Keywords Sustainability, Enablers, Total interpretive structural modelling (TISM), Fuzzy-MICMAC analysis, Integrated logistics

Paper type Research paper

1. Introduction

Today, many businesses are endeavoring to integrate logistics in supply networks that traverse the globe, comprise several tiers of suppliers and distributors, and use different transport modes and carriers. The study, first, focuses on integrating the logistics function. Second, the emphasis is given on incorporating sustainability in integrated logistics. Third, various enablers are identified for making the integrated logistics sustainable. The output of this research can be directly applicable to logistics, helping managers devise strategies

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specifically for incorporating sustainability in the integrated logistics. This acts as a significant contribution to the competitiveness and business growth. An integrated logistics system streamlines production, execution, transportation, sorting, and services in distribution, reverse logistics, forwarding, and managing inventories. It is a paradigm that provides improved efficiencies for customer services, reduced costs, and reduced lead-time variability. Many industries focus and strive to optimize the overall operations involved in the supply chain by reducing the product's delivery time, inventory holding costs, and overall reduction of cost-to-market. The outbound logistics cycle starts with the physical movements of products from manufacturers to retailers and, finally, to the consumers who are the end-users or customers.

In the current scenario, there is a massive surge of sustainability at the different level of a supply chain. The basic intent of sustainability is to establish an interaction among economy-, ecology-, and societal-related factors. Sustainability is mapped to various supply chain drivers such as facilities, inventory, transportation, sourcing information, and pricing with a goal for every firm. Green practices help in the validation of environmental issues as well as it tempts various companies to drift their service procedures from an orthodox environment to sustainable-oriented environment. Consumer durables are heterogeneous in nature and are delivered to geographically dispersed customers from manufacturers via forward processing facilities whereas the returned products are taken back from the customers and shipped to the manufacturers. This is done via collection facilities for the purpose of safe disposal of products and its recovery. Recovery of used products and their reprocessing, which includes remanufacturing, recycling, disposal, incineration, etc., not only increase operating costs, but also lead to an increase in greenhouse gases (GHGs) emissions. Sustainability is used as an approach in designing green supply chain (GSC) logistics. The activities of reverse logistics highly affect the operations of forward logistics such as storage spaces and transport capacities. The forward and backward movement of the product has necessitated the development of sustainable development index. Hence, the objective includes the identification of various enablers required for an integrated logistics of the sustainable supply chain by developing a hierarchical framework for the outbound logistics of consumer durable supply chain as shown in Figure 1. From triple bottom line, sustainability can be diversified to additional ingredients such as operational and technical as shown in Figure 2.

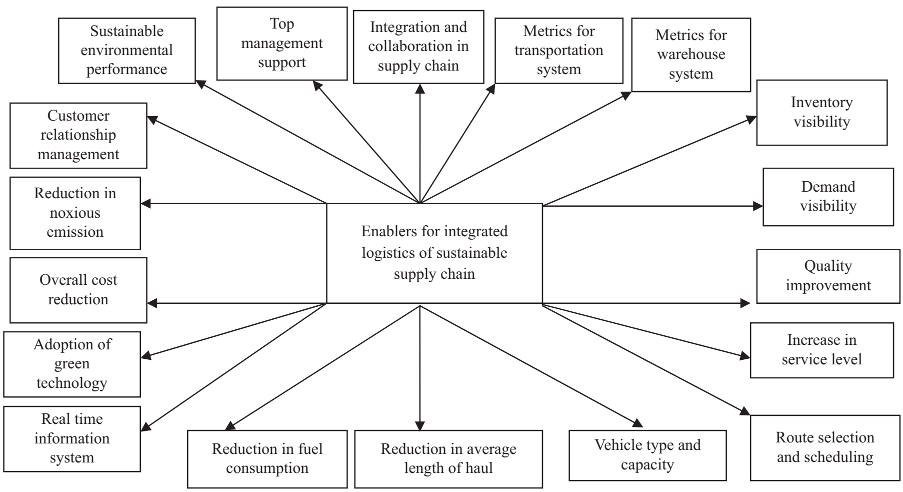


Figure 1.
Enablers identified for integrated logistics of sustainable supply chain

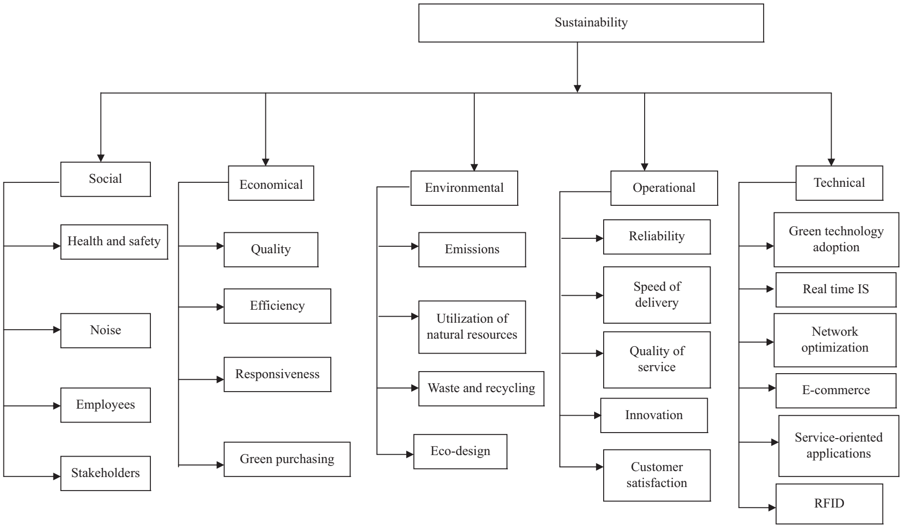


Figure 2.
Ingredients that build sustainability

The research questions addressed in the study are presented below:

RQ1. What are the enablers for establishing sustainability in integrated logistics?

RQ2. How these enablers are related among themselves?

RQ3. What methodology is used for finding the relationship among enablers?

RQ4. Why there is a need of this methodology?

RQ5. What are the enablers that fall under strategic, operational, and performance level of TISM?

The present study is an attempt to extend the alternative methods to generate a theory to explain the non-linear and complex interactions among the enablers within the dynamic environment of an integrated logistics. Hence, a questionnaire-based survey was carried out as well as the TISM framework is built, followed by an interaction matrix, MICMAC analysis, and fuzzy-MICMAC analysis. Fuzzy-MICMAC is used to resolve the existing limitations of binary digits. Traditional MICMAC has classified the enablers on the basis of "0" and "1" entry. However, MICMAC can be further performed on the basis of fuzzy inputs, which assumes intermediate values between 0 and 1. The analysis shows the effect of one factor on the other.

The structural alignment of the remainder of the paper is organized as follows. Section 2 is the literature review of integrated logistics for the sustainable supply chain. Section 3 contains the methodology with various steps involved in the development of TISM model. Afterward, the analysis of results is presented in Section 4. The resulting MICMAC analysis is shown in Section 5. Section 6 discusses the managerial implications, and, finally, Section 7 comprises conclusion, limitations, and future directions.

2. Literature review

From the existing literature, it is evident that the theory on sustainable integrated logistics is still underdeveloped. In past, theory-based research has either used qualitative research methods or quantitative research methods. Hence, a majority of studies lack research design and data analysis related to sustainable integrated logistics. The fundamental idea underlying in the logistics integration strategy is that instead of considering each shipment, firm, and vehicle individually, one should consider them as component of an integrated logistics system. The transportation of goods constitutes a major enabling factor for most economic, environment, and social activities. The need of integrated logistics explicitly refers to the optimization of advanced management. In present paper, an attempt has been made to the systems theory as Sushil (2012) argued that the systems theory can offer unique advantages in comparison to other theories. A framework for sustainable supply chain management was introduced by performing a large-scale literature review and conceptual theory building, thus demonstrating the relationships among social, economic, and environmental aspects (Carter and Rogers, 2008). The effectiveness of logistics and supply chain integration on firm competitiveness in manufacturing firms utilizing the resource-based view of competitive advantage along with the transaction cost economics theory was given by Mellat-Parast and Spillan (2014).

A qualitative evaluation is made for different types of uncertainties impacting on transport operations along with the development of conceptual models to categorize the different factors on the basis of literature review (Sanchez-Rodrigues *et al.*, 2010). Carter and Liane Easton (2011) developed a theoretical framework for the evolution and future directions of empirical sustainable supply chain management by conducting a systematic literature review methodology across a 20-year time frame. An inductive theory building the grounded theory was used to profile individual-level perspectives on sustainability and supply chain partnering with an introduction of the concept of Sustainable Supply Chain Orientation (Signori *et al.*, 2015). In 2004, the ecological dimension in planning, operations, and management of supply chains was defined by Zhu and Sarkis. From the existing literature, it is found that the basic elements of green practices affecting GSC are internal environmental management, green purchasing, and eco-design which are widely used to measure the green practices (Zhu and Sarkis, 2004; Zhu *et al.*, 2005). Lam and Dai (2015) proposed a methodology that focused on translating the customer requirements for environmental management into systematic metrics for logistics service providers to develop their environmental sustainability performance. Glock and Kim (2015) minimized the costs of producing and delivering a product as well as carbon emission resulting from transportation by developing a mathematical model that considers both operating costs and carbon emissions from transportation. Mohanty and Shankar (2017) enlisted 25 enablers for a sustainable integrated logistics and developed a model using fuzzy-TISM.

The overall goal is to understand about all enablers that lead to sustainability in an integrated logistics. Integrated logistics reduce the overall costs within a supply chain, and reduce lead times while increasing reliability (Mason *et al.*, 2003). In order to achieve this goal, manufacturers, retailers, and third-party logistics need to share the inventory levels, production schedules, demand, and product characteristics constituting of its dimensions, locations, and destination, available resources such as transportation mode, warehouse capacity, and delivery-driven shipments. Using an integrated logistics system can help to minimize lead-time variations and, consequently, large inventory buffers were not needed. An integrated system generates solutions using real-time visibility for the products when a problem occurs on the route of the carriers. Thus, rerouting orders make efficient use of driver time and satisfy the urgent customer need. This, on the other way, leads to sustainability by saving economical, social, and environmental benefits. Generating and building a theory using TISM and fuzzy-MICMAC for an integrated logistics to achieve sustainability is the main contribution of this research. Interpretive structural modeling (ISM) and total interpretive structural modeling (TISM) have been used in many studies. However, with a few exceptions, researchers have failed to use ISM and TISM in generating a theory. Further, ISM has its own limitations. So, the focus of this research is based on the TISM technique for generating a theory related to integrated logistics. Some of the definitions of sustainability are given in Table I.

Table I.
Definitions of sustainability

S. no	Authors	Definitions
1	Seuring and Müller (2008)	Sustainable supply chain management is the management of material, information, and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e. economic, environmental and social which are derived from customer and stakeholder requirements
2	Carter and Rogers (2008)	Sustainable supply chain management is defined as the strategic, transparent integration, and achievement of an organization's environmental, social and economical goals in system coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its chains
3	WCED, SPECIAL WORKING SESSION (1987)	Sustainability has been defined as the level of human consumption and the activity which can continue into the foreseeable future, so that the system which provides goods and services to humans persists indefinitely

The questions were derived from existing literature, brainstorming of expert group and nominal group technique. A questionnaire survey is carried by taking expert's opinion and qualitative views. Based on expert's opinion, the major enablers of integrated logistics were identified. The industries include third-party logistics companies, consumer durable industries, and institutional organizations for this research study.

The experts were the managers from third-party logistics companies, managers from consumer durables industries, environmentalists, organizational researchers, and academicians.

3. Main enablers of integrated logistics for the sustainable supply chain

3.1 Top management support (E1)

It is an elemental component of the supply chain in every organization that provides valuable decisions and its commitment for the support during various uncertain hours. Management should be proactive rather than reactive for the adoption of green practices in every possible aspect (Dubey, Gunasekaran, Papadopoulos and Childe, 2015). Hence, top management support is a vital enabler.

3.2 Integration and collaboration in supply chain (E2)

Integration is essential as it helps to reduce conflicts of demands, thus improving the visibility along the supply chain. With technological integration, suppliers and customers are positively linked to the environmental performance (Vachon and Klassen, 2006). Collaboration in supply chain reduces inventory, thus improving the visibility and reducing the demand fluctuations. It helps to reduce the environmental impacts associated with the physical distribution flow in the supply chain (Klassen and Vachon, 2003). There is an improvement in the dimensions of manufacturing performance, quality, delivery, and flexibility in addition to the environmental performance when the collaboration with suppliers takes place on environmental issues (Klassen and Vachon, 2003).

3.3 Metrics for transportation system (E3)

The transportation system is one of the vital components that consume between one-third and two-thirds of the total logistics costs (Sadjady, 2011). The main aim of transportation is to increase the satisfaction level of the customer by delivering the right quantity of products to the right place at the right time (Chopra and Meindl, 2007). The different modes for product movement include road, rail, air, water, and pipelines (Johnson *et al.*, 1999), and now digital media also plays an important role in transportation (Ballou, 2004) and therefore considered as the sixth mode.

3.4 Metrics for warehouse system (E4)

From the existing literature, it is evident that warehousing, storage of goods, and the handling of material are the necessary activities of products which is referred to as "transportation at zero miles per hour," and this uses around 20 percent of the total logistics distribution costs (Ballou, 2004). The various sub-functions included in the warehouse management system are movement, storage, and information transfer. It embarks on addressing the consumer demands for different types of durables from different geographies, simultaneously reducing time-to-market and improving supply chain efficiencies (Madadi *et al.*, 2010).

3.5 Inventory visibility (E5)

Inventory visibility is an important enabler which helps in balancing the inventory levels according to demand. By these, companies can reduce their operating costs with an increase in business growth, thus creating sustainable value and return on investment. The inventory visibility is made easier with the help of technology (Mason and Spring, 2011).

3.6 Demand visibility (E6)

It includes the transit of demand from the customers to retailers and from the retailers to the manufacturers, which, in turn, gives rise to a number of products to be manufactured. The goal of the demand visibility improves the supply chain by making data available, thus extending the scope for promotion of quick response to change by reshaping demand, redirecting supply as well as controls various risks (Lin *et al.*, 2002). Demand visibility is a prerequisite to supply chain agility and responsiveness which further leads to a sustainable supply chain and balances the reachability of the product from the manufacturer to the end-users.

3.7 Quality improvement (E7)

The impact of globalization associated with various demands in competitive environment has necessitated the need for managers in manufacturing to take decisive actions for environmental changes, thus improving quality and efficiency by implementing various strategies. Cost reduction, improvement of customer satisfaction as well as minimization of environmental impacts are the basic parameters for quality improvement (Rahman, 2009).

3.8 Increases in service level (E8)

An increase in service level can be achieved by IT enablement. The emphasis on information and communication technology for coordination and integration plays an important role for a shift from traditional supply chain to sustainable supply chain (McKinnon, 1999). It also includes high availability of raw materials, intermediate products, and finished products that are guaranteed against optimal inventory cost.

3.9 Route selection and scheduling (E9)

Strategic decisions for vehicle fleet composition to make the best possible use of fleet with the capacitated vehicle routing problem and the heterogeneous vehicle routing problem (HVRP) using the genetic algorithm was given by Liu (2013). Courier routing planning and real-time adjustments for scheduling the stochastic travel time and demand was given by Yan *et al.* (2013) using mathematical modeling. An efficient algorithm for evaluating logistics network reliability subject to distribution cost and the minimal path- based algorithm to evaluate the reliability index with two schemes to reduce the search space was proposed by Niu *et al.* (2014).

3.10 Vehicle type and capacity (E10)

Fuel consumption depends on the vehicle type and capacity, which is the size of the vehicle. The more capacity that can be accumulated per time of vehicle movement from source to destination consumes less fuel with an eventual reduction of noxious emission. The utilization of vehicle capacity is subject to five sets of constraints. They are regulatory, market related, inter-functional, infra-structural, and equipment related (McKinnon, 2007).

3.11 Reduction in average length of haul (E11)

An increase in the number of separate links in the supply chain would lead to an increase in the average length of haul. The structure of the supply chain is one of the deciding factors of increasing average length of haul. In the case of logistics, most of the time, the goods are shipped having an approximate knowledge of distance, but no route optimization is done during shipment. Hence, the distance traveled becomes high, but with the use of IT-based vehicle routing and scheduling, the average length of haul is reduced, which also helps to optimize the distance of route and capacity. Optimization of route helps in reduction of average length of haul (Baumgartner *et al.*, 2008).

3.12 Reduction in fuel consumption (E12)

Reduced fuel consumption gives rise to the concept of green transportation. Electric vehicles are environmentally friendly since their engines have almost no emissions. The adaptation of efficient engines helps in reduction of fuel consumption of various types of vehicles. It also leads to energy source efficiency and reduces CO_2 emissions per tonne kilometer. Fossil-based fuel, renewable energy obtained from solar and the wind, nuclear, and geothermal energy, helps in reduction of consumption of fuel (Dekker *et al.*, 2012).

3.13 Real-time information system (E13)

The enablement of information technology (IT) serves as the best practice for companies who use technological instruments, especially the IT tools. IT tools serve as the basic means of spreading information and knowledge to spatially dislocated parts of the company (Jharkharia and Shankar, 2005). It helps to save the systematic structure that provides information on specific process and proceedings thus spreading the information based on real-time mode throughout the supply chain. This augments effectiveness and reduces the consumption of time for developing the knowledge. It helps in improving the transparency along the supply chain, thus improving forecasting and planning procedures. It reduces uncertainty in demand and supply, thus creating flexibility. It also counters the challenge of invoice shortage and inconvenient buying with the efficient usage of emerging IT-enabled technologies.

3.14 Adoption of green technology (E14)

Green technology adoption reduces negative externalities in day-to-day operations as well as increases the capacity of decision making in an integrated logistics by which the overall supply chain could evaluate and embrace various measures to seed green manufacturing, thus reducing noxious emissions. Green adoption helps in recycling, reuse, and recovery process which further helps in reducing waste for designing a green environment (Dubey, Gunasekaran, Papadopoulos and Childe, 2015; Dubey, Gunasekaran and Ali, 2015). Green IT is the green adoption of various strategic technologies such as advanced analytics, client computing, social computing, reshaping the data center, virtualization for resource availability, flash memory, activity monitoring for security, and mobile applications.

3.15 Cost reduction (E15)
GHGs, water pollution, and land use mostly incur external costs to the environment and climate. Others, such as air pollution, noise, congestion, accidents, etc., impose harm to human life and generate unnecessary costs to the entire economy (Demir *et al.*, 2015). Madadi *et al.* (2010) have developed two reasonable cost-saving models, namely, decentralized ordering model and centralized ordering model to investigate the effect of collective ordering by retailers on the total inventory cost of the system.

3.16 Reduction in noxious emission (E16)
Negative externalities of freight transportation have been categorized into seven categories. They are air pollution, GHGs, water pollution, noise pollution, congestion, accidents, and land use. The study suggested that air pollution consists of sulphur oxides, nitrogen oxides, carbon monoxide, volatile organic compounds, particulates, and other gases. GHGs consist of carbon dioxide equivalent, methane, nitrous oxide, ozone, and chloro-flouro carbon (Demir *et al.*, 2015). These elements affecting the environment should be minimized.

3.17 Customer relationship management (CRM) (E17)
Customers are more aware in practicing green products by buying it as it is environmentally friendly. Every product design and its movement in the supply chain are done for the sake of consumers, so it is important to cluster and segment them. Customers are from various corner of the world, so the supply chain strategy should focus more on what the customers want.

3.18 Sustainable environmental performance (E18)
It depicts the indexing of environmental sustainability, which tracked 21 elements covering natural resource endowments, environmental management efforts, pollution levels of past and present, and society's initiative to improve its environmental performance over time (Wong *et al.*, 2009). Energy demand and CO_2 emission are the frequently discussed topics. The relationship between life cycle assessment-based environmental impacts and their management in the supply chain has often pointed to optimization issues such as transport to end customer resources. These resources include water, energy, or waste (Seuring, 2013).

4. Methodology

The preference of TISM is considered over ISM as ISM interprets only the nodes whereas TISM interprets both nodes and links in the digraph. The arrangement of enablers graphically in levels with direct links and transitive links is a diagraph. In ISM, all transitive links are eliminated, whereas TISM can have some important transitive links, thus giving a better explanatory framework as shown in Figure 3. It answers three key questions of theory building, i.e. what, how, and why. In TISM, the basis of the relationship is considered along with the contextual relationship. It represents the driving-dependence relationship as in ISM, thus facilitating to understand the whole system for taking better decisions (Sushil, 2012). MICMAC is known as "matriced impact croises multiplication applique." The objective of the MICMAC analysis (Mandal and Deshmukh, 1994) is to analyze and to identify the driving power and dependence of the variables toward sustainable supply chain in an integrated logistics. Various enablers are mapped according to their driving power and dependence. The MICMAC analysis reveals the existence of dependent factors, independent factors, linkage factors, and autonomous factors. From the final reachability matrix, the existence of transitive and direct link is found. According to Sushil (2012), TISM considers only the existence of an interaction

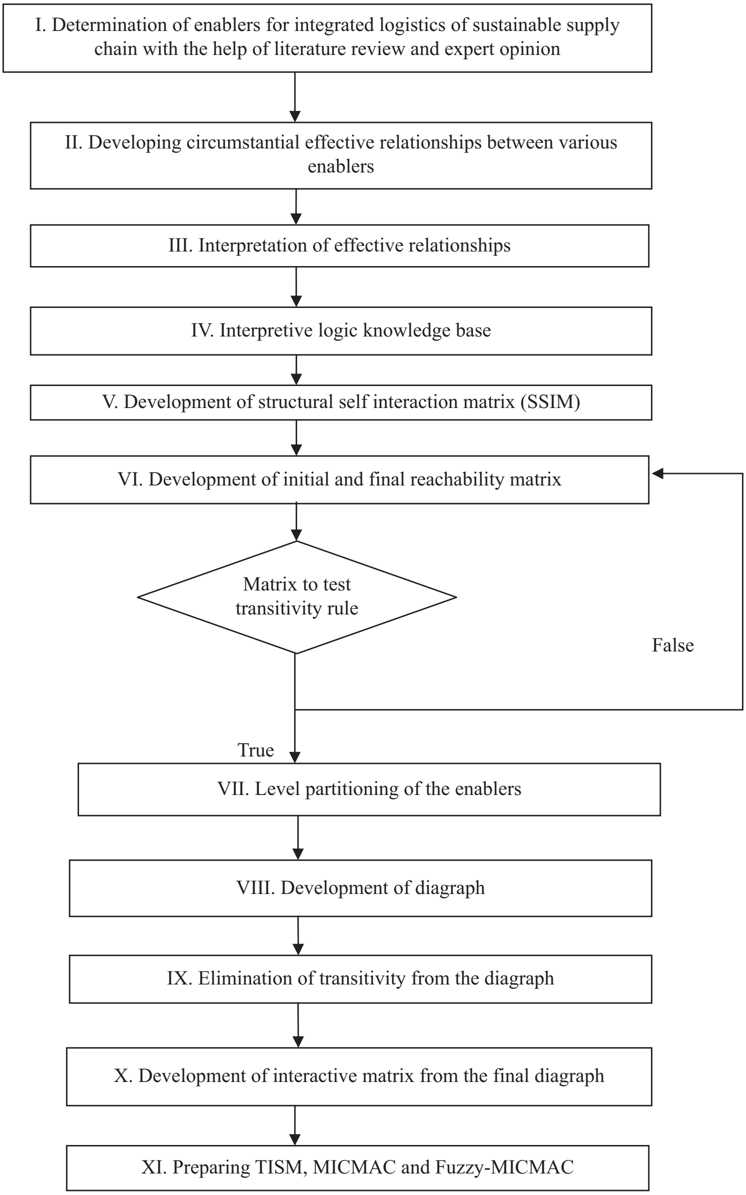


Figure 3.
Flow diagram for preparing TISM

between elements, the possibility of interaction is also considered as an extension in fuzzy-TISM. So TISM can be extended to fuzzy-TISM. This research considers fuzzy-MICMAC analysis for an uncertain environment. In conventional MICMAC for TISM, only the binary type of relationships is seen where fuzzy-MICMAC helps in enhancing its sensitivity and responsiveness in any uncertain environment.

4.1 Stepwise processes involved in the development of TISM model with fuzzy-MICMAC

Step 1: different enablers that help in sustainability building are identified through literature review, questionnaire-based survey, and expert's opinion.

Step 2: establishing the contextual relationship between the enablers.

Step 3: development of structural self-interaction matrix (SSIM) for variables show the pair-wise interactions among the enablers. In each "*x-y*" link, the interpretation is used to develop the "knowledge base".

Step 3.1: SSIM is developed with the following variables:

V: variable x will help to achieve variable y;
A: variable y will be achieved by variable x;
X: variables x and y will help achieve each other; and
O: variables x and y are unrelated.

Step 3.2: initial reachability matrix is developed.

Step 3.2.1: if (x, y) entry in the SSIM is V, then (x, y) entry in the reachability matrix becomes 1 and the (y, x) entry becomes 0.

Step 3.2.2: if (x, y) entry in the SSIM is A, then (x, y) entry in the reachability matrix becomes 0 and the (y, x) entry becomes 1.

Step 3.2.3: if (x, y) entry in the SSIM is X, then (x, y) entry in the reachability matrix becomes 1 and the (y, x) entry becomes 1.

Step 3.2.4: if (x, y) entry in the SSIM is O, then (x, y) entry in the reachability matrix becomes 0 and the (y, x) entry becomes 0.

Step 3.3: matrix is checked for the presence of transitive relation and is converted into a final reachability matrix.

Step 3.3.1: entries with 1^* is filled for showing the transitivity relationship to fill the gap.

Step 4: level partitioning is done in reachability matrix.

Step 5: development of reachability matrix in its conical form.

Step 6: development of diagraph.

Step 7: interaction matrix represents the connectivity between the nodes denoted by 1 and where there is no connectivity it is denoted as 0.

Step 8: development of TISM.

Step 9: driving power and Dependence are derived from a conical form of reachability matrix.

Step 10: MICMAC analysis is done for clustering various enablers, and the driving power and dependence of the variables is identified.

Step 11: steps for fuzzy-MICMAC analysis.

Step 11.1: first, the total numbers of levels "L" are found from the digraph. Divide the levels "L" of the diagraph into two halves. If they are even number, then $m = n$, where "m" is first half and "n" is the second half.

Step 11.2: if the total number of levels considered as "L" obtained from step 11.1 are odd numbers, then we perform (L+1/2). Let us consider the number of levels "L" in the diagraph is 11, then we perform $(11+1)/2 = 6$, i.e. we assign $n = 6$ which is the second half of the diagraph and $m = 5$ where $m < n$.

Step 11.3: now each half is further subdivided to m' as upper half and n' as lower half, i.e. m has m' and n', and n also has m' and n'. Next, we follow step 11.2 in case the levels in that half is odd.

Step 11.3.1: if the levels in a particular half are an odd number, then we consider (L+1/2). Let us consider $L = 5$ for a particular m half, then we perform $(5+1)/2 = 3$, i.e. we assign $n' = 3$, and $m' = 2$, and the enablers present on the third level are considered from the upper part of the selected half, i.e. m.

Step 11.3.2: if the levels in a particular half, let us say *n,* are an even number, then we consider ($L/2$). Let us consider $L = 6$ for a particular half, then $m' = n' = 3$, and the enabler is considered on the third level of the upper half.

Step 11.4: select the enablers at a point of time to assign numerical values, i.e. the membership values of the reachability matrix obtained from the fuzzy direct reachability matrix (FDRM).

Step 11.4: proceed by filling the rows horizontally with the membership function values.

Step 11.5: if the link is direct, value assigned to the enabler is as follows:

on the same level = 0.5;
below the chosen enabler = 0.3;
if extremely below the chosen enabler = 0.1;
if above the chosen enabler = 0.7; and
if extremely above the chosen enabler = 0.9.

Step 11.6: let us assume the values considered for FDRM are as follows.

if the link is transitive, values assigned to the enabler are as follows:

on the same level = 0.3;
below the chosen enabler = 0.1; and
above the chosen enabler = 0.5.

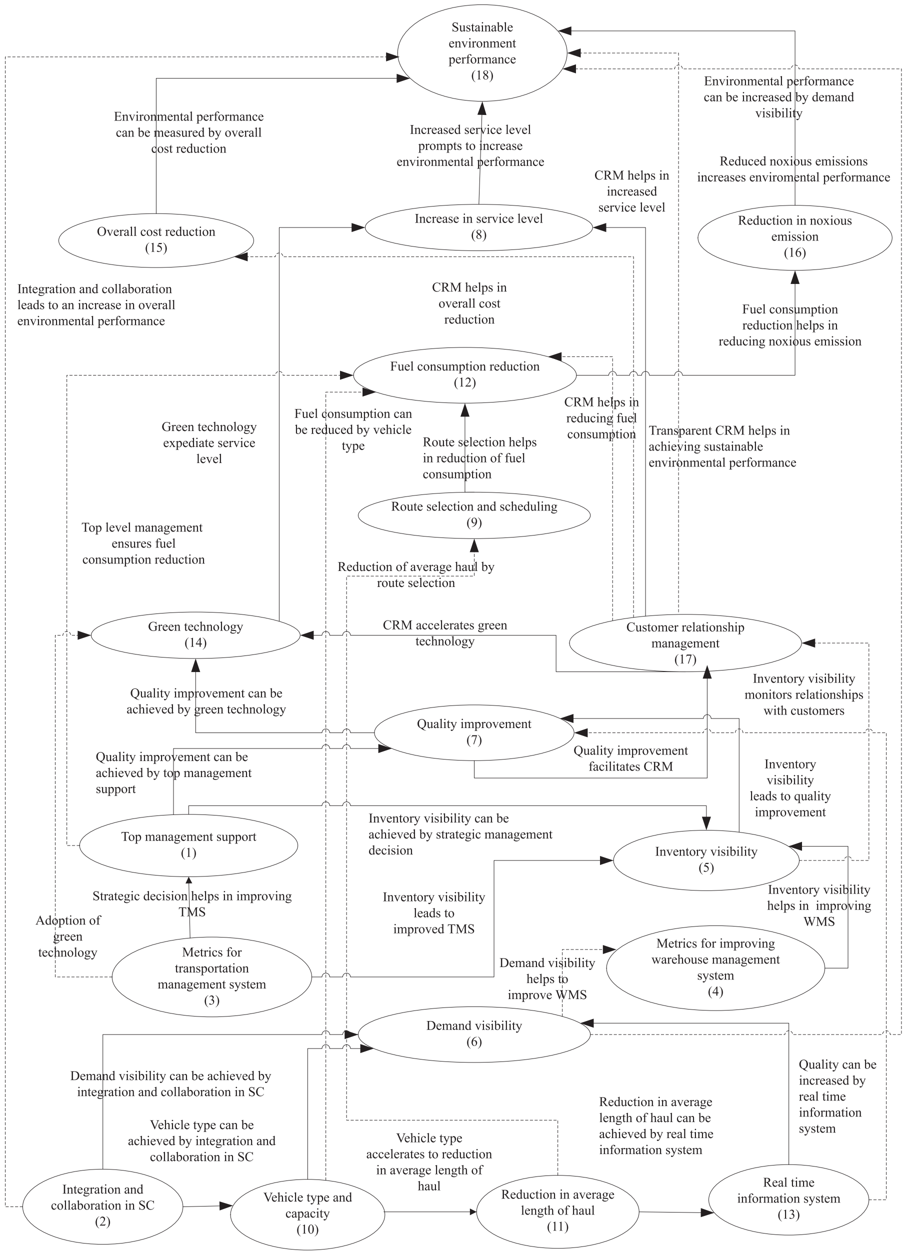
5. TISM analysis

The basic objective of this research is to identify the various enablers that would integrate the logistics system for the consumer durables. TISM-based models are self- explanatory as observed in Figure 4. It describes the relationship directions where the links interpret in what way one enabler leads to another. Table II depicts the SSIM. It shows the contextual relationship where the existence of a relationship between two enablers is shown. In Table III, the initial reachability matrix is shown. It is filled with 1 or 0 depending upon the symbols V, A, X, O. Table IV shows the final reachability matrix. It represents the existence of a transitive relationship. Tables V and VI show the level partitioning, which is done for the level-wise arrangement of the enablers. It depicts the reachability set, antecedent set, and interaction set for all the enablers. Table V depicts level I which consists of enabler 18. Table VI shows the summary of various iterations of partitioning that takes place at various levels. Level II consists of enablers 8, 15, 16; level III consists of enabler 12; level IV consists of enabler 9; level V consist of enablers 14 and 17; level VI consists of enabler 7; level VII consists of enablers 1 and 5; level VIII consists of enablers 3 and 4; level IX consists of enabler 6; and level X consists of enablers 2, 10, 11, 13. In Table VII, enablers with different levels are enlisted. Table VIII shows the conical form of reachability matrix which is developed by clustering variables at the same level, across rows and columns of the final reachability matrix. Based on the conical form of reachability matrix, the diagraph is obtained. Table IX shows the interaction matrix. A TISM model for integrated logistics of sustainable supply chain depicts 16 direct relations as shown by direct links and 11 transitive relations represented by dotted links in the model.

6. MICMAC analysis

MICMAC analysis is represented in Figure 5. Based on the driving power and dependence, the enablers have been classified into four clusters, as: cluster I: autonomous variables; cluster II: dependence variables; cluster III: linkage variables; cluster IV: driving variables. The position of each variable based on its dependence and driving power is depicted in Table X.

Cluster I consists of autonomous variables. These factors have weak driving power and weak dependence (Dubey, Gunasekaran, Papadopoulos and Childe, 2015; Dubey, Gunasekaran and Ali, 2015).



Notes: ——→ Controls or augments; - - - - - - -→ significant transitive link

Figure 4.
TISM model for integrated logistics of sustainable supply chain of consumer durables

Only one enabler is obtained in this cluster, that is demand visibility (E6). This enabler is relatively disconnected from the system, with which they have few links, which may be strong.

Cluster II consists of dependent variables that have weak driver power, but strong dependence. In this cluster, seven enablers were obtained. They are metrics for

Table II. Structural self-interaction matrix (SSIM)

Ele. no	Enablers	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	Top management support	V	V	V	V	V	V	O	O	O	O	V	V	O	O	A	A	A
2	Integration and collaboration in SC	O	V	O	V	X	X	O	O	O	O	V	V	V	V	V	V	
3	Metrics for transportation system	V	O	V	V	V	O	V	A	A	V	V	V	O	O	O		
4	Metrics for warehouse system	V	O	V	V	V	O	O	O	O	O	V	V	A	A			
5	Inventory visibility	O	O	V	V	A	A	V	O	O	O	V	V	O				
6	Demand visibility	O	V	O	V	O	A	O	O	O	O	V	V					
7	Quality improvement	V	V	O	O	A	A	O	O	O	O	O						
8	Increase in service level	V	V	O	O	A	A	O	O	O	O							
9	Route selection and scheduling	V	O	V	V	A	A	V	V	O								
10	Vehicle type and capacity	V	O	V	V	A	O	O	O									
11	Reduction in average length of haul	V	O	V	V	A	A	V										
12	Reduction in fuel consumption	V	O	V	V	A	A											
13	Real-time information system	O	O	O	V	V												
14	Adoption of green technology	V	X	V	V													
15	Overall cost reduction	V	O	O														
16	Reduction in noxious emission	V	O															
17	Customer relationship management (CRM)	O																
18	Sustainable environmental performance																	

Table III. Initial reachability matrix

El. no	Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Top management support	1	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
2	Integration and collaboration in SC	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	1	0
3	Metrics for transportation system	1	0	1	0	0	0	1	1	1	0	0	1	0	1	1	1	0	1
4	Metrics for warehouse system	1	0	0	1	0	0	1	1	0	0	0	0	0	1	1	1	0	1
5	Inventory visibility	0	0	0	1	1	0	1	1	0	0	0	1	0	0	1	1	0	0
6	Demand visibility	0	0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	1	0
7	Quality improvement	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
8	Increase in service level	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
9	Route selection and scheduling	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	1
10	Vehicle type and capacity	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1
11	Reduction in average length of haul	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1	1	0	1
12	Fuel consumption reduction	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
13	Real-time information system	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	0	0
14	Green technology adoption	0	1	0	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1
15	Overall cost reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
16	Reduction in noxious emission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
17	Customer relationship management (CRM)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
18	Sustainable environmental performance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Notes: DrP, sum of 1's in rows; De, sum of 1's in columns

transportation management system (E3), quality improvement (E7), increasing in service level (E8), route selection and scheduling (E9), fuel consumption reduction (E12), overall cost reduction (E15), reduction in noxious emission (E16), and sustainable environmental performance (E18).

Cluster III consists of linkage variables that have strong driving power and also have strong dependence. These enablers are unstable in the fact that any action on these enablers will have an effect on others and also a feedback on themselves. This cluster has four enablers. They are top management support (E1), inventory visibility (E5), adoption of green technology (E14), customer relationship management (E17).

Cluster IV includes the independent enablers having strong driving power and weak dependence. This cluster has five enablers. They are integration and collaboration in the

El. no	Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Top management support	1	1*	0	0	1*	1*	1	1	1*	1*	1*	1*	1	1	1	1	1	1
2	Integration and collaboration in SC	1	1	1	1	1	1	1	1	1*	1*	1*	1*	1	1	1	1*	1	1*
3	Metrics for transportation system	1	1*	1	0	1*	0	1	1	1	1*	1*	1	1*	1	1	1	1*	1
4	Metrics for warehouse system	1	1*	0	1	1*	0	1	1	1*	1*	1*	1*	1*	1	1	1	1*	1
5	Inventory visibility	1*	0	0	1	1	0	1	1	0	0	0	1	0	1*	1	1	1*	1*
6	Demand visibility	1*	0	0	1	0	1	1	1	0	0	0	0	0	1*	1	1*	1	1*
7	Quality improvement	0	0	0	0	0	0	1	0	0	0	0	0	0	1*	0	0	1	1
8	Increase in service level	0	0	0	0	0	0	0	1	0	0	0	0	0	1*	0	0	1	1
9	Route selection and scheduling	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	1
10	Vehicle type and capacity	1*	1	1	1*	1*	1*	1*	1*	1*	1	0	1*	1*	1*	1	1	1*	1
11	Reduction in average haul length	1*	1	1	1*	1*	1*	1*	1*	1*	0	1	1	1*	1*	1	1	1*	1
12	Fuel consumption reduction	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
13	Real-time information system	1*	1	1*	1*	1	1	1*	1	1	1	1	1	1	1	1	1*	1*	1*
14	Green technology adoption	1*	1	1*	1*	1	1*	1*	1	1	1	1	1	1*	1	1	1	1	1
15	Overall cost reduction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
16	Reduction in noxious emission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
17	Customer relationship management (CRM)	0	1*	0	0	1*	0	0	1*	1*	1*	1*	1*	0	1	1*	1*	1	1*
18	Sustainable environmental performance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Note: Level partitions

Table IV. Final reachability matrix

supply chain (E2); metrics for warehouse management system (E4); vehicle type and capacity (E10); reduction in the average length of haul (E11); and real-time information system (E13). It is observed that a variable with a strong driver power is called the key variable that falls into the category of independent or linkage enablers.

6.1 Fuzzy-MICMAC analysis

To convert from traditional MICMAC analysis to fuzzy-MICMAC, a supplementary contribution is defined by qualitative consideration on a 0-1 scale as shown in Table XI.

The opinions of the industry experts, stakeholders, policy makers, academicians, etc., are considered again for rating the relationships among the enablers. The FDRM is derived from Table IV. The value for each enabler in the FDRM is assigned using steps 11.5 and step 11.6 taken from the stepwise processes involved in the development of TISM model with a fuzzy-MICMAC analysis. To illustrate with the TISM model obtained in this research, the total numbers of levels "L" = 10 as found from the diagraph. These levels "L" of the diagraph are divided into two halves. In this case, the obtained levels for m is 5 and n are 5, where "m" is first half and "n" is the second half of the TISM diagraph. From the above, each half has an odd number of levels, so we perform (L+1/2). Let us consider the second half "n" which has five levels, so again to subdivide the levels using the above formula (5+1)/2 = 3 is obtained, where $n' = 3$ which is the second half of n, and $m' = 2$ where $m' < n'$, and the enablers present in the 3rd level of second half, that is in the nth half, are considered for assigning fuzzy values to be inserted in FDRM. In the diagraph shown in Figure 4 enablers at the eighth level is considered. The enabler is considered from the left to right in a particular level. The first enabler considered is E3 in the eighth level of the diagraph, and its relationships with other enablers are assigned with fuzzy values taken from the expert's opinion and the FDRM is developed after a mapping from Table IV. After the formation of FDRM, as shown in Table XII, matrix multiplication takes place where FDRM is taken as an initial table and is multiplied repeatedly with itself until the hierarchies of the driving power and dependence are constant. Fuzzy matrix

Table V.
Iteration 1

Enablers	Reachability set	Antecedent	Intersection	Level
1	1,2,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,10,11,13,14	1,2,5,6,10,11,13,14	
2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,10,11,13,14,17	1,2,3,4,10,11,13,14,17	
3	1,2,3,5,7,8,9,10,11,12,13,14,15,16,17,18	2,3,10,11,13,14	2,3,10,11,13,14	
4	1,2,4,5,7,8,9,10,11,12,13,14,15,16,17,18	2,4,5,6,10,11,13,14	2,4,5,10,11,13,14	
5	1,4,5,7,8,12,14,15,16,17,18	1,2,3,4,5,6,10,11,13,14,17	1,4,5,14	
6	1,4,6,7,8,14,15,16,17,18	1,2,6,10,11,13,14	1,6,14	
7	7,14,17,18	1,2,3,4,5,6,7,10,11,13,14	7,14	
8	8,14,17,18	1,2,3,4,5,6,8,10,11,13,14,17	8,14,17	
9	9,11,12,15,16,18	1,2,3,4,9,10,11,13,14,17	9,11	
10	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18	1,2,3,4,10,13,14,17	1,2,3,4,10,13,14,17	
11	1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18	1,2,3,4,9,11,13,14,17	1,2,3,4,9,11,13,14,17	
12	12,15,16,18	1,2,3,4,5,9,10,11,12,13,14,17	12	
13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,10,11,13,14	1,2,3,4,10,11,13,14	
14	1,2,3,4,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,5,6,7,8,10,11,13,14,17	1,2,3,4,5,6,7,8,10,11,13,14,17	
15	15,18	1,2,3,4,5,6,9,10,11,12,13,14,15,17	15	
16	16,18	1,2,3,4,5,6,9,10,11,12,13,14,16,17	16	
17	2,5,8,9,10,11,12,14,15,16,17,18	1,2,3,4,5,6,7,8,10,11,13,14,17	2,5,8,10,11,14,17	
18	18	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18	18	Level I

Notes: Level I – 18. Table V shows that enabler 18 appears in level I

Element	Reachability set	Antecedent set	Intersection	Level
1	1,2,5,6,10,11,13	1,2,3,4,5,6,10,11,13	1,2,5,6,10,11,13	VII
2	2,10,11,13	2,10,11,13	2,10,11,13	X
3	2,3,10,11,13	2,3,10,11,13	2,3,10,11,13	VIII
4	2,4,10,11,13	2,4,6,10,11,13	2,4,10,11,13	VIII
5	1,4,5	1,2,3,4,5,6,10,11,13	1,4,5	VII
6	6	2,6,10,11,13	6	IX
7	7	1,2,3,4,5,6,7,10,11,13	7	VI
8	8,14,17	1,2,3,4,5,6,8,10,11,13,14,17	8,14,17	II
9	9,11	1,2,3,4,9,10,11,13,14,17	9,11	IV
10	2,10,13	2,10,13	2,10,13	X
11	2,11,13	2,11,13	2,11,13	X
12	12	1,2,3,4,5,9,10,11,12,13,14,17	12	III
13	2,10,11,13	2,10,11,13	2,10,11,13	X
14	1,2,3,4,5,6,7,10,11,13,14,17	1,2,3,4,5,6,7,10,11,13,14,17	1,2,3,4,5,6,7,10,11,13,14,17	V
15	15	1,2,3,4,5,6,9,10,11,12,13,14,15	15	II
16	16	1,2,3,4,5,6,7,9,10,11,12,13,14,16	16	II
17	2,5,10,11,14,17	1,2,3,4,5,6,7,10,11,13,14,17	2 ,5,10,11,14,17	V
18	18	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18	18	I

Table VI.
Iteration 1-10 showing enablers with various levels

S. no	Enabler code	Enablers	Levels in TISM
1	E18	Sustainable environment performance	I
2	E15	Overall cost reduction	II
3	E8	Increase in service level	II
4	E16	Reduction in noxious emission	II
5	E12	Fuel consumption Reduction	III
6	E9	Route selection and scheduling	IV
7	E14	Adoption of green technology	V
8	E17	Customer relationship management	V
9	E7	Quality improvement	VI
10	E1	Top management support	VII
11	E5	Inventory visibility	VII
12	E3	Metrics for transportation system	VIII
13	E4	Metrics for warehouse system	VIII
14	E6	Demand visibility	IX
15	E2	Integration and collaboration in SC	X
16	E10	Vehicle type and capacity	X
17	E11	Reduction in average length of haul	X
18	E13	Real-time information system	X

Table VII.
List of variables and their levels in TISM

multiplication is based on Boolean matrix multiplication (Vasantha Kandasamy *et al.*, 2007). The rules of fuzzy matrix are defined as:

if Ã is a fuzzy relation defined on x X y, and
Ñ is a fuzzy relation defined on y X z, then
Ã o Ñ is a fuzzy relation defined on x X z.

The fuzzy max-min composition is defined as $\mu_{\tilde{A}o\tilde{N}}(x, z) = \max(\min(\mu_{\tilde{A}}(x, y), \mu_{\tilde{N}}(y, z)))$.

According to the fuzzy set theory, when two fuzzy matrices are multiplied, the product matrix is also a fuzzy matrix. The final fuzzy-MICMAC matrix is shown in Table XIII.

From the fuzzy-MICMAC analysis, it is revealed that most of the enablers are found as independent variables under cluster IV which are those having strong driving power and

	18	15	8	16	12	9	14	17	7	1	5	3	4	6	2	10	11	13	Dri Pow	Rank
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	X
15	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	IX
8	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	4	VIII
16	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	IX
12	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	VIII
9	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	6	VII
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	I
17	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	12	IV
7	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4	VIII
1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	16	III
5	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0	0	0	0	11	V
3	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	16	III
4	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	16	III
6	1	1	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	10	VI
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	I
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	17	II
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	17	II
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	I
Dep	18	14	12	14	12	10	13	13	11	10	10	6	8	7	9	8	9	8		
Rank	I	II	IV	II	IV	VI	III	III	V	VI	VI	X	VIII	IX	VII	VIII	VII	VIII		

Notes: Dep, dependence; Dri Pow, driving power

Table VIII. Conical form of reachability matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18
E1	–	0	0	0	**1**	0	**1**	0	0	0	0	*1*	0	0	0	0	0	0
E2	0	–	0	0	0	**1**	0	0	0	**1**	0	0	0	0	0	0	0	*1*
E3	**1**	0	–		**1**	0	0	0	0	0	0	0	0	*1*	0	0	0	0
E4	0	0	0	–	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
E5	0	0	0	0	–	0	**1**	0	0	0	0	0	0	0	0	0	*1*	0
E6	0	0	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	*1*
E7	0	0	0	0	0	0	–	0	0	0	0	0	0	**1**	0	0	**1**	0
E8	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0	0	0	**1**
E9	0	0	0	0	0	0	0	0	–	0	0	0	0	0	0	0	0	0
E10	0	0	0	0	0	0	0	0	0	–	**1**	*1*	0	0	0	0	0	0
E11	0	0	0	0	0	**1**	0	0	*1*	0	–	0	**1**	0	0	0	0	0
E12	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	**1**	0	0
E13	0	0	0	0	0	**1**	*1*	0	0	0	0	0	–	0	0	0	0	0
E14	0	0	0	0	0	0	0	**1**	0	0	0	0	0	–	0	0	0	0
E15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	**1**
E16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	**1**
E17	0	0	0	0	0	0	0	**1**	0	0	0	*1*	0	0	*1*	0	–	*1*
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–

Notes: Bold "1" represents direct link; italic "*1*" represents transitive link

Table IX. Interaction matrix

weak dependence, and this shows the existence of sensitivity in the fuzzy-MICMAC as compared to that of traditional MICMAC (Figure 6).

7. Managerial implications

Managing the environment is one of the highly concerned areas. This paper provides specific, crisp, and important implications of sustainability to all the entities who contribute their vital

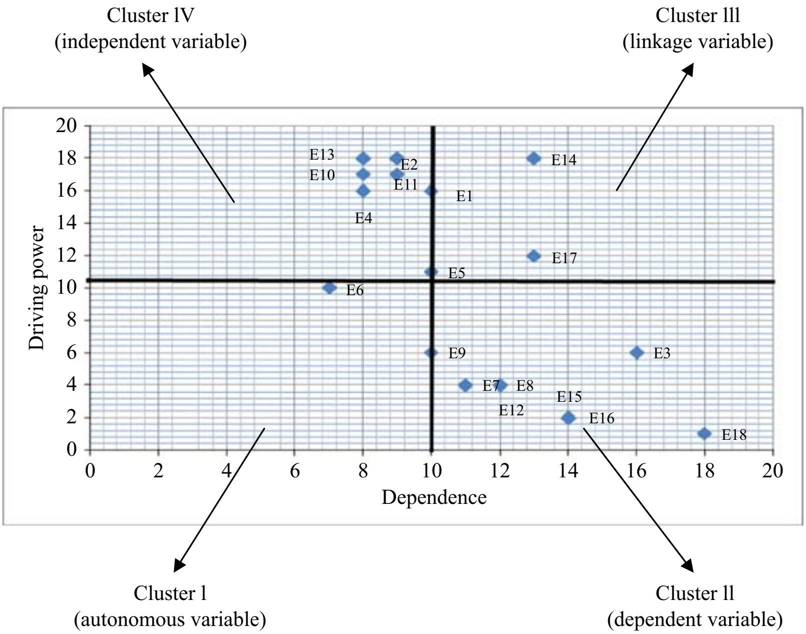


Figure 5. MICMAC analysis for cluster of variables

Enabler code	Enablers	Position co-ordinates (X,Y)
E1	Top management support	(10,16)
E2	Integration and collaboration in SC	(9,18)
E3	Metrics for transportation system	(16,6)
E4	Metrics for warehouse system	(8,16)
E5	Inventory visibility	(10,11)
E6	Demand visibility	(7,10)
E7	Quality improvement	(11,4)
E8	Increase in service level	(12,4)
E9	Route selection and scheduling	(10,6)
E10	Vehicle type and capacity	(8,17)
E11	Reduction in average length of haul	(9,17)
E12	Fuel consumption reduction	(12,4)
E13	Real-time information system	(8,18)
E14	Adoption of green technology	(13,18)
E15	Overall cost reduction	(14,2)
E16	Reduction in noxious emission	(14,2)
E17	Customer relationship management	(13,12)
E18	Sustainable environment performance	(18,1)

Table X. Position co-ordinates of enablers

Interaction possibility	No (*N*)	Very low	Low	Medium	High	Very high	Full
Scale value	0	0.1	0.3	0.5	0.7	0.9	1

Table XI. Possibility of numerical values of the reachability

Table XII.
Fuzzy direct reachability matrix (FDRM)

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18
E1	0	0.1	0	0	0.5	0.3	0.7	0.9	0.5	0.1	0.1	0.5	0.1	0.7	0.9	0.9	0.7	0.9
E2	0.7	0	0.7	0.7	0.7	0.7	0.7	0.9	0.5	0.3	0.3	0.5	0.3	0.7	0.9	0.5	0.7	0.5
E3	0.7	0.1	0	0	0.5	0	0.7	0.9	0.7	0.1	0.1	0.7	0.1	0.5	0.9	0.5	0.7	0.5
E4	0.7	0.1	0	0	0.5	0	0.7	0.9	0.5	0.1	0.1	0.5	0.1	0.7	0.9	0.9	0.7	0.9
E5	0.3	0	0	0.3	0	0	0.7	0.9	0	0	0	0.7	0	0.5	0.9	0.9	0.5	0.9
E6	0.3	0	0	0.7	0.5	0	0	0.9	0	0	0	0	0	0.5	0.9	0.9	0.5	0.9
E7	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.7	0.9
E8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0.7	0.9
E9	0	0	0	0	0	0	0	0	0	0	0.1	0.7	0	0	0.9	0.9	0	0.9
E10	0.3	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0.3	0.5	0.5	0.9	0.5	0.9
E11	0.3	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.7	0.3	0.5	0.9	0.9	0.5	0.9
E12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0	0.9
E13	0.3	0.5	0.5	0.5	0.7	0.7	0.7	0.9	0.9	0.1	0.1	0.7	0	0.7	0.9	0.5	0.5	0.9
E14	0.1	0.1	0.3	0.3	0.3	0.1	0.1	0.9	0.7	0.1	0.1	0.7	0.1	0	0.9	0.9	0.5	0.9
E15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
E16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
E17	0	0.1	0	0	0.3	0	0	0.5	0.5	0.1	0.1	0.5	0	0.5	0	0.5	0	0.5
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table XIII.
Final fuzzy-MICMAC matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	SUM
E1	0.3	0.1	0.3	0.3	0.3	0.3	0.5	0.5	0.7	0.1	0.1	0.7	0.1	0.7	0.9	0.7	0.7	0.9	8.2
E2	0.7	0.3	0.3	0.7	0.5	0.3	0.7	0.7	0.7	0.1	0.1	0.7	0.3	0.7	0.7	0.7	0.7	0.9	9.8
E3	0.3	0.1	0.3	0.3	0.5	0.3	0.7	0.7	0.5	0.1	0.1	0.5	0.1	0.7	0.7	0.7	0.7	0.9	8.2
E4	0.3	0.1	0.3	0.3	0.5	0.3	0.7	0.7	0.7	0.1	0.1	0.7	0.1	0.7	0.7	0.7	0.7	0.9	8.6
E5	0.3	0.1	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.1	0.1	0.5	0.1	0.5	0.5	0.7	0.7	0.9	7.0
E6	0.7	0.3	0.3	0.3	0.5	0.3	0.7	0.7	0.5	0.1	0.1	0.5	0.1	0.7	0.5	0.5	0.7	0.9	8.4
E7	0.1	0.1	0.3	0.3	0.3	0.1	0.1	0.5	0.5	0.1	0.1	0.5	0.1	0.5	0.5	0.5	0.3	0.9	5.8
E8	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.5	0.5	0.1	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	4.4
E9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.7	0.7	0.1	0.9	3.7
E10	0.7	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.3	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9	9.8
E11	0.7	0.1	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.3	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9	9.6
E12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7
E13	0.5	0.1	0.7	0.5	0.5	0.5	0.7	0.7	0.7	0.3	0.3	0.7	0.3	0.5	0.7	0.9	0.7	0.9	10
E14	0.3	0.1	0.1	0.5	0.1	0.3	0.5	0.5	0.5	0.1	0.1	0.7	0.1	0.5	0.7	0.7	0.7	0.9	7.4
E15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E17	0.3	0.1	0.3	0.3	0.3	0.1	0.1	0.1	0.5	0.1	0.1	0.5	0.1	0.5	0.5	0.5	0.5	0.5	5.4
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	5.4	2.0	4.2	5.2	5.2	4.0	6.4	7.6	7.8	2.0	1.9	7.6	2.2	7.6	8.6	8.8	8.0	12.5	

role in the storage, distribution, and consumption of consumer durables in a horizontal supply chain that comprises the entities such as manufacturers, retailers, and the customers. The higher level includes the managers, policy makers, government, academicians, decision makers, and practitioners, and the operational level involves manufacturers, third-party logistics, retailers, and end-customers who cater for sustainability. Hazardous emissions are mostly observed during manufacturing and movement of the durables through different distribution channels of the supply chain, so continuous monitoring and proper controlling of undesirable threats to the environments during the manufacturing and movement of these durables in an outbound logistics helps in establishing sustainability. Further, the products should be manufactured in such a way that reverse engineering can be applied to the GSC,

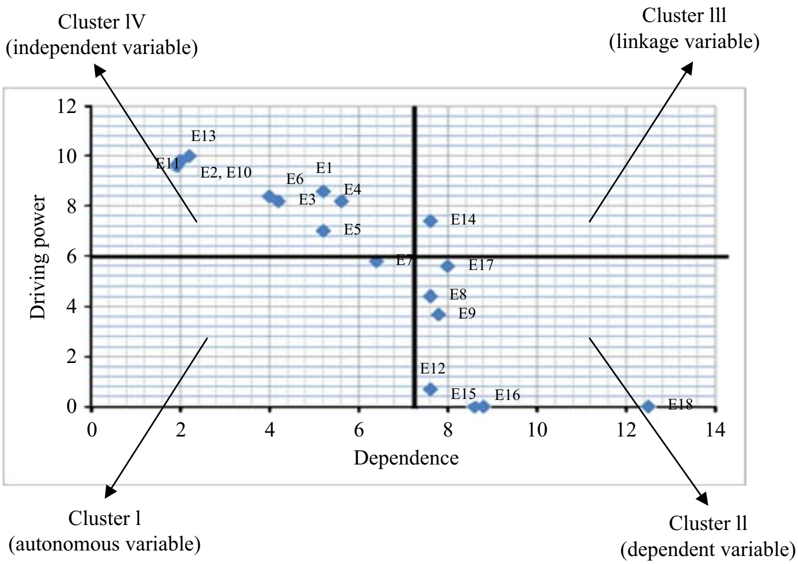


Figure 6. Fuzzy-MICMAC analysis for cluster of variables

thus achieving sustainability with an increased capability of manufacturing eco-designed products. Government's regulation should be often regularized for preserving GSC practices of consumer durables under the retail sector. Generally, it should be mandated by the government that noxious emission should be up to certain range according to the environmental measures, and if more as the manufacturing defined range, then a penalty cost must be incurred. Sustainable models would help managers handle the conflicting goals such as reducing the product's cost and time-to-market as well as increasing quality and its availability. Consumer awareness regarding green purchasing should also be encouraged.

8. Conclusion and future directions

This research is focused on the identification of various enablers for an integrated logistics of sustainable supply chain and development of a hierarchical framework based on TISM. The traditional MICMAC is converted to fuzzy-MICMAC by qualitative consideration on a 0-1 scale. A modification is done to the existing algorithm of TISM. The diagraph is divided into equal halves, and the enablers falling into those halves are assigned the fuzzy values taken from the opinion of various experts. The FDRM is considered, and the value for each enabler in the FDRM is assigned using steps 11.5 and step 11.6 from the stepwise algorithm processes developed in subsection 3.1 mentioned under Section 3. The obtained fuzzy-MICMAC for the cluster of variables is different from the general MICMAC as more number of enablers is found as independent variables which make the model more efficient.

Further, the proposed TISM model basically aims at the development of enablers in a hierarchical manner which concludes that the integration and collaboration in the supply chain (E2), metrics for warehouse management system (E4), vehicle type and capacity (E10), reduction in the average length of haul (E11), and real-time information system (E13) play a vital role in reducing noxious emissions in an integrated logistics for sustaining supply chain. The developed TISM helps in knowing the direct and transitive relationships between variously identified enablers required for an integrated logistics, and these initiatives would positively influence the overall environmental performance. This research has its own limitations, as the developed model is based on literature review, questionnaire-based survey, and experts' opinion.

In a traditional MICMAC analysis, only binary type of relationships is seen, but here fuzzy-MICMAC analysis is performed which shows the sensitivity of the model in an uncertain environment. The future scope would focus on quantifying the proposed model mathematically where the enablers, in general, are the factors such as increased service level, overall cost reduction, metrics for transportation management systems, warehousing system, and reduction in average length of haul can be measured. The research can be further extended using some real scenarios as case studies for an illustrative analysis with some more additive constructs. The study on barriers of the sustainable supply chain of consumer durables can be carried in the future. The present study can be extended to neuro-TISM by fusing neural network with TISM. This would allow predicting the integrated logistics model for sustainable supply chain after considering the fuzzy values from the FDRM as the inputs to the input layer of neural network. The neuro-TISM model would help to reduce disruptions in the integrated logistics.

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