Global Journal of Flexible Systems Management (June 2014) 15(2):113–130
DOI 10.1007/s40171-014-0059-8

ORIGINAL ARTICLE

Flexible Decision Approach for Analysing Performance of Sustainable Supply Chains Under Risks/Uncertainty

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Received: 6 October 2013 / Accepted: 16 January 2014 / Published online: 7 February 2014

Abstract *Concern related to green and sustainability is growing from past few years in the research area of supply chain management. Collectively, these concerns involves a higher number of interacting factors, which further can multiply complexity by the decrease in visibility of the risks in supply chain operations and so add to its vulnerability. To make supply chain (SC) capable to bear simultaneously regular and risk condition, one requires proactive planning and flexibility in the decisions making. To provide supply chain designers a proactive decision model, this paper proposes to use a flexible decision approach, i.e. Interpretive Structural Modeling (ISM) for recognizing the combined interactions between factors influencing sustainable risk bearing SC. However, the interpretation of the interactive relationships represented by directed links for the identified factors relatively lacks in the ISM approach, and thus may distort the process of decision making. Therefore, in this study, ISM is extended to the Total Interpretive Structural Modeling (TISM) approach to overcome these issues in interpreting the directed links in the structural model for considered factors. Further, by using relationship analysis, we graphically categorize factors on the basis of their impact on performance. Finally, TISM based the proposed model evaluates the causality and illustrate factors with interpretation of relations via directed links in the form of Interpretive Matrix, and suggests that factors at the bottom level are crucial for sustainability focused chain to build its capability on risks and risk issues. The implications at managerial level and conclusions are presented in the end.*

Keywords Flexibility · Green · Interpretive Structural Modeling (ISM) · Total Interpretive Structural Modeling (TISM) · Performance improvement · Risk · Supply chain · Sustainability

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Introduction

Ecological concern and sustainability of supply chains (SCs) has gained significant attention from past few years (Paulraj 2009; Ashby et al. 2012; Mangla et al. 2013a). Environmental and sustainability issues are relevant to supply chain planners, because their supplying authorities, ultimate users, regulating agencies, governmental legislation and workforce demands greening the SC. However, the term sustainability in SCs is described as an integrative function to understand economic, environmental, and social responsibilities (Font et al. 2008). Further, the Brundtland Commission has well-defined sustainability as the art of fulfilling the current needs of users with no compromise with the future (WCED 1987).

Sustainability has been interpreted in a variety of ways, ranging from an inter-generational philosophical position to a multidimensional term for business management. Early sustainability initiatives tended to focus on environmental issues but with time, it increasingly adopting a triple bottom line (i.e., environment, economic, and social) approach. As this approach involves a higher number of interacting factor and every activity has some objective risk factor. So a higher degree of complexity can be expected in the network. Nonetheless, the risk in the supply network might happen at any time, however, the attention for these uncertain events have also been increased in past few years (Kilgore 2003; Hendricks and Singhal 2003). In support, according to survey reports conducted by Accenture (151 supply chain administrative) and FM Global (>600 financial managers), the SC becomes more prone to risks and risky events, not only so further these risks significantly reduces the overall performance of an organization (Smyrlis 2006; Ferrer et al. 2007).

Therefore, to reduce or avoid the occurrence and negative consequences of risk and risk events and to achieve the goal of sustainability, an organization should address supply chain risks, and take some timely measures to manage the environmental and social issues along with maximizing of profit. However, the research on concern of risk and risk issues in the sustainable SC is still in infancy. In this paper, authors attempt to fill this hole of space in the sustainable supply chain dimension.

Further, to manage disruptions and risks in supply chains efficient planning and preparedness is required. Here, we build a generic framework for SC that has capability to sustain under risks and uncertainties along with managing environmental, social and economical concern issues. In addition, there are various factors and variables associated with a SC those are already producing or could be the source of risks in a SC. In this concern, initially fourteen factors have been identified for a sustainability focused risk bearing supply chain (SRBSC). And later, this study examines and analyzes the various identified factors by proposing the multi criteria decision model and for this; an Interpretive Structural Modeling (ISM), based flexible modeling approach, which is further extended with Total Interpretive Structural Modeling (TISM) is utilized to build a structural model representing interpretation of interactions among the involved factors to focus risk bearing capability in the sustainable supply chain network.

The remaining of this manuscript is prepared as: Literature review is presented in the next section. The development of a generic framework for SRBSC is described in the next section. While in the next section explains the methodology of research along with the description to ISM and TISM approach. An example to show the utility of the proposed approach is presented in the next section. The research discussion and managerial implication is provided in the subsequent section, and the ending section of this paper discusses conclusions and future scope of work in the domain.

Review of Literature

To cope with various ecological and social issues and challenges spurred by profit and non-profit business, sustainable supply chain plays a significant role, and so the introduction and implementation of sustainability in supply chain management is increasing (Chaabane et al. 2011; Ahi and Searcy 2013). Sustainability in SCs explicitly deals with the uncertainties related to the environment, social and economic aspects on broad (Linton, et al. 2007), which is also supported by the "triple bottom line" concept to maintain trade-off between the environmental, economic and social performance of organization (for more details refer to Elkington (2004), Ciliberti et al. (2008), Seuring et al. (2008), Font et al. (2008), Pagell and Wu (2009), and Wolf (2011).

Nonetheless, supply chain network includes supplying authorities, manufacturing units, stockrooms, and distributing strait structured to procure materials in raw, transform it to final products and distribute to the end users. It is worth noticing that the SC offers a wide scope of adoption and development of sustainability and the concept of sustainability in supply chain management is broadly described by using two terms sustainable supply chain management and green supply chain management (Ashby et al. 2012).

For the purpose of this study, sustainable supply chain is defined as….the SCs where all the three dimensions of sustainability, namely the economic, environmental, and social ones, are taken into account, and hence sustainable supply chain management (Ciliberti et al. 2008, p. 1580). On the other side, green supply chains can be understood as….integration of environment considerations into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumer, and end-of-life management of green products (Wee et al. 2011, p. 603). However, both sustainability and greening the supply chain networks are more comparable on the ecological aspect but differs on the issues of social and economic benefits. Therefore, SSCM can be considered as an extension of GSCM, and more suits to our research.

Moreover, the terminology of risk may be understood as the occurrence of unexpected and unintended events within a network. The supply chain risks have a direct impact on the productivity of an organizational supply chain (Mitchell 1995; Sarkis 2001). Thus, if supply chain risks are not managed efficiently, the consequences could be degradation in quality of product, gap in communication and loss of the customer good-will and many more (Chopra and Sodhi 2004; Christopher and Peck 2004; Kleindorfer and Saad 2005; Manuj and Mentzer 2008a, b). Further, Zsidisin (2003) define risks in the SC as the likelihood of an uncertain event which can interrupt the supply network. While, the sources of these risks in the SC may be natural calamities such as earthquakes, thunderstorms, floods, landslides, etc. (Chopra and Sodhi 2004; Atkinson 2006), or issues of quality in supplying, supplier strategies, and flaws in methods of shipping and/or supplying the products (Zsidisin et al. 2004), inaccurate forecasting of demand (Christopher and Lee 2004), the variation in prices of materials and tools (Barry 2004), and inefficient ecological and social concerns in processing methods (Carter and Jennings 2004; Christopher and Peck 2004). This is either drive or likely to drive by some and more issues, for instance, increase in supply chain complexity (because of global advancements, sourcing strategies, etc.), product demand and supply variability, instability of labor, poor communication among partners, and governmental pressures and legislation (for details refer to Juttner et al. 2003; Manuj and Mentzer 2008a, b; Mitra and Webster 2008).

A Generic Framework for SRBSC

For perspective of organizations, the initiating or implementing the concept of green and sustainability is not easy due to association of various factors. There are numerous kinds of unexpected events and the complexities associated to SC, having a tendency to disrupt it adversely. So, this is important for supply chain experts and operation managers to think and build a sustainability focused supply chain that enough capable to sustain in uncertain and risk surroundings, and can be understood as SRBSC. A generic framework for a SRBSC is presented in Fig. 1.

In present work, we investigate the concept of sustainability under the concern of uncertain surroundings in a supply chain network. Based on previous studies, Carter and Rogers (2008) describe sustainability as an integrative approach of environmental, social, and economic decisive factor that helps an organization to achieve the desired objective of value maximization. While, Jorgensen and Knudsen (2006), Carter and Easton (2011) collaborates supply chain management and sustainability in terms of corporate social responsibility.

The proposed generic framework in this research is an attempt to demonstrate various risks and disruptive issues concerning to environmental, social and economic aspects in an organizational supply chain. Each concern namely economical, social and environmental holds related risk sources, and issues. This framework provides interaction among the triple bottom line issues with risks and disruptive events in SCs, and is as shown in Fig. 1. Further within the context of this framework, we define the approach of managing risks in the SC as the capability of an organizational supply chain to recognize, analyze and manage the risks related to its economical, ecological (green) and societal aspects. Significantly, due to transient surroundings the idea of the green and sustainable supply chain alone could not resolve global issues in the SC. Thus, it needs to build green and sustainability focused and risk manageable supply chains which are capable enough to sustain in these uncertain surrounds.

Solution Methodology: Flexible Decision Modeling Using ISM and TISM Approach

The nature of analysis carried out in our study is kind of problem solving. Here, the authors aim to study the interaction among various factors or attributes affecting the risk bearing and sustaining capability of a SC in normal, unsuitable and uncertain conditions of the environment. This study illustrates a general overview that how the

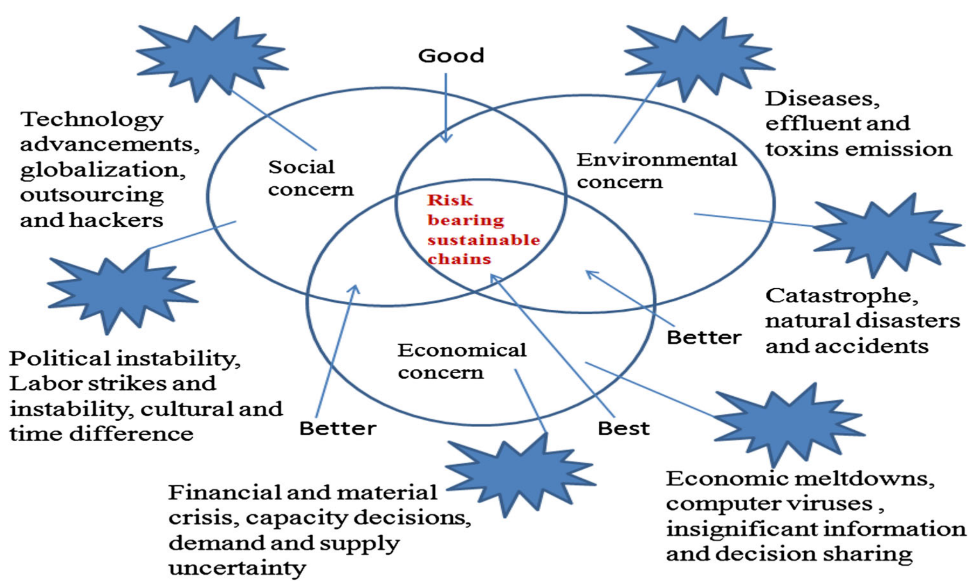

Fig. 1 Generic framework for SRBSC

consideration of unexpected events can improve the risk bearing capability in the sustainable supply chain. Furthermore, to fulfil the objectives of the study, we required qualitative data which is collected through (i) by studying the literature related to sustainable supply chains and risks management and (ii) semi-structured interviews is conducted with the select supervisors and managers at middle level and top level who are responsible for managing sustainable operations in the firms. The selection of organizations for comprising the sample size is random i.e. any object can be included in sample space assigning equal probability to them. In order to make more productive and effective decisions especially for organizational perspective, multi criteria decision making (MCDM) approach plays a significant part. It provides a systematic and well-structured illustration of criteria and factors related to the issue. Further, MCDM can be categorized into the Multi-Attribute Decision Making (MADM) and the Multi-Objective Decision Making (MODM) approach. The MADM process is discrete type and aids in decision making when limited/number of decision criteria are assessed (Chen and Hwang 1992), however, MODM is continuous type, and deals with decision issues, when one could assess the large number of criteria (Mangla et al. 2012). Now, almost every organization has its own transient problems and decision issues, and in that way it following either MODM or MADM approach. Noticeably, dynamic issues involves many factors and are more difficult to analyse, and for that reason, a flexible decision making is requisite (Mangla et al. 2013a). In this study, flexible MODM approach, Interpretive Structural Modeling (ISM) is used to study to analyze inter-relationships among recognized factors for the SRBSC. In addition to it more effective for the organization, it is required to interpret the relationships among recognized factors, i.e. how, and in what way one factor influences the other factor for accomplishing the desired organizational objective, and thereby ISM is upgraded to Total Interpretive Structural Modeling (TISM) approach. Nonetheless, the necessary details of ISM and TISM are given in subsequent subsections.

Interpretive Structural Modeling

The ISM methodology helps in understanding the complexity of the system and inter-related elements (Sushil 2012). ISM methodology starts with the recognition of factors related to the problem and then extends with the development of the model on the basis of the interactions between factors (Quereshi et al. 2007, 2008). Further, different researchers have applied ISM methodology to solve various issues in different domain and some of them are illustrated as shown in Table 1.

For this research, authors have concerned over the risk bearing capability of sustainability focused supply chain. The sustainability focused and risk manageable supply chain in further depends upon a number of interacting factors. A methodical understanding and analysis of these factors and would be significant for the managers and supply chain planners. ISM approach suits to these conditions to analyze the interaction among factors. The ISM process simplifies the modeling process and provides visible, well-defined models in the end for further implications (Saxena et al. 2006; Mangla et al. 2013a, b). Further, Sage (1977) and Warfield (1974) explain ISM as an interactive knowledge procedure, which has the capability of structuring different and related elements, and their relationships into a comprehensive form. The method is known as interpretive due to dependency on the judgment of the experts in decision making and reasonably helpful in analyzing the interaction among variables (Saxena et al. 2006).

The flow chart demonstrating various steps involved in the ISM methodology is shown in Fig. 2, and details for applying ISM methodology is illustrated as below (Saxena et al. 1992).

(i) Initially, factors should be finalized in relation to the objective of the study (i.e. building green and sustainability-focussed risk bearing supply chain). To collect the relevant information about the study elements or factors past studies may be used. A group discussion session may be conducted.
(ii) Contextual relationships should be developed among identified factors.

Table 1 Examples illustrating implications of ISM methodology

Saxena et al. (1992)	Explores the scenario for conserving energy in reference to Indian cement industries
Mandal and Deshmukh (1994)	This study has covered the interaction among the factors to select a vendor
Ravi and Shankar (2005)	The interaction between various barriers of reverse logistics is demonstrated
Diabat and Kannan (2011)	The interrelationship between drivers in implementation of green in supply chain is analysed
Mangla et al. (2012)	They have identified the various drivers and outcome factors and analyzed the interactions between them for a product recovery system
Mangla et al. (2013a)	Interaction among the identified factors related to green product recovery system is investigated in this study
Mathiyazhagan et al. (2013)	This study has explored the barriers in implementing green initiatives in SMEs

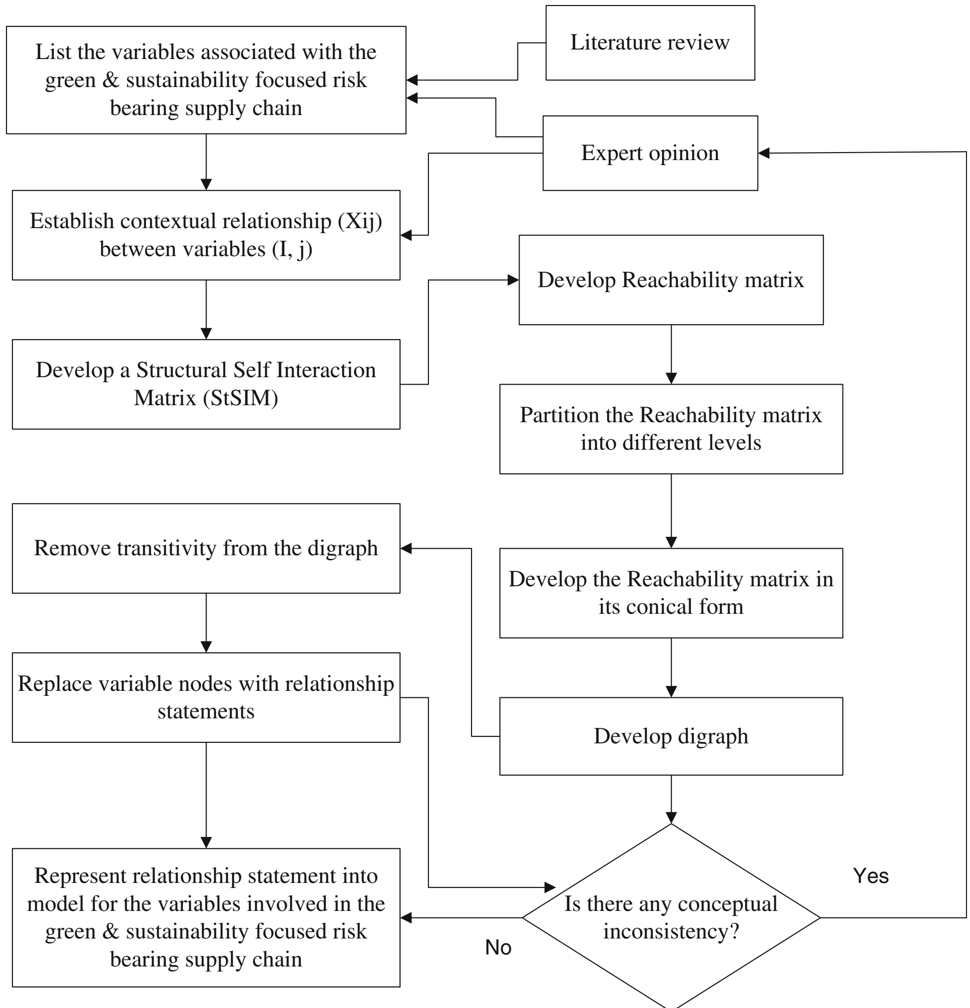

Fig. 2 Flow diagram for ISM methodology

(iii) Developing a Structural Self-Interaction Matrix (StSIM), this depicts pair wise interactions among the identified factors. A detailed description of the representations utilizes for indicating the directions of interaction among the factors are given as, if we consider the factors under study are i and j, at that time the representation 'V' indicates that factor i lead toward factor j, the representation 'A' indicates that factor j leads toward factor i. The representation 'X' indicates that factor i and j would ease to achieve each other and the representation 'O' indicates that factors are not related to each other. Then, form an initial reachability matrix (RM) on the basis of StSIM using some rules, as given as below:

- The (i, j) entry V in StSIM corresponds to the (i, j) entry 1 in RM and the (j, i) entry 0.
- The (i, j) entry A in StSIM corresponds to the (i, j) entry 0 in RM and the (j, i) entry 1.
- The (i, j) entry X in StSIM corresponds to the (i, j) access 1 in RM and the (j, i) entry 1.
- The (i, j) entry O in StSIM corresponds to the (i, j) access 0 in RM and the (j, i) entry 0.

(iv) An initial RM needs to be inspected to check the transitivity relations among the identified factors. Subsequently, prepare the final RM from initial RM. According to the transitivity connect rule, if a factor 'X' is connected to 'Y' and 'Y' is connected to 'Z', then 'X' will also to 'Z'.

(v) Partition, the final RM to obtaining the different levels for the hierarchy. Further, construct the reachability and antecedent set for every factor. However, the reachability set includes factor itself and the other factors that might be achieved with the help of the concerned factor. In the same way, the antecedent set includes factors itself and the other factors that might help to achieve the concerned factor. Next, derive the intersection or common sets for all factors. Furthermore, the factor which posses' identical entry in the intersection and reachability sets given top-level positions, and accordingly, it is eliminated. This process is iteratively repeated till all the factors acquire their respective levels.

(vi) Based on final RM and different level obtained for the identified factors, the digraph should be drawn to represent directional relationships.

(vii) Developing the final ISM based model after putting the factor nodes with statements in drawn directed digraph.

(viii) Finally, reviewing the proposed final ISM based model to check any conceptual irregularity, and if any then incorporating required modifications.

Through an edge by ISM is that it transforms complex and poorly sketched problems/models into clear, realistic and definite solutions, and in this manner, facilitates in answering what and how in the theory building. Though, the methodology of ISM entails several limitations, for instance, it lacks in analysing the causality of links, those not proficient in providing the answer of why in the theory building. In addition, the interpretation of links is limited in ISM based modeling, and thereby pose an issue via exposing the final model to multiple interpretations by the user according to their knowledge and experience. To overcome these issues, we have upgraded ISM to TISM, and which is described in details in next subsection.

Total Structural Modeling

To enhance the process of decision making, the final constructed structural models which delineate various relationships among considered factors and attributes need to be adequately interpreted. For the purpose, the 'Interpretive Matrix' has been developed as a managerial means which is quite useful in understanding and interpretation of the relationships in structural models in a certain dimension (Sushil 2005). The logic of the interpretive matrix is capable to interpret the directed and undirected binary or fuzzy relations for a structural model. On the other side, for a graphical model, relations can be interpreted using the side of the link linking the pair of elements having the relation, and in this way, by interpreting both the nodes and links, which was partial in ISM, an ISM based model can be upgraded as a total interpretive structural model (TISM). Further, TISM is widely accepted as a decision modeling approach, and is used by several scholars to model their problem (Nasim 2011; Srivastava and Sushil 2011; Sushil 2012). While, the basic procedural step of TISM is presented in Fig. 3 (Sushil 2012), however also describes as below:

(i) To identify and define elements and or factors in accordance with the study objective is the initiating step in the modeling of their relationships.

(ii) For modeling the identified elements, it is required to develop the contextual relationship between them. To fulfill the purpose of this research, the contextual relationship between different elements may be defined as an example, 'A should help achieve B' or 'A should help achieve B'.

(iii) To derive the interpretation of the relationship is the first step in further to the conventional ISM, as it is difficult to interpret that in what way the contextual relationships within the structural model would work. Therefore, for upgrading ISM to TISM, the interpretation of the relationship should be defined, may differ for different types of structures. However, in case of intent structures, we should interpret the relationship by understanding the basic mechanism of learning and knowledge about considered pair factors and generally it is defined in the form 'In what way A should/will help achieve B?'.

(iv) The interpretive logic of pair-wise comparison need to define. It has been already described that in conventional ISM, the StSIM is constructed to show the direction of relationship between factors. In order to upgrade it to TISM, it is suggested to utilize of the concept of interpretive matrix (Sushil 2012). The interpretive matrix would aids in interpreting the each pair wise comparison by answering the interpretive query in respect to the directional relationship between the considered elements. It need to remember while making pair-wise evaluations, that one element (say, ith) would be evaluated to all other elements (from I to 1, 2, 3…,n). And, there will be two possible directional links i–j or j–i, in correspond to each pair of elements (i, j) in the Knowledge Base, and the respective entry could be 'Yes(Y)' or 'No(N)' and it is to be further interpreted in case of 'Yes'. This will reveal the interpretive logic of the paired relationships in the form of 'Interpretive Logic—Knowledge Base'.

(v) To construct RM and check for transitivity. The pairwise evaluations in the Interpretive Logic—Knowledge Base are transformed into RM, which is based on logic that the entry 1 in i–j cell, corresponds to the entry 'Y' in the Knowledge Base, while entry 0 corresponds to the entry 'N' in the knowledge base. Then, it is checked for transitive relationships, and accordingly, for each new transitive link, the Knowledge Base has also updated. In the Knowledge Base, it is suggested to put the entry 'Transitive' along with causal logic if it is possible to explain the transitive relationship meaningfully, or else it is left as it is.

(vi) To do the level partitioning for identifying the levelwise positions of elements, and it is conducted in similar to conventional ISM (Saxena et al. 2006).

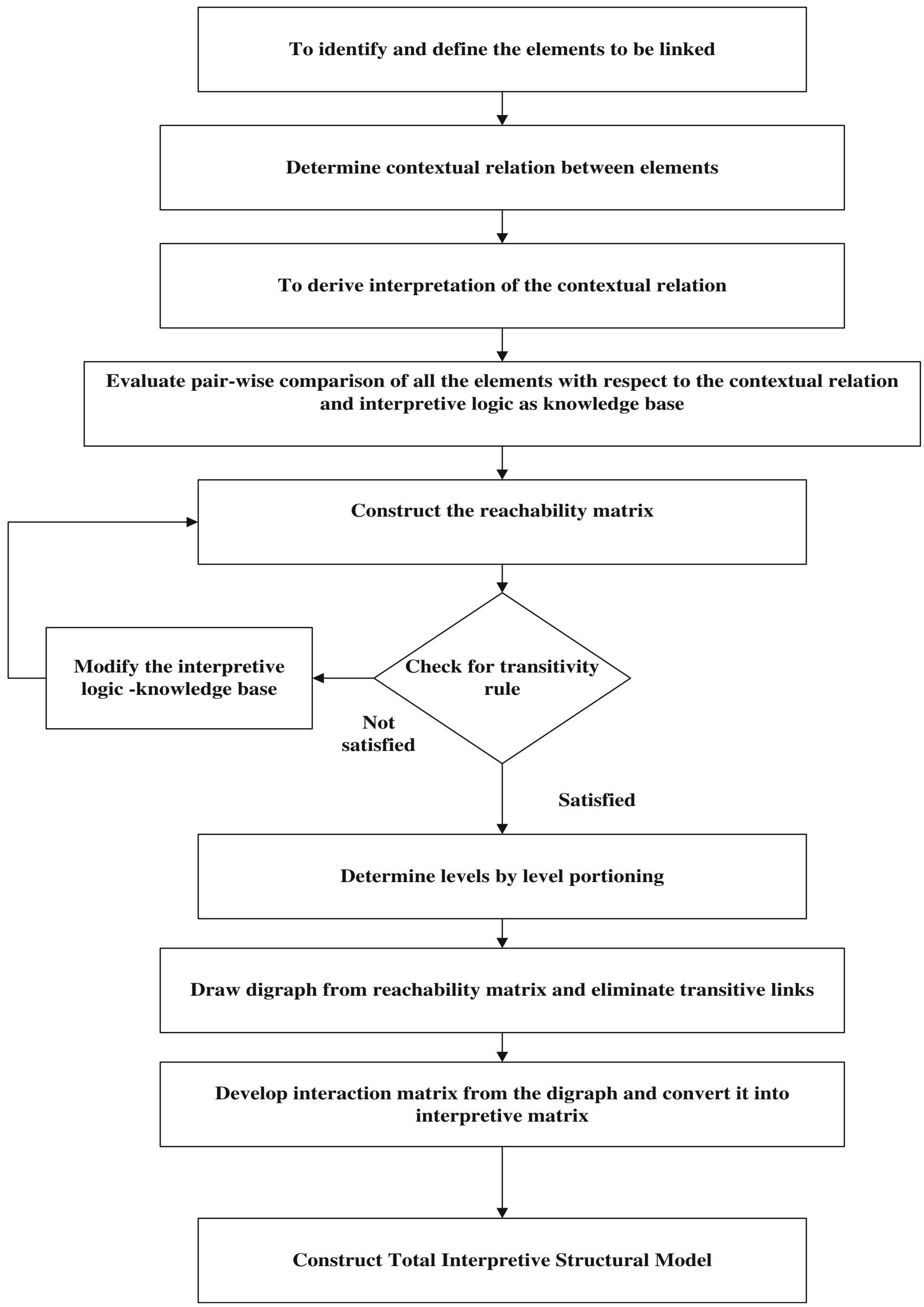

Fig. 3 Flow diagram for TISM methodology

(vii) The digraph is developed by arranging elements at their respective levels and the directed links are drawn according to relationships revealed in the RM. Only those transitive relationships should be retained whose interpretation is crucial.

(viii) To construct the interaction matrix, and for this, the final digraph need to transform into a binary interaction matrix which depicts all the interactions in terms of putting of entry 1, and further based on the Knowledge Base- Interpretive Logic, the entries 1 in the cell are interpreted with the respective relevant interpretation to form the interpretive matrix.

(ix) To construct TISM based Model. Using the relevant and interpretive information provided in the interpretive direct interaction matrix and digraph, the

TISM should be developed. Further, the statement written in boxes interpreting the elements replaces the respective nodes in the digraph. The interpreting interactions which are written in the interaction matrix should be illustrated at the side of the respective links in the structural model.

In this study on extending ISM to TISM approach, a novel decision model is proposed for building the risk managing capability in the sustainability focused supply chain, and is illustrated using an arbitrary example as presented below.

An Example

To test the proposed flexible decision approach using ISM and TISM, we have considered an example of arbitrary organizational sustainability focused supply chain and the problem is to build its risk bearing capability under regular and risk condition. For this, initially different factors related to build risk bearing capability in sustainability focused supply chain is explored (see "Interpretive Structural Modeling" section), while the details of applying the projected modeling approach is given as:

ISM Application

Recognition of Factors

On the basis of review of literature and the outlook of professionals of the SC and the academia, 14 important factors concerning the risk-bearing capability sustainability focused supply chain of considered example have been recognized and listed in Table 2.

Formation of StSIM and RM

The StSIM is constructed on the basis of contextual relationship between recognized factors (see Table 3).

Afterwards, based on rules as defined in the previous section, the RM, i.e. initial and final RM has been derived from the StSIM (see Table 4), This matrix presents the set of two interactions among the factors affecting sustainability and risk bearing initiatives for an example under study. Furthermore, based taking into account the transitivity interactions among identified factors, the, initial RM transformed into the final RM (see Table 5).

Level Partitioning for RM and Prepare the Digraph

Using step 5 in the ISM approach, the developed final RM is divided into distinct levels. The proposed ISM hierarchy illustrates that factor positioned at a level would not help to access other factor lying above to it. A higher-positioned level identified, they are removed from the list. From Table 6, Approach for continuous improvement (F14) to sustain in uncertain conditions of the environment is positioned at level 1 and hence on the top of ISM hierarchy. For iteration-1, approach for continuous improvement factor is found to have same reachability and the intersection sets, and so qualifies to hold level 1, and it is eliminated from the set. In this way, based on repeated iterations (a total 6 iterations in the considered example),

Table 2 Listing of factors concerning risk bearing capability of sustainability focused supply chain

Description of factors	Sources
Corporate social responsibility (F1)	Steurer (2006), Jorgensen and Knudsen (2006), Cruz and Matsypura (2009), and Carter and Easton (2011)
Decision and information sharing level (F2)	Prater (2005), Wadhwa et al. (2007), and Baihaqi and Sohal (2012)
Role of legitimacy (F3)	Beamon (2005), Walker et al. (2008), and Mangla et al. (2012)
Strategic risk planning (F4)	Zsidisin et al. (2004), Atkinson (2006), and Tang (2006)
Allocation of resources (F5)	Mason-Jones and Towill (1998) and Christopher and Lee (2004)
SC visibility and mutual transparency (F6)	Agarwal and Shankar (2002) and Christopher and Peck (2004)
Supply chain integration (F7)	Mason-Jones and Towill (1998) and Tang (2006)
Supply chain flexibility and agility (F8)	Agarwal and Shankar (2002), Lee (2004), Wadhwa et al. (2007), and Nandakumar et al. (2012)
Training and labour skill (F9)	Manuj and Mentzer (2008a, b) and Mangla et al. (2013a)
Supplier commitment (F10)	Christopher and Peck (2004), Zhu et al. (2008), and Mangla et al. (2012, 2013b)
Network and global complexion understanding (F11)	Atkinson (2006), Manuj and Mentzer (2008a, b), and Gurnani et al. (2012)
Security issues knowledge (F12)	Chopra and Sodhi (2004), Manuj and Mentzer (2008a, b), and Gurnani et al. (2012)
Knowledge and understanding about supply chain risks (F13)	Chopra and Sodhi (2004), Christopher and Peck (2004), Manuj and Mentzer (2008a, b), Tang and Musa (2011), and Gurnani et al. (2012)
Approach for continuous improvement (F14)	Mangla et al. (2012, 2013a)

Table 3 Structural self-interaction matrix

Factors	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Corporate social responsibility (F1)	V	V	V	V	V	V	V	V	A	V	V	V	A	
Decision and information sharing level (F2)	V	V	V	V	V	V	V	V	A	V	V	V		
Role of legitimacy (F3)	V	V	V	V	V	V	V	V	A	V	V			
Strategic risk planning (F4)	V	V	V	V	V	V	V	V	A	V				
Allocation of resources (F5)	V	V	V	V	V	V	V	V	A					
SC visibility and mutual transparency (F6)	V	V	V	V	V	V	V	V						
Supply chain integration (F7)	V	V	V	V	V	V	V							
Supply chain flexibility and agility (F8)	V	V	V	V	V	V								
Training and labour skill (F9)	V	V	V	V	V									
Supplier commitment (F10)	V	V	V	V										
Network and global complexion understanding (F11)	V	X	X											
Security issues knowledge (F12)	V	X												
Knowledge and understanding about supply chain risks (F13)	V													
Approach for continuous improvement (F14)														

Table 4 Initial RM

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Corporate social responsibility (F1)	1	0	1	1	1	0	1	1	1	1	1	1	1	1
Decision and information sharing level (F2)	1	1	1	1	1	0	1	1	1	1	1	1	1	1
Role of legitimacy (F3)	0	0	1	1	1	0	1	1	1	1	1	1	1	1
Strategic risk planning (F4)	0	0	0	1	1	0	1	1	1	1	1	1	1	1
Allocation of resources (F5)	0	0	0	0	1	0	1	1	1	1	1	1	1	1
SC visibility and mutual transparency (F6)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Supply chain integration (F7)	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Supply chain flexibility and agility (F8)	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Training and labour skill (F9)	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Supplier commitment (F10)	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Network and global complexion understanding (F11)	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Security issues knowledge (F12)	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Knowledge and understanding about supply chain risks (F13)	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Approach for continuous improvement (F14)	0	0	0	0	0	0	0	0	0	0	0	0	0	1

the level positions for all identified factors are obtained, as shown in Table 6. After determining all levels, the digraph is constructed for considered example as shown in Fig. 4.

Development of the Final ISM Model

Depending upon the level partition matrix, an ISM model for various factors imperative to understand the concept of SRBSC is proposed (see Fig. 5). Considering the ISM model, due to positioning at the bottom of the hierarchy, the SC visibility and mutual transparency (F6) is a very significant factor for building the risk bearing capabilities in sustainability focused supply chains. ISM hierarchy has been described as a relationship of various factors while moving from level 12 (SC visibility and mutual transparency) towards the desired outcomes, i.e. level 1 (Approach for continuous improvement) as shown in Fig. 5.

The final ISM based model lacks in interpreting the relationships for the considered factors written in box-type representation, and, in order to overcome the issues, we have upgraded ISM to TISM.

TISM Application

Identifying the Factors and Contextual Relationship

The first step of identification of the factors for the considered example is the same in TISM as already done in ISM. The contextual relationship is developed that in what

Table 5 Final RM

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driving influence
Corporate social responsibility (F1)	1	0	1	1	1	0	1	1	1	1	1	1	1	1	12
Decision and information sharing level (F2)	1	1	1	1	1	0	1	1	1	1	1	1	1	1	13
Role of legitimacy (F3)	0	0	1	1	1	0	1	1	1	1	1	1	1	1	11
Strategic risk planning (F4)	0	0	0	1	1	0	1	1	1	1	1	1	1	1	10
Allocation of resources (F5)	0	0	0	0	1	0	1	1	1	1	1	1	1	1	9
SC visibility and mutual transparency (F6)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Supply chain integration (F7)	0	0	0	0	0	0	1	1	1	1	1	1	1	1	8
Supply chain flexibility and agility (F8)	0	0	0	0	0	0	0	1	1	1	1	1	1	1	7
Training and labour skill (F9)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	6
Supplier commitment (F10)	0	0	0	0	0	0	0	0	0	1	1	1	1	1	5
Network and global complexion understanding (F11)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
Security issues knowledge (F12)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
Knowledge and understanding about supply chain risks (F13)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
Approach for continuous improvement (F14)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence influence	3	2	4	5	6	1	7	8	9	10	13	13	13	14	

way one factor will influence the other using the step 2 in TISM, and an illustration for this is presented in Table 7.

Derive the Interpretive Logic of Pair-Wise Comparison, and Construct RM

For upgrading ISM to TISM and based on step IV of the TISM approach, the final developed RM is evaluated to derive the interpretive logic of the all pair wise comparison for the identified factors. Further, using the step 5 in the TISM approach, the RM is drawn (which is same as in ISM approach), and it is inspected further to check for transitive relations.

Drawing the Digraph

Based on the ISM approach, the levels for the identified factors are identified and corresponding digraph has been drawn as shown in Fig. 4. While, transitive relations should be handled carefully in respective to their importance.

Construct the Interaction Matrix, and TISM Based Final Model

Using the step 8 in TISM approach, the interaction matrix is developed, as shown in Appendix 1 (Table 8). Further, using the relevant and interpretive information provided in the interpretive direct interaction matrix and digraph, the TISM model is developed for considered example as shown in Fig. 6. This offers the total interpretation of the structural model in terms of the interpretation of both nodes and links.

Relationship Analysis

For conducting relationship analysis, we have graphically analyzed the driving and dependence influence of the factors. On this basis, factors are categorized as autonomous, dependent, unstable or linkage, and independent factors. Further, the final RM provides the value of driving and dependence influence for each factor (Table 5). The factors, which we have stated like SC visibility and mutual transparency, SC integration, information and decision sharing, SC flexibility and agility and knowledge of supply risks all, are related to understand the theory of risk and building the knowledge to the probable risk issues, and it is crucial for an organizational perspective. Due to global changes in technology and multiple complexities in dimensions of sustainability and risk, the initiation and implementation of SRBSC practice is tedious. Further, if decision maker lacks in knowledge of understanding and relative significance of the factors related to the system, the cumulative behavior of the system will be difficult to estimate. In this consideration, initially we identified and further analyzed the factors graphically using relationship analysis as shown in Fig. 7.

Furthermore, the factors having less driving influence as well as dependence come under Quadrant 1 (named as autonomous elements). While factors having weak driving but strong dependence influence comes under Quadrant 2 (named as dependent elements). Similarly, other set of factors both strong driving and dependence influence comes under Quadrant 3 (named as linkage elements). These factors are further considered to be highly unstable and sensitive. A slight change in assessment of these factors can affect the whole system. Therefore, for a stable system less

Table 6 Level partition of factors

Factors	Reachability set	Antecedent set	Intersection set	Level
Iteration-1				
F1	1,3,4,5,7,8,9,10,11,12.13,14	1,2,6	1	
F2	1,2,3,4,5,7,8,9,10,11,12,13,14	2,6	2	
F3	3,4,5,7,8,9,10,11,12,13,14	1,2,3,6	3	
F4	4,5,7,8,9,10,11,12,13,14	1,2,3,4,6	4	
F5	5,7,8,9,10,11,12,13,14	1,2,3,4,5,6	5	
F6	1,2,3,4,5,6,7,8,9,10,11,12,13,14	6	6	
F7	7,8,9,10,11,12,13,14	1,2,3,4,5,6,7	7	
F8	8,9,10,11,12,13,14	1,2,3,4,5,6,7,8	8	
F9	9,10,11,12,13,14	1,2,3,4,5,6,7,8,9	9	
F10	10,11,12,13,14	1,2,3,4,5,6,7,8,9,10	10	
F11	11,12,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	
F12	11,12,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	
F13	11,12,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	
F14	14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	14	Level 1
Iteration-2				
F1	1,3,4,5,7,8,9,10,11,12.13	1,2,6	1	
F2	1,2,3,4,5,7,8,9,10,11,12,13	2,6	2	
F3	3,4,5,7,8,9,10,11,12,13	1,2,3,6	3	
F4	4,5,7,8,9,10,11,12,13	1,2,3,4,6	4	
F5	5,7,8,9,10,11,12,13	1,2,3,4,5,6	5	
F6	1,2,3,4,5,6,7,8,9,10,11,12,13	6	6	
F7	7,8,9,10,11,12,13	1,2,3,4,5,6,7	7	
F8	8,9,10,11,12,13	1,2,3,4,5,6,7,8	8	
F9	9,10,11,12,13	1,2,3,4,5,6,7,8,9	9	
F10	10,11,12,13	1,2,3,4,5,6,7,8,9,10	10	
F11	11,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	Level 2
F12	11,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	Level 2
F13	11,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	11,12,13	Level 2
Iteration-3				
F1	1,3,4,5,7,8,9,10	1,2,6	1	
F2	1,2,3,4,5,7,8,9,10	2,6	2	
F3	3,4,5,7,8,9,10	1,2,3,6	3	
F4	4,5,7,8,9,10	1,2,3,4,6	4	
F5	5,7,8,9,10	1,2,3,4,5,6	5	
F6	1,2,3,4,5,6,7,8,9,10	6	6	
F7	7,8,9	1,2,3,4,5,6,7	7	Level 6
F8	8,9,10	1,2,3,4,5,6,7,8	8	Level 5
F9	9,10	1,2,3,4,5,6,7,8,9	9	Level 4
F10	10	1,2,3,4,5,6,7,8,9,10	10	Level 3
Iteration-4				
F1	1,3,4,5	1,2,6	1	
F2	1,2,3,4,5,	2,6	2	
F3	3,4,5	1,2,3,6	3	
F4	4,5,	1,2,3,4,6	4	
F5	5	1,2,3,4,5,6	5	Level 7
F6	1,2,3,4,5,6	6	6	

Table 6 continued

Factors	Reachability set	Antecedent set	Intersection set	Level
Iteration-5				
F1	1,3,4	1,2,6	1	
F2	1,2,3,4	2,6	2	
F3	3,4	1,2,3,6	3	
F4	4	1,2,3,4,6	4	Level 8
F6	1,2,3,4,6	6	6	
Iteration-6				
F1	1,3	1,2,6	1	Level 10
F2	1,2,3	2,6	2	Level 11
F3	3	1,2,3,6	3	Level 9
F6	1,2,3,6	6	6	Level 12

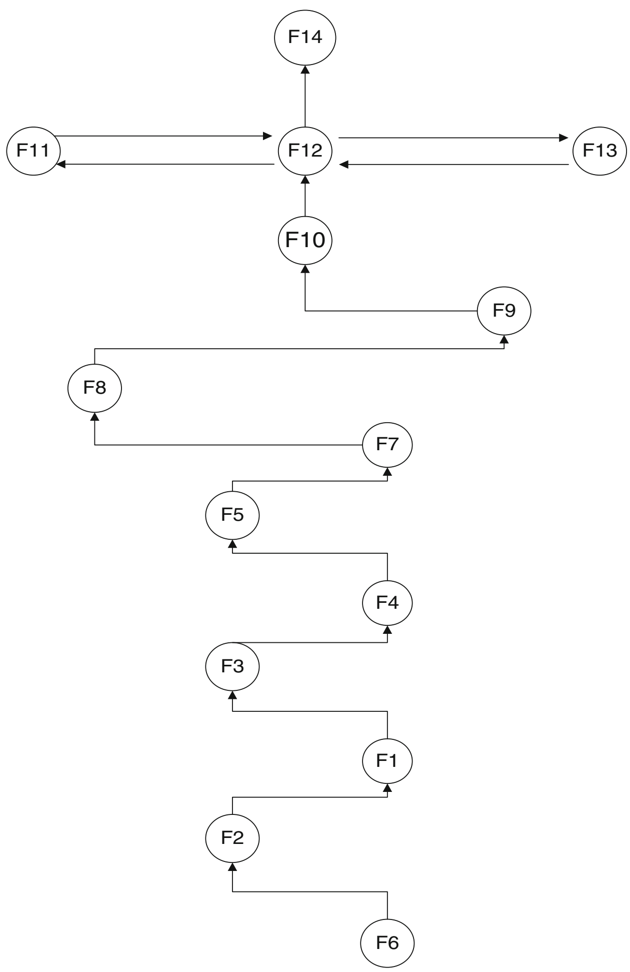

Fig. 4 Digraph with direct links and no significant transitive link

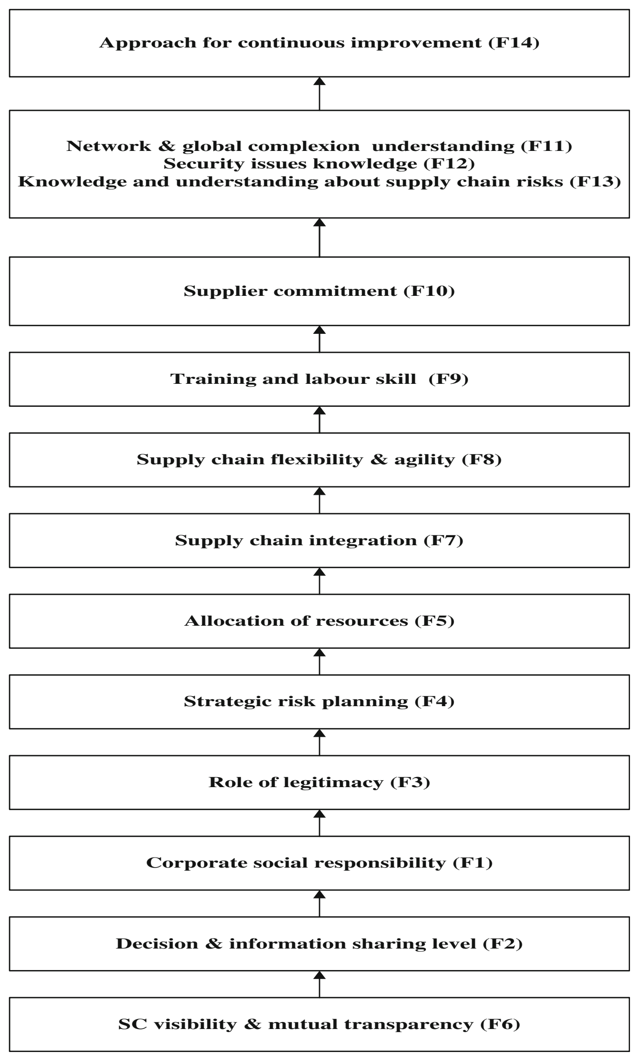

Fig. 5 Final ISM model

number of factors is required to be there in this sector. In our study also we have no factor been found in this sector.

Additionally, the factors having high driving influence but less dependency over other factors comes under Quadrant 4 (named as independent elements) (Mangla et al. 2012). Because, these factors have strong driving influence i.e. they strongly affect other sector factors and weak

Table 7 Factors, contextual relationship and interpretation for the considered example

Factors	Contextual relation	Interpretation
Factors affecting SRBSC	Factor A will influence/enhance other considered factor B to built risk manageable or bearing capability of sustainable supply chain	How or in what way factors A will influence/ enhance other considered factor B to built risk manageable or bearing capability of sustainable supply chain?
Corporate social responsibility (F1), Decision and information sharing level (F2) up to Approach for continuous improvement (F14)		

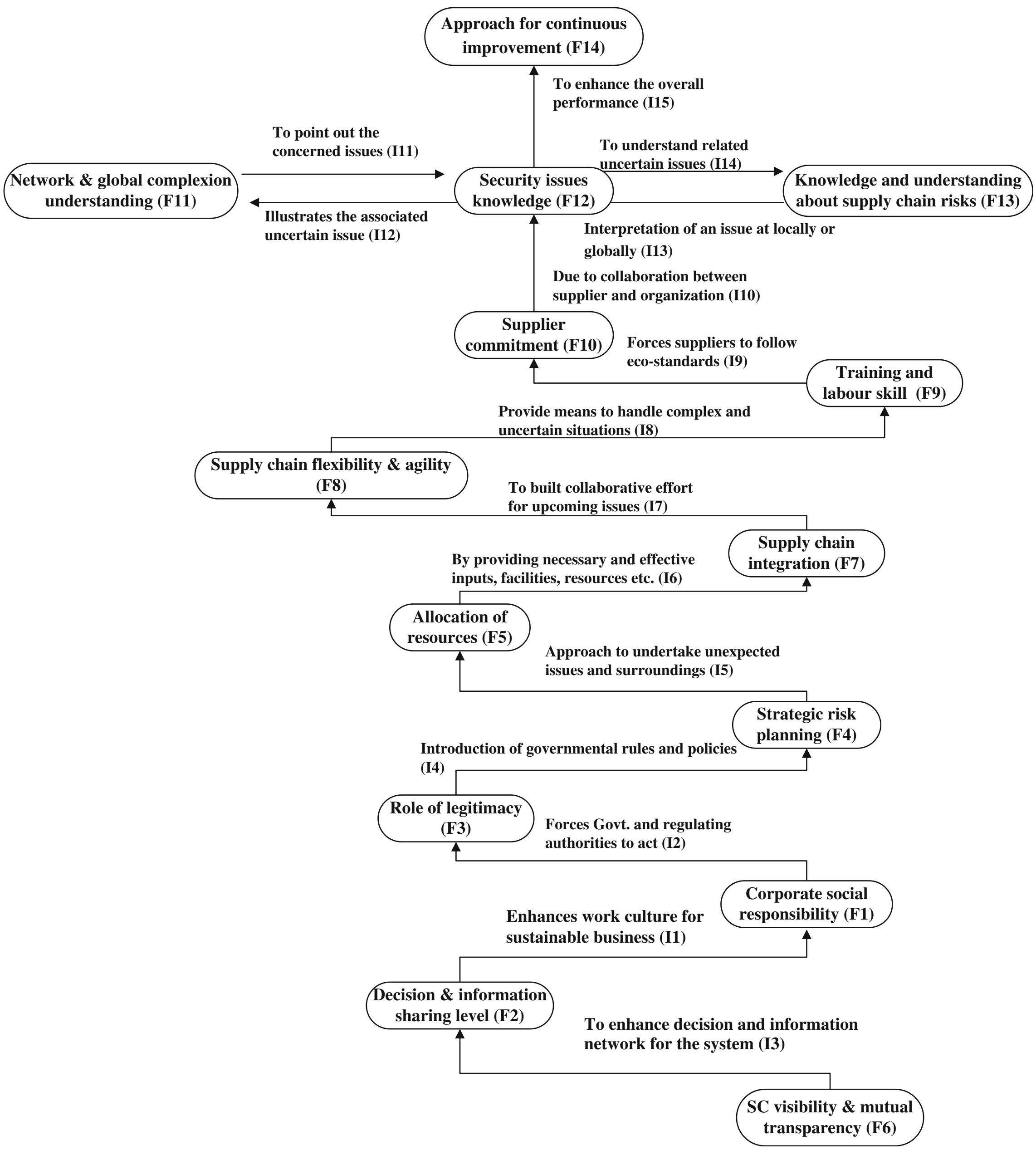

Fig. 6 Final TISM model

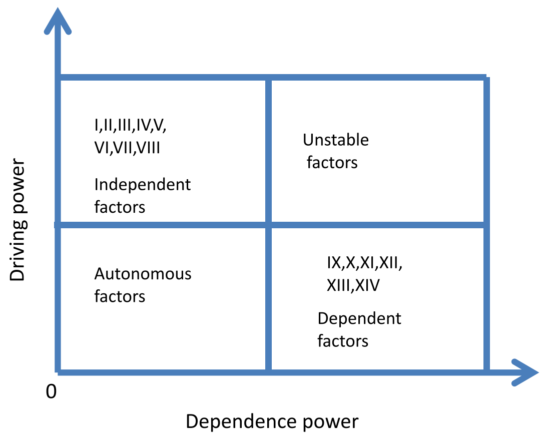

Fig. 7 Driving and dependence influence matrix

dependence influence i.e. didn't much depend on other sector factors. As these factors help to attain desired outcome factors positioned at the higher levels in the ISM hierarchy, so there is a strong need to address them. As, due to shortened life cycles of products and environmental consciousness, collaboration and smart use of resources in various processes are becoming important these days. Finally, the organization should focus to become more productive with a tendency to sustain under the environment of uncertainties and risk events.

Discussion and Implications for Managers

As stated earlier, the increasing environmental consciousness and awareness will force the introduction of new laws and policies, which further drives the business decisions to a new competitive world. In case, the proposed model may be used to obtain estimates on system performance and continuous improvement for specific characteristics of risk bearing based sustainability focused supply chains. For increasing the responsiveness and overall performance of the system, flexible aspect of the sustainable supply chain is crucial. Moreover, under stable or normal conditions, the sustainable supply chain may behave satisfactorily, however, under risks and uncertain surrounds, flexibility in supply chain planning can offer an edge to build the SC more on proactively (preventive or reactive) to sustaining in the global environment.

The model proposed in this study offers an attempt to establish as an investigational tool, with which the proper selection of various factors might help to analyze and answer questions about the risk bearing behavior of sustainable supply chains. Further, our research also promises several implications at managerial level, which are given as:

- In this study, no factor is found under Quadrant 1 dimension, it means that amongst all identified factors; no one posse's weak driving impact and dependence influence.
- The factors listed under Quadrant 2, i.e. training and labour skill (F9), supplier commitment (F10), network and global complexion understanding (F11), security issues knowledge (F12), knowledge of supply chain risks (F13), and approach for continuous improvement (F14) have little driving tendency but strong dependency on other factors such as corporate social responsibility (F1), decision and information sharing (F2), role of legitimacy (F3), strategic risk planning (F4), allocation of resources (F5), SC visibility and mutual transparency (F6), supply chain integration (F7), supply chain flexibility and agility (F8). Finally, approach for continuous improvement (F14) factor positioned at level 1 in the ISM hierarchy; this factor denotes the possibilities and the requirements of continuing evaluation and development on a broad perspective to enhance the sustainable and risk bearing behavior in SCs.
- One more categorization of factors Quadrant 3, i.e. having strong driving as well as dependence influence called as unstable/linkage elements. Due to which, within a system any action on these sector factors have strong dependence on each other and also having a great impact on other sector factors. In case, no factor is seen as unstable element.
- The independent factors of the Quadrant 4 for the SRBSC, such as corporate social responsibility (F1), decision and information sharing (F2), role of legitimacy (F3), strategic risk planning (F4), allocation of resources (F5), SC visibility and mutual transparency (F6), supply chain integration (F7), supply chain flexibility and agility (F8) occupied lower levels in proposed ISM model. Because, these factors have strong driving impact influence i.e. they strongly affect other sector factors and weak dependence influence i.e. did not much depend on other sector factors. These sector factors structured the base of the ISM hierarchy so should be highly intentioned to fulfill desired objectives. Summarizing, there must be some planning and strategies towards effectively allocation of the independent factors, which helps in successful understanding the concept of sustainability along with risk bearing capability in SCs.

The proposed model can be adopted not only to focus social-economical-environmental issues but also benefits in the organization's perspective. While the proposed ISM based model which is extended with TISM for TISM based final model offer additional means to build causal relations among the identified factors for the organizational edge. It also enables the managers to build competency for their SC to sustain under normal and risks, by understanding the relationship mechanism, i.e. in what way, one factor is affecting other one.

Conclusions and Scope for Future Work

In this work, a sustainability focused SRBSC influenced by various factors has been studied. The sustainable and green are the need of today's SC and organizations have already initiated or thinking to initiate the concept of sustainability in their SC. As initiation or implementation of green and sustainability is not so easy, due to association of certain factors and attributes. In this context, based on relevant literature and in consultation with experts, the authors have identified 14 important factors concerning the risk-bearing capability of sustainability focused supply chain. The knowledge of uncertain factors and issues in sustainability focused supply chains provides preliminary beginning to the organization's objective to value maximization under risks.

Our research proposes a flexible decision modeling approach, i.e. ISM to analyze the interaction and examination of various factors along with concerning risks in green and sustainability focused supply chain issues. The proposed ISM model can help top management to plan the set of specific actions to conduct sustainable and risk sources, assessing and managing operations along with maximization of market share. However, the ISM lacks in interpretation of relationships between considered factors, so ISM is upgraded to TISM, which can effectively illustrate the interpretations for the directed links in the final TISM based model. Additionally, a relationship analysis is also presented on the basis of driving and dependence influence of the factors for exemplar under study. The developed driving influence-dependence matrix provides a clear illustration for the relative importance of factors.

In the end, we discussed the potentials and scope for further improvement. The final TISM based methodology is primarily depends on the experience and judgment of the decision makers so need to be carefully used. In research, we generalized in approach to develop an ISM and TISM based structural model and which could be tested further for a specific industry sector. Further, the proposed TISM model can be used to develop hypotheses for finding the impact of social, environmental and global changes on the performance of SRBSC. The identification of drivers and barriers for building risk mitigation strategies in SRBSC for various organizational contexts (i.e. small, medium and large organizations) can also be considered as another area of research in green and sustainable supply chain context.

Appendix 1

See Table 8.

Table 8 Interaction matrix

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(a) Binary matrix														
Corporate social responsibility (F1)	–	0	1	0	0	0	0	0	0	0	0	0	0	0
Decision and information sharing level (F2)	1	–	0	0	0	0	0	0	0	0	0	0	0	0
Role of legitimacy (F3)	0	0	–	1	0	0	0	0	0	0	0	0	0	0
Strategic risk planning (F4)	0	0	0	–	1	0	0	0	0	0	0	0	0	0
Allocation of resources (F5)	0	0	0	0	–	0	1	0	0	0	0	0	0	0
SC visibility and mutual transparency (F6)	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Supply chain integration (F7)	0	0	0	0	0	0	–	1	0	0	0	0	0	0
Supply chain flexibility and agility (F8)	0	0	0	0	0	0	0	–	1	0	0	0	0	0
Training and labour skill (F9)	0	0	0	0	0	0	0	0	–	1	0	0	0	0
Supplier commitment (F10)	0	0	0	0	0	0	0	0	0	–	0	1	0	0
Network and global complexion understanding (F11)	0	0	0	0	0	0	0	0	0	0	–	1	0	0
Security issues knowledge (F12)	0	0	0	0	0	0	0	0	0	0	1	–	1	1
Knowledge and understanding about supply chain risks (F13)	0	0	0	0	0	0	0	0	0	0	0	1	–	0
Approach for continuous improvement (F14)	0	0	0	0	0	0	0	0	0	0	0	0	0	–

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
(b) Interpretive matrix														
Corporate social responsibility (F1)	–	–	I2	–	–	–	–	–	–	–	–	–	–	–
Decision and information sharing level (F2)	I1	–	–	–	–	–	–	–	–	–	–	–	–	–
Role of legitimacy (F3)	–	–	–	I4	–	–	–	–	–	–	–	–	–	–
Strategic risk planning (F4)	–	–	–	–	I5	–	–	–	–	–	–	–	–	–
Allocation of resources (F5)	–	–	–	–	–	–	I6	–	–	–	–	–	–	–
SC visibility and mutual transparency (F6)	–	I3	–	–	–	–	–	–	–	–	–	–	–	–
Supply chain integration (F7)	–	–	–	–	–	–	–	I7	–	–	–	–	–	–
Supply chain flexibility and agility (F8)	–	–	–	–	–	–	–	–	I8	–	–	–	–	–
Training and labour skill (F9)	–	–	–	–	–	–	–	–	–	I9	–	–	–	–
Supplier commitment (F10)	–	–	–	–	–	–	–	–	–	–	–	I10	–	–
Network and global complexion understanding (F11)	–	–	–	–	–	–	–	–	–	–	–	I11	–	–
Security issues knowledge (F12)	–	–	–	–	–	–	–	–	–	–	I12	–	I13	I15
Knowledge and understanding about supply chain risks (F13)	–	–	–	–	–	–	–	–	–	–	–	I14	–	–
Approach for continuous improvement (F14)	–	–	–	–	–	–	–	–	–	–	–	–	–	–

I1 enhances work culture for sustainable business, *I2* forces Govt. and regulating authorities to act, *I3* to enhance decision and information network for the system, *I4* introduction of governmental rules and policies, *I5* approach to undertake unexpected issues and surroundings, *I6* by providing necessary and effective inputs, facilities, resources, etc., *I7* to built collaborative effort for upcoming issues, *I8* provide means to handle complex and uncertain situations, *I9* forces suppliers to follow eco-standards, *I10* due to collaboration between supplier and organization, *I11* to point out the concerned issues, *I12* illustrates the associated uncertain issues, *I13* interpretation of an issues at locally or globally, *I14* to understand related uncertain issues, *I15* to enhance the overall performance

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Key Questions

1. Why it is necessary to understand the concept of risk/ uncertainty in green focused sustainable supply chain?
2. How an organization can address supply chain risks together with in managing the environmental and social issues along with maximizing of profit?
3. In what way, a flexible decisions making approach (ISM and TISM) can be helpful for sustainable supply chain to make it capable to build its capability on risks and risk issues?
4. How the causality and interaction among the factors can be evaluated in determining the factors those crucial for sustainability focused chain?

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