

Interpretive Structural Modelling (ISM) Methodology and its application in Supply Chain Research



Nilesh Wankhade, Gautam Kumar Kundu

Abstract: *The horizon of the supply chain (SC) in the business is increasing continuously and becoming complex with its expanding role, which is result of technological advancement, ever increasing customer expectation, regulatory compliances and changing business models. Researchers used various methods to understand SC complexity and decipher the factors impacting the SC processes and concepts. Interpretive Structural Modelling (ISM) is one of the methods which is widely used in literature to transform complex and abstract business phenomenon or vaguely defined business processes into clearly articulated, visual, structured models. This method includes interactive technique which helps to structure and build the comprehensive systematic model for set of different but related elements.*

The objective of this paper is to review the literature on ISM as methodology for understanding the complexity of SC challenges, issues, barriers and enablers of various processes or functions and their classifications based on SC processes using a structured approach. This study further elaborates the process for modelling structure and presented ISM as a modelling approach by elaborating steps and important features.

Discussion and managerial implications of using and extending ISM in SC are provided to conclude the review.

Keywords : *Supply Chain Management, Interpretive Structural Modelling, ISM, SSIM, Research methodology in SC, Modelling in SC*

I. INTRODUCTION

Supply Chain (SC) of businesses have been experiencing rapid globalization [1] and emerging technological changes along with technological trends are changing the landscape of SC along with the environment in which it operates. The boundaries of SC are expanding due to increasing collaboration and coordination with various partners in the value chain. This collaboration in SC can create new revenue opportunities across the chain [2], improves SC performance and efficiency.

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* Correspondence Author

Nilesh Wankhade*, Research Scholar – VITBS, VIT University, Vellore, TN, India. Email: nileshwankhade@gmail.com. Ph +1 479 312 7875

Gautam Kumar Kundu, Professor – VITBS, VIT University, Vellore, TN, India. Email: gkk@vit.ac.in

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However, this also simultaneously increases the complexity. Prominent reasons for such complexity in SC are overlapping boundaries of SC processes, multiple factors impacting these processes which may be directly or indirectly related and interaction among them. Such interaction complicates the structure [3]. When structures are not defined properly then understanding the SC problems becomes challenging [4]. This raises the requirement of methodology

which can be used for complex and issues with abstract information having less clarity which also involves many variables among which interaction is not clearly defined. Interpretive structural modelling (ISM) is one of the widely used methodology to overcome such challenges [5]. ISM is well established modelling and learning technique to depict the complex structure into carefully designed pattern implying graphics as well as words with the help of comprehensive and systematic model [6]. ISM is well suited for inductive research where detailed observations transform to empirical generalization to ascertain the relationship among variable and derive the frameworks. Review articles confirm the trends in SC research moving from theoretical to empirical articles [7, 8]. The motivation for the review is the result of this importance and complexity of SC, suitability of ISM methodology in SC area and moving trends in the field of research from theoretical to empirical nature.

The key objectives of this paper are

- To review the literature on ISM as methodology in SC research area
- To understand the key characteristics and steps of implementation of ISM
- Compare and understand ISM with respect to other multi criteria decision making methodologies.
- Detailed review of literature related to SC issues, barriers and enablers of various processes or functions for the use of ISM as methodology
- To explore and understand the advantage and limitation of ISM.

The objective is also to discuss and comment on managerial implications of using ISM to understand SC issues.

This subsequent sections in this paper are organized as follow - section 2 describes the review methodology, section 3 explains the ISM and its application in SC research area followed by section 4 for discussion and section 5 for managerial implication.



II. REVIEW METHODOLOGY

The key objective of the review of literature is to describe, summarize, evaluate, clarify, and/or integrate the content of the primary reports [9]. This is the process of iterative cycle of defining keywords, literature search followed by analysis [10]. This paper also follows the same rationale.

As suggested by some authors [11] and in line with the recent review papers [12, 8] which includes collection of articles after detailed keyword search from select research databases, data analysis by elimination of duplicates and irrelevant papers, Sorting and grouping, detailed analysis with commentary with discussion and findings. Fig. 1 depicts the research methodology adopted in this paper.

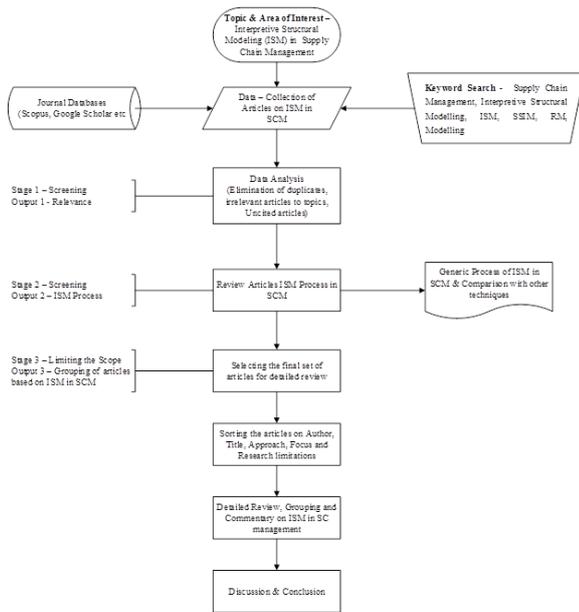


Fig. 1. Research Methodology

The approach is extended to extract the 3-stage output of data collection. Stage 1 includes the extensive search of the paper published in the SC research area which includes the ISM as key methodology. Keyword search criteria is employed to identify the prospective articles for consideration. In this study, the query keywords used were ISM in Supply Chain Management, ISM, Interpretive Structural Modelling, Supply Chain Practices, and Modelling. Using these keywords five different combinations are made and articles are searched in various databases such as Science Direct and Google Scholar. Initial results of search are mentioned in Table 1.

Result of multiple keyword search is further refined based on keyword combination relevance in titles and abstract.

Table I – Google Scholar result on 22 Jan 2018

Search keywords	Google Scholar
ISM OR Supply Chain Management	10100
Supply Chain AND ISM	13400
Supply Chain AND Interpretive Structural Modelling	1720
Supply Chain AND Practice AND Modelling AND ISM	5570
All in title: ISM and "Supply Chain"	14
All in title: Supply Chain AND Interpretive Structural Modelling	6

*NOTE - Search Conditions Exact Match and between Year 2010 - 2018

Stage 2 includes the second level refinement, which is done after removal of duplicates and further refinements is done based on presence of search keyword combinations in title followed by abstract, article keywords, conclusion and then in full article with respective importance. 111 papers from the list analyzed to review the applicability of ISM approach in SC Management research. The list of key journals and the count of articles are mentioned in Table II

Table II – Distribution of Journal and Article Count

Journal Title	Number of Articles
Benchmarking: An International Journal	4
IEEE Conferences	4
International Journal of Logistics Systems and Management	3
Global Business Review	3
Journal of Modelling in Management	3
Global Journal of Flexible Systems Management	2
Mathematical Problems in Engineering	2
The TQM Journal	2
The International Journal of Advanced Manufacturing Technology	2
International Journal of Engineering Technology & Management Research	2
International Journal of Production Management and Engineering	2
Production & Operations Management	1
Business Process Management Journal	1
International Journal of Applied Decision Sciences	1
International Journal of Business and Information	1
Journal of Industrial and Production Engineering	1
International Journal of Business Excellence	1
International Journal of Engineering and Management Research	1
Mathematics in Practice and Theory	1
Applied Mathematical Modelling	1
International Journal of Environmental Science and Technology	1
International Journal of Information Systems and Supply Chain Management	1
Journal of Business Economics and Management	1
International Journal of Innovation and Technology Management	1
International Journal of Integrated Supply Management	1
Journal of Industrial Engineering and Management	1
Journal of Manufacturing Technology Management	1
International Journal of Management Science and Engineering Management	1
Management Decision	1
International Journal of Operations & Production Management	1
Management Research News	1
Production Planning & Control	1
Uncertain Supply Chain Management	1
International Journal of Quality & Reliability Management	1
Supply Chain Forum: An International Journal	1
Value Engineering	1
International Journal of Production Research	1
Others	56
Total	111

Identified articles are reviewed to meet the objective of understanding ISM process as used in SC research. Generic steps along with various approaches and the comparison with other techniques are explained in section 3.1.



Stage 3 of screening is intended to limit the articles from the literature for detailed review to meet objective 3, 4 and 5. Out of 111 articles considered for this review, 49 articles are selected and further reviewed for the use of ISM as methodology

III. ISM AND ITS APPLICATION IN SC RESEARCH AREA

This section describes the review of ISM literature, its characteristics, key steps involved in ISM and its application as methodology for understanding the complexity of SC challenges, issues, barriers and enablers of various processes or functions and their classifications based on content, context and process using a structured approach

A. Interpretive Structural Modeling (ISM)

To analyze the complex socioeconomic systems John N. Warfield at Battelle Memorial Institute developed the interactive learning technique in 1973 which results into comprehensive and systematic model to provide the structure for different but related elements. This technique considers the roadmap of complex problems where multiple options are available [13]. A discrete mathematics-based theory, ISM is also a graph theory which is generally used in group decision making with computer programming [14]. ISM helps in better articulation of the mental models with the help of visual representation [15]. Thus ISM can be explained as modelling method which converts the complex model and presents in graphical content which is derived from designed patterns containing visuals along with textual descriptions to provide relationship among the various parameters in hierarchical manner [16].

ISM belongs to the multi criteria decision making (MCDM) approaches which are widely used in operations research and considered as valuable tool [17]. MCDM also includes many other methodologies like Analytic Network Process (ANP), Goal Programming, Value Analysis, Analytic Hierarchy Process (AHP), Best Worst Method, PROMETHEE etc. which are used in the different areas of operations management and SC management. Literature [18] provides the comparison of ISM technique with AHP and ANP and details out the advantages of ISM implementation by commenting on below 4 aspects

- ISM involves a set of criteria which are interconnected rather than loose network in ANP or strict discipline of hierarchy in AHP,
- ISM helps to address the complexities of practical challenges and problems however ANP deals with nonlinear and AHP fails as complexity increases,
- ISM generates the “leads to” relationships among the criteria and ANP Considers the interdependencies
- ISM has higher ability for capturing dynamic complexity as compare to ANP and AHP

B. The key characteristics of ISM can be summarized as follow

- The relationship among the components or elements is based on the interpretation of the group or individual
- Models are structured based on relationship among the elements

- Modeling technique provides the digraph models to depict the relationship between the components
- ISM supports to ensure order and direction on the complexity of relationships among various elements of a system.
- Widely used in group learning process of complex issues where inputs on various elements related to research area are generated using various methods like brainstorming, structured interviews, Delphi methods or opinion from academicians and industry expert which is extended with further analysis with MICAMC, Fuzzy Micmac, TOPSIS, Fuzzy Topsis, ANP, Fuzzy ANP etc. to evaluate the driving and dependence power among groups.

C. Steps in ISM methodology

ISM uses Boolean algebra and graph theory for MCDM process to construct the directed graph with or without computer programming [3]. This makes it easy to use by bringing the simplicity in approach. Literature [19, 20, 3, 21] explain the process and steps involved in ISM methodology which are also explained in below steps and figure 2.

- Variable/factors identification: The variables of the system are identified which are relevant to the problem or issue. This can be achieved with a group problem-solving technique like brain storming sessions, Delphi method or opinion from academicians and industry expert.
- Building the contextual relationship: From the variables identified in step 1, a contextual relationship is built among the variables with respect to whom the pairs of variables would be examined.
- After resolving the enabler set and the contextual relation, a structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of elements of the system under consideration.
- Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if element A is related to B and B is related to C, then A is necessarily related to C.
- The reachability matrix obtained in earlier step is converted into the canonical matrix format by arranging the elements according to their levels.
- From the canonical matrix form of the reachability matrix a directed graph is drawn by means of vertices or nodes and lines of edges and the transitive links are removed based on the relationships given above in the reachability matrix. The resultant digraph is converted into an ISM, by replacing enabler nodes with statements

IV. ISM METHODOLOGY IN SC MANAGEMENT

Considering the advances in the SC and increasing complexity, there are abundant research done in last few decades.

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However right from definition, scope, different elements of SC and also the way it operates in various environment varies from business to business. SC management revolves around SC strategy, practices and partners. SC practices are those which integrate SC partners (supplier, manufacturer, distributors and customers) and this integration is difficult than perceived by academicians and consultants [22]. Considering the various characteristics of ISM, this methodology is found to be simple and applicable to study and explore the various real life SC challenges and as well as different issues, barriers and enablers of various SC processes.

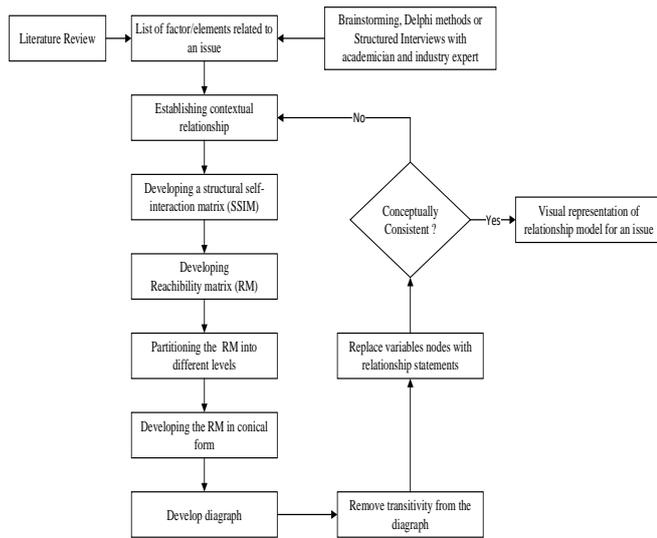


Fig. 2. ISM methodology and Steps

Source: [19, 20, 3, 21]

As explained in methodology the literature from 2010 to 2018 which are focused on SC area and used ISM as methodology are targeted for review. These includes the review articles by [23] which focuses on the review of the articles from 1994 to 2014 for ISM methodology use in various application areas including SC. Out of 110 articles considered for this review, 49 articles are selected and further reviewed for the use of ISM as methodology after grouping them into the 10 different categories as SC Management, SC Process & Practices, SC Performance Management, SC Collaboration, SC Agility, Quality, SC Risk Management, Humanitarian SC, Service SC, Green SC (GSC) & Sustainability in SC. Table 3 mentions the application of by various researchers in issues related to SC areas

Table III – Application of ISM in SC research

SC Area	Paper	Problem/Subject/Application Area
SC Agility	[24]	Modelling supply chain Agility
Green SC	[25]	Theory of Green SC using TISM
Humanitarian SC	[26]	Analysis of critical success factors of humanitarian supply chain
SC Quality	[27]	Barriers to total quality management implementation
SC Performance	[28]	Risk propagation and its impact on performance
SC Collaboration	[2]	Modelling the enablers of supply chain collaboration
SC Performance	[29]	Lean, green and resilient practices influence on supply chain performance
SC Process &	[30]	Modelling of the supplier development and

SC Area	Paper	Problem/Subject/Application Area
Practices		selection process enablers
SC Risk Management	[31]	Analysis of SC Risks in different contexts
Service Supply Chain	[32]	Inhibitors and enablers of service supply chain
SC Agility	[33]	Evaluate Supplier Agility Criteria and Ranking Suppliers
Green SC	[34]	To extract the interrelationships among the identified behavioral factors of GSCM
Humanitarian SC	[35]	Supply Chain Management for Human Life Betterment
SC Quality	[36]	Barriers affecting the effective utilization of quality tools and technique in SC
SC Collaboration	[37]	Modeling the benefits of supply chain collaboration
SC Performance	[38]	Interactions Among the Barriers of Supply Chain Performance Measurement
SC Process & Practices	[39]	Modelling of the supplier development and selection process enablers
SC Risk Management	[40]	Competitiveness of uncertainty and risk measures in supply chain
Service Supply Chain	[41]	Modelling the services supply chain of management consulting institutes
SC Sustainability	[42]	Enablers of Sustainable supply Chain
SC Process & Practices	[43]	Relationship and Vendor selection criteria in SC
SC Process & Practices	[44]	Influence Factors of the Supply Chain Distribution Center Location
SC Sustainability	[45]	Flexibility factors in Sustainable Supply Chain
SC Process & Practices	[46]	Analysis of the procurement related attributes in JIT supply chain management.
Green SC	[47]	Barriers in Green SC Management implementation
SC Quality	[48]	Critical success factors in quality function deployment
SC Process & Practices	[49]	Evaluation of buyer-supplier relationships
SC Process & Practices	[50]	Analysis knowledge flow element in the supply chain coordination
SC Process & Practices	[51]	Influencing Factors of Knowledge Sharing in Pharmaceutical Supply Chain
Green SC	[52]	Barriers to Implement Sustainable Supply Chain Management
SC Management	[5]	Critical barriers of supply chain management in Manufacturing
SC Process & Practices	[53]	Interaction of critical factors of supplier development
SC Process & Practices	[54]	Modelling the supply chain knowledge flow enablers
SC Process & Practices	[55]	Modeling the enablers of Six Sigma
SC Management	[56]	Modelling the enablers of supply chain management
SC Process & Practices	[20]	Reconfiguration of supply chain network
SC Process & Practices	[57]	Integration of Six Sigma and ISM to improve Supply Chain Coordination
SC Performance	[58]	sustainable supply chain performance
SC Process & Practices	[59]	Barriers in green lean six sigma product development process
SC Process & Practices	[60]	Benefits of Implementing Big Data Driven Supply Chain Management
SC Performance	[61]	interactions among the variables of supply chain performance measurement system

SC Quality	[62]	Factors Affecting the Quality of Construction Engineering
SC Process & Practices	[63]	To evolve mutual relationships among the information sharing enablers
SC Process & Practices	[64]	Mutual relationships among IT based enablers of Supply Chain Management
Green SC	[65]	Enablers in Green SC Management implementation
SC Quality	[66]	Modeling for integrating quality management in manufacturing and service counterparts.
SC Quality	[67]	Identification of influential quality management variables
SC Sustainability	[68]	Critical success factors of sustainable supply chain management practices
SC Sustainability	[69]	Interactions among sustainability supplier selection criteria

A. SC Process & Practices

Selection and managing the vendors or suitable suppliers in the SC has become a key strategic consideration. However, nature of these decisions is usually complex and unstructured. From this group authors [39, 30, 43] provides the model to for supplier selection and development process and identified the key enables using ISM followed by MICMAC approach. Literature [49] evaluated this relationship in automotive domain in Indian context using ISM also provided the empirical evidences for the interaction between the critical factors of supplier development [53]. Researcher [54, 50] also used ISM in modelling and analyzing the enablers of knowledge sharing and management in SC and also in specific to Pharmaceutical SC [51]. Researchers [44, 20] used ISM in network network analysis of SC. In context to six sigma process in SC, some authors [55] modelled the enablers and some [42] presented the barriers in green lean six sigma product development process or provided model of integration of six sigma and ISM to improve SC coordination [57]. ISM is used to analyze the procurement related attributes in ‘just in time’ SC management [46] and also used to model the advantages of implementing big data driven SC [60]. For enablers of IT and ICT processes of SC researchers [64, 63] used ISM for modelling the framework.

B. SC Performance Management

Well managed SC provide competitive advantage [61, 70, 71] and become the cornerstone in the differentiation strategy [72]. The process of SC performance management provides the control to manage the complexity of SC ensuring the objectives are achieved and SC is well managed. ISM has been used by researchers [38, 73, 58] to study the interaction between the variables and barriers for the SC performance management. [29] used ISM to explore how lean, green and resilient practices influence on SC performance

C. SC Management

There are many studies on SC management and various enablers and barriers for implementation SC practices. [56] identified 18 key enablers and developed model which is integrated by using ISM and the fuzzy MICMAC approach. This approach is used to identify and classify the important enablers and reveal the direct and indirect effects of each enabler on the SC implementation. [5] identified the barriers of SC management in manufacturing contexts using ISM methodology.

D. SC Collaboration

Collaboration between the SC partners and especially the independent firms which belongs to same value chain provides the larger benefits in achieving customer satisfaction than working alone [2]. [68] used ISM for modelling the barriers for achieving the SC collaboration and [37] used ISM for modelling the enablers of SC collaboration and its benefits to SC.

E. SC Agility

SC agility is the trait of SC which states the ability of SC to respond quickly and efficiently to a volatile marketplace. [24] using ISM proposed 13 enablers of agility in SC and also presented hierarchy-based model along with the mutual relationships among these enablers. [33] applied ISM model to evaluate the agility as criteria for supplier selection and ranking using fuzzy TOPSIS-AHP Methods.

F. Quality

Literature showed that quality in SC is positively associated with performance outcome such as financial performance, business performance, and profitability. Earlier studies pointed out many barriers for achieving quality in various domains. [67] identified the influential quality variables and their interaction using ISM. [27] identified 12 barriers and used ISM as methodology to analyze interaction among these barriers to TQM implementation. [36] used ISM to analyze the barriers affecting the effective utilization of quality tools and techniques. [48] explored critical success factors in quality function deployment, [66] used ISM for integrating quality management in manufacturing and service counterparts, [62] used ISM for factors affecting the quality of construction engineering

G. SC Risk Management

“There is no silver-bullet strategy” [74] for protecting organizational SC, hence it is imperative to manage the SC risks to minimize disruptions. Considering the complexity and clarity over research issues pertaining to SC risks management researchers [28, 31, 40] used ISM to model the SC risk, understand risk propagation and its impact on performance and analyze the competitiveness of uncertainty and risk measures in SC

H. Humanitarian SC

To reduce the adverse impact of disasters and to improve the disaster relief practices, academicians and practitioners are emphasizing on a number of diverse factors of humanitarian SC. Considering the inadequate clarity and complexity, ISM is used by [35] to analyze the key enablers and by [26] to analyze the critical success factors along with interaction between these enabler/factors in humanitarian SC

I. Service SC Management

Service SC differs to manufacturing SC however complexity trait remains same or indeed increases depending upon the domain and environment in which it operates. [32] explored ISM to delineate the interrelationship between the enablers of a telecom service SC in the Indian context.

[41] used empirical investigation for modelling the services SC of management consulting institutes in Iran using integrated fuzzy Delphi-ISM approach.

J. GSC & Sustainability in SC

GSC Management includes strategic actions by collaborating partners and stakeholders of the SC to mitigate and/or eliminate the adverse impacts of business activities, spread across the chain, on the environment, thereby ensuring the sustainability [75]. ISM is used by [34] to extract the interrelationships among the identified behavioral factors of GSC Management.

[47, 65] used it to explore the enablers and barriers to GSC management implementation and interaction between those variables. [76] explored ISM to find critical success factors of sustainable SC management practices. [42, 52, 69] used ISM to explore the enablers and barriers to sustainable SC management implementation and interaction between those variables. [25] extended this methodology and used Total interpretive structure modelling (TISM) to build the theory of GSC management. [45] analyzed flexibility factors in Sustainable SC using TISM.

Green oriented flexible SC is a complex term as it has to retain its eco-friendly characteristics and flexibility attributes simultaneously.

V. RESULT AND DISCUSSION

ISM is MCDM and analysis tool which helps in thorough understanding of complex situation with a construct of visual map of the situation by incorporating pair-wise comparison, Transitive Logic and Concept Synthesis. Unlike other analysis tools/methodologies, ISM does not divide the complex problems into smaller parts but connects the elements to build the situation. This makes it suitable for various studies at a high level of abstraction. Especially in the fields of SC where multiple partners are involved, process are complex and integrated. AS mentioned in the detailed review, ISM is used in the various areas of SC such as SC Process & Practices, SC performance management, SC collaboration, SC agility, quality, SC risk management, humanitarian SC, service SC, green SC (GSC) & sustainability in SC. Various advantages of using ISM in SC are the process is systematic and computationally very efficient. If transitive inference used properly then number of relation queries will be reduced by 50-80% [3]. This methodology improves the quality of interdisciplinary and interpersonal communication within the context of the problem situation and domain. However, the key limitation of ISM includes its dependence on interpretation of the group related to relationship among the elements of research issue. It also attracted criticism from scholars due to a lack of consensus in terms of the level of confidence which may be attributed to the results due to variations in experts' opinions [25]. With various methods and experts' views, the variables can be analyzed to derive the driving and dependance power of variables related to problem or issue. However, unlike other methodologies like Structural equation modeling (SEM) methodology these models are not statistically validated.

VI. MANAGERIAL IMPELICATION

The ISM methodology can be used as a powerful tool for identifying the enablers and barriers of any processes. Considering the structure approach along with simplicity, practicing managers can provide the mind map of complex problems. With the help of various methodologies like structured literature review, interviews, Delphi methods and brainstorming various elements affecting the process can be identified. Further using ISM these variables can be converted into diagraph and presented as a model which can be interpreted and understood with simplification. Interaction between these variables can be understood. Dependent variables and driving factors can be effectively understood by extending these models with ANP, TOPSIS, DEMATEL, MICMAC, fuzzy MICMAC approaches. Considering all this ISM is best suited to effectively analyze the complex issues in SC as a group activity. Due to structured methodology/process it enables the team to focus on the problem at hand. ISM methodology facilitates buy-in of the participants as it links all the ideas and elements in the situation map by providing the relationship among them rather than other processes which works on elimination of the ideas. However, working knowledge and subject matter expertise among the participants are must for making decisions and communicating the rationale behind the individual decisions while identifying the relation among the variables. This makes ISM results as contextual dependent. Other limitation of this methodology is that it does not provide the causality of the links [15]. These limitations can be overcome if ISM is used as integrated approach with the other analytical tools like total interpretive structural modelling (TISM), analytic network process (ANP), structural equation modelling (SEM), interpretive ranking process (IRP), thematic analysis, technique for order of preference by similarity to ideal solution (TOPSIS), path analysis, concept advanced ISM (CAISM), analytic hierarchy process (AHP), decision-making trial and evaluation laboratory (DEMATEL) etc.

VII. CONCLUSION

This study attempted to understand, explore and review ISM methodology along with its applicability in SC Management Research. To achieve this, systematic approach of methodology review is followed, complexity of various SC concepts and processes are understood and research work is studied which describes the SC challenges, issues, barriers and enablers of various processes or functions and their classifications based on SC processes using a structured approach. We conclude that despite of the underlying sophistication, this methodology is simple, structured, easy to learn and implement in practical situations. This can be used and group or personal analysis tool. We discussed the advantages as well as limitation of ISM approach in understanding SC issues and provided the managerial implications of using and extending ISM in SC. We reviewed the extensive literature in SC research are which used this technique during 2011 to 2018.



However, there are two limitations to this study. First, the article which are reviewed are limited from English journals and focused only on SC area making the review less exhaustive. Second this study was focused on ISM methodology and hence commentary on the variables and their interactions with each other in various research papers is not provided. Driving and dependence power in various scenarios are not discussed in detail. This study can be further extended to compare the use of integrated ISM with other analysis tools. Authors consider that this study would provide references for ISM methodology in SC research area to academic researchers and practitioners along with its importance and guidance for its use.

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AUTHORS PROFILE



Nilesh Wankhade is a senior consultant in the manufacturing and logistics domain working at Bentonville, AR, USA. He is research scholar and pursuing PhD degree from VIT Business School, Vellore, India. He holds post graduate diploma in Industrial Engineering from National Institute of Industrial Engineering Mumbai, India and has 12+ years of experience in automotive, transportation and logistics with IT consulting domain. His research interests include supply chain management, SC Agility & performance management, business and technological trends and their impact on supply chain performance. Nilesh can be contacted at nileshwankhade@gmail.com.



Goutam Kumar Kundu is a Professor at VIT Business School, VIT University, India. He holds a PhD degree from VIT University and a master's degree in industrial engineering and Operations Research from IIT Kharagpur, India and has 28+ years of experience in IT services sector. He is certified CISA, PMP and ASQ-SSBB. His research interests include supply chain management, service management, education quality, lean principles and its application in services. Goutam can be contacted at kgoutamk@yahoo.com or gkk@vit.ac.in.