Deployment of Interpretive Structural Modelling Methodology in Supply Chain Management –An overview

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Abstract

Purpose*-The purpose of this paper is to review a sample of the literature relating to Interpretive Structural Modelling (ISM) and its deployment for modelling purposes in the area of supply chain management (SCM).*

Design/methodology/approach*- The literature is examined from the three perspectives. First, concept of ISM and examines ISM as modelling technique. Second, use of ISM by the various researchers in their research for modelling. Third, use of ISM for modelling in the area of supply chain management.*

Findings*- ISM is a systematic application of some elementary graph theory in such a way that theoretical, conceptual and computational advantage are exploited to explain the complex pattern of conceptual relations among the variables. From the literature review, we can conclude that many researchers have used ISM for modelling the variables of: reverse logistics, vendor managed inventory, IT enabled supply chain management etc.*

Research limitation/implications*-The scope of this literature review is by design limited to ISM and it does not cover in investigating other modelling techniques. Literature review investigates sample of important and influential work in the area of application of ISM in the research.*

Originality/Value*-This study reviews a sample of recent and classic literature in this field and in doing so this paper provides some comprehensive base and clear guidance to researchers in developing, defining and presenting their research agenda for applying ISM methodology in a systematic and convincing manner.*

Key words: Interpretive Structural Modelling, SCI, SMEs, SCM

1.0 Introduction

The term “supply chain” “supply chain management”, “supply chain integration” is not well-defined constructs. They have different meanings to different people and organizations [1]. Supply chain is described as chain linking each element from customer and supplier through manufacturing and services so that flow of material, money and information can be effectively managed to meet the business requirements [2]. John T Mintzer et al. [3] identified three degrees of supply chains: a direct supply chain, an extended supply chain and an ultimate supply chain. An ultimate supply chain includes all the organizations involved in all the upstream and downstream flows from the ultimate supplier to ultimate customer. Thus, it may be more accurate to use the term supply network or supply web to describe the supply chains[3]. As a philosophy, SCM takes a system approach to viewing the supply chains as a single entity, rather than as fragmented parts, each performing its own functions [2].

1.1 Modelling Techniques

In the literature, three contemporary techniques like: Interpretive Structural Modelling (ISM), Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP) are used for modelling and multi criteria decision making in the area of SCM. Jitesh Thakkar et al. [4] compared these three techniques and extracts from that comparison is shown in the Table 1. This comparison aims to present outstanding merits of ISM.

ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue [5]. ISM is a graph- theoretic method that belongs to the casual mapping family of approaches. It falls in to soft Operations Research (OR) family of approaches. It is primarily intended as a group learning process but can also be used individually. It is a process, which helps groups of people in structuring their collective knowledge [6]. ISM methodology is an interactive learning process whereby a set of different directly and indirectly related elements are structured into a comprehensive systematic model. The model so developed by ISM portrays the structure of a complex issue, a system of a field of study, in a carefully designed pattern employing graphics as well as words. ISM methodology helps to impose order and direction on the complexity of relationships among elements of a system [5]. ISM is being employed to address problems that are complex and subjective.

Table 1: Brief comparison between AHP, ANP and ISM

Analytic Hierarchy process(AHP)	Analytic Network Process(ANP)	Interpretive Structural modelling Technique(ISM)
Discipline of hierarchy has to be strictly followed	Deals with loose networks	Involves a set of interconnected criteria
Assumes functional independence of an upper part of hierarchy from its lower one	Takes into account the interdependencies and non-linearity	Establishes the "leads to" relationships among the criteria
Fails in complex real life problems	Useful in real life non-linear problems	Captures the complexities of real life problems
Moderate ability for capturing dynamic complexity	Lower ability for capturing complexity	Higher ability for capturing dynamic complexity

(Source: Jitesh Thakkar 2008)

Many researchers like: Jharkharia S and Shankar R [7], V Ravi [8], Faisal et al.[6], Jitesh et al. [4] etc. have used ISM methodology for modeling the variables of SCM for improving the performance of the supply chain. However, the review of the existing literature on application of ISM reveals that there is no comprehensive literature review is available. This paper reviews a sample of recent and classic literature in this field of application of ISM and in doing so this study provides some comprehensive base & clear guidance to management researchers in developing, defining and presenting their research agenda for applying ISM methodology in a systematic and convincing manner. The main purpose of this literature review is to list, classify and review existing literature for the application of ISM methodology in general and specifically in the area of SCM.

The rest of the paper is organized as follows: next section discusses the framework for the literature review followed by detailed review of the literature, finally conclusions references are presented.

2.0 Framework for Literature Review

The research methodology employed for literature review is the literature survey. The intention of the literature review was to collect information from a pool of research articles. Some select articles published in the recent time on the issue: Yan and Kefen[9], Jharkharia [7], V Ravi [8], Rick G [10] etc. have provided the adequate ground to begin with. The articles have been collected from the literature primarily through journals and the list of journal resources and the number of papers is presented in the Table 3. The literature search has been carried with the help of e-brary search engines available at library of Ibra College of Technology and Sultan Qaboos University, Sultanate of Oman. This e-brary is having the access to journals published by a numerous publisher like Emerald and Elsevier publications etc. The literature review methodology is shown in Figure 1.

Table 2: Number of papers in each classification

Classification area	Number of papers
Total papers collected	38
Basic concept/definition papers in ISM	4
Papers in the area of SCM	19
Other areas	15

To make review more comprehensive, scrutiny of collected papers is carried out based on the "Application of ISM in the research". As a result, 38 articles were chosen for the inclusion in this literature review. To remain with in the scope of the proposed research area (SCM), further scrutiny is carried out for "deployment of ISM in SCM". As a summary, the number of articles and their break up is shown below in the Table2.

3.0 Classification of the Literature

As the pertinent objective of the literature is to investigate the literature for the use of ISM in supply chain management, therefore the selected articles are grouped in to three categories focussing on

i. ISM concept and definitions- basic papers
ii. Application of ISM methodology in supply chain management: The papers in SCM are further sub-classified based on their area of application.
iii. Application of ISM in the areas other than SCM

The main classification and sub classification of literature is shown in the Figure 2 and summary of literature review under the proposed classification scheme are listed in the Tables-4, 5 and 6.

4.0 Literature Review

In this section, literature available (through journal articles mostly) on application and development of ISM is reviewed.

S. No	Name of the Journal	Number of articles
1	International Journal of Operations and Production Management	1
2	Technological Forecasting and Social Change	3
3	Transportation Research Part	1
4	Business Process Management Journal	1
5	The Journal of Enterprise Information Management	2
6	International Journal of Productivity and Performance Management	3
7	ICFAI University Press	1
8	Journal of Enterprise Information Management	1
9	University of Illinois at Urbana-Champaign	1
10	The Journal of International Education Studies	1
11	Business Process Management Journal	4
12	Information Management and Computer Security	1
13	Construction Innovation	1
14	Journal of Constructional Engineering Management	1
15	IEEE Transactions	3
16	CRC Press 2008	1
17	International Journal of Information Technology and Decision making	1
18	International Journal of Management Science and Engineering Management	1
19	International Journal of Engineering Science and Technology	1
20	International Journal Business Performance Management,	1
21	World Academy of Science, Engineering and Technology	1
22	European Conferences on Information Systems	1
23	Journal of Manufacturing Technology Management	1
24	British food journal	1
25	Industrial Management and Data Systems	1
26	Industrial Management and Data Systems	1
27	International Journal of Technology Management	1
28	Information and Management	1
29	Journal of Business Logistics	2
30	Reverse Logistics Executive Council Pittsburgh, PA	1
31	Management Research News	1
32	Supply Chain Management- an International Journal	2
33	International Journal of Logistics Management	1
34	International Journal of Logistics Management.	1

Table 3. The article resources-Journals

4.1 Interpretive Structural Modelling(ISM)

Warfield [13] first proposes ISM in 1973. It is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem. It enables researchers to develop a map of the complex relationships between many elements involved in a complex decision situation [14], [15], [16].

It transforms unclear, poorly articulated mental models of systems in to visible, well-defined models, which will be useful for solving the problem under consideration [8], [17]. The ISM methodology is interpretive in that the group of experts decides weather and how the items are related, and it is structured in that, on the basis of relationship, it extracts an overall structure from complex set of items, and it is modelling in that it portrays the specific relations and over all structure in a diagraph (Directed graph) model. It is a tool for imposing order and direction on the complexity of relationships among variables [18].

ISM is a systematic application of some elementary graph theory in such a way that theoretical, conceptual and computational advantage are exploited to explain the complex pattern of conceptual relations among the variables [19]. The various steps for adopting the ISM methodology is extracted from [8], [13], [23], are explained in the next paragraph. Logical flow of ISM implementation is shown in Figure 3.

1. ISM begins with an issue or problem.
2. The next step is to identify the elements that comprise the issue context are listed. Any one of the following techniques can do the identification of elements:

Figure 1: Literature review framework

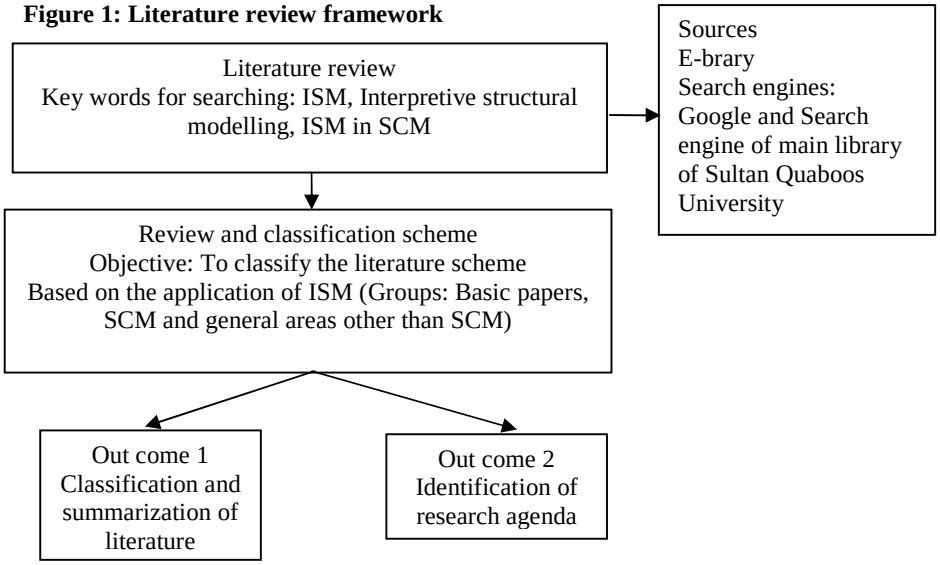
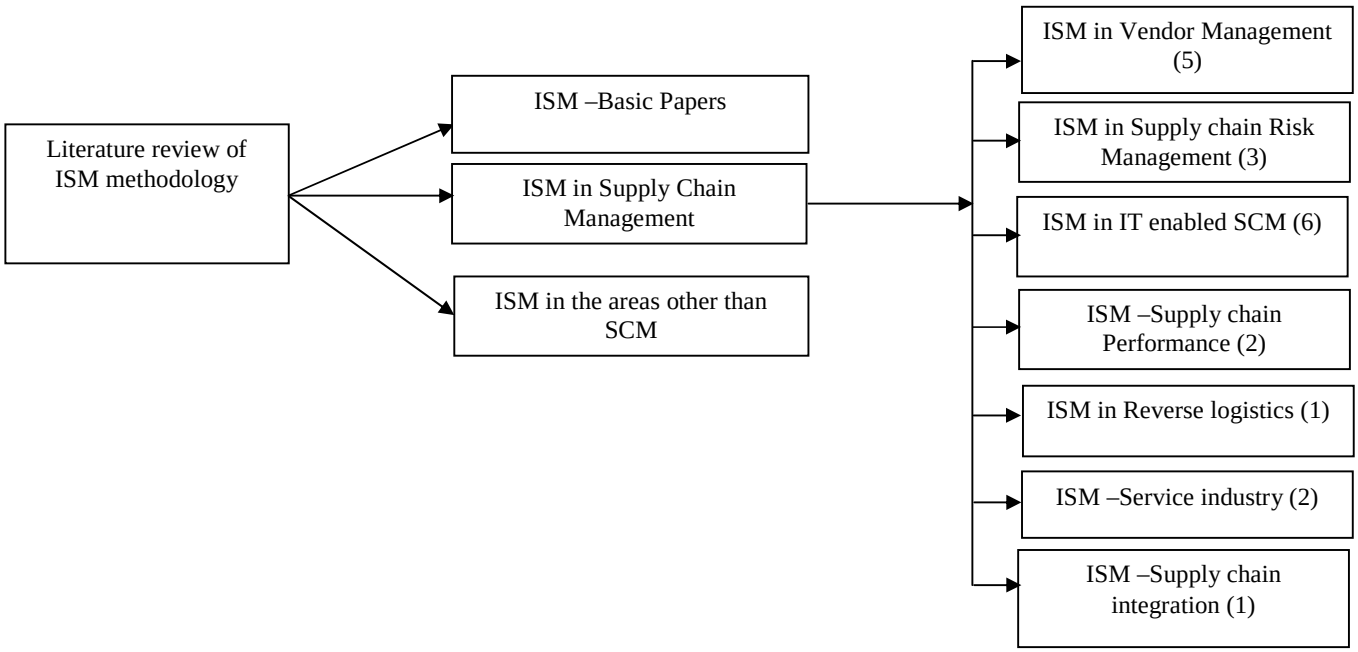


Figure 2- Classification and Sub classification of the literature



Note: (N) Indicates Number of Papers in That Classification

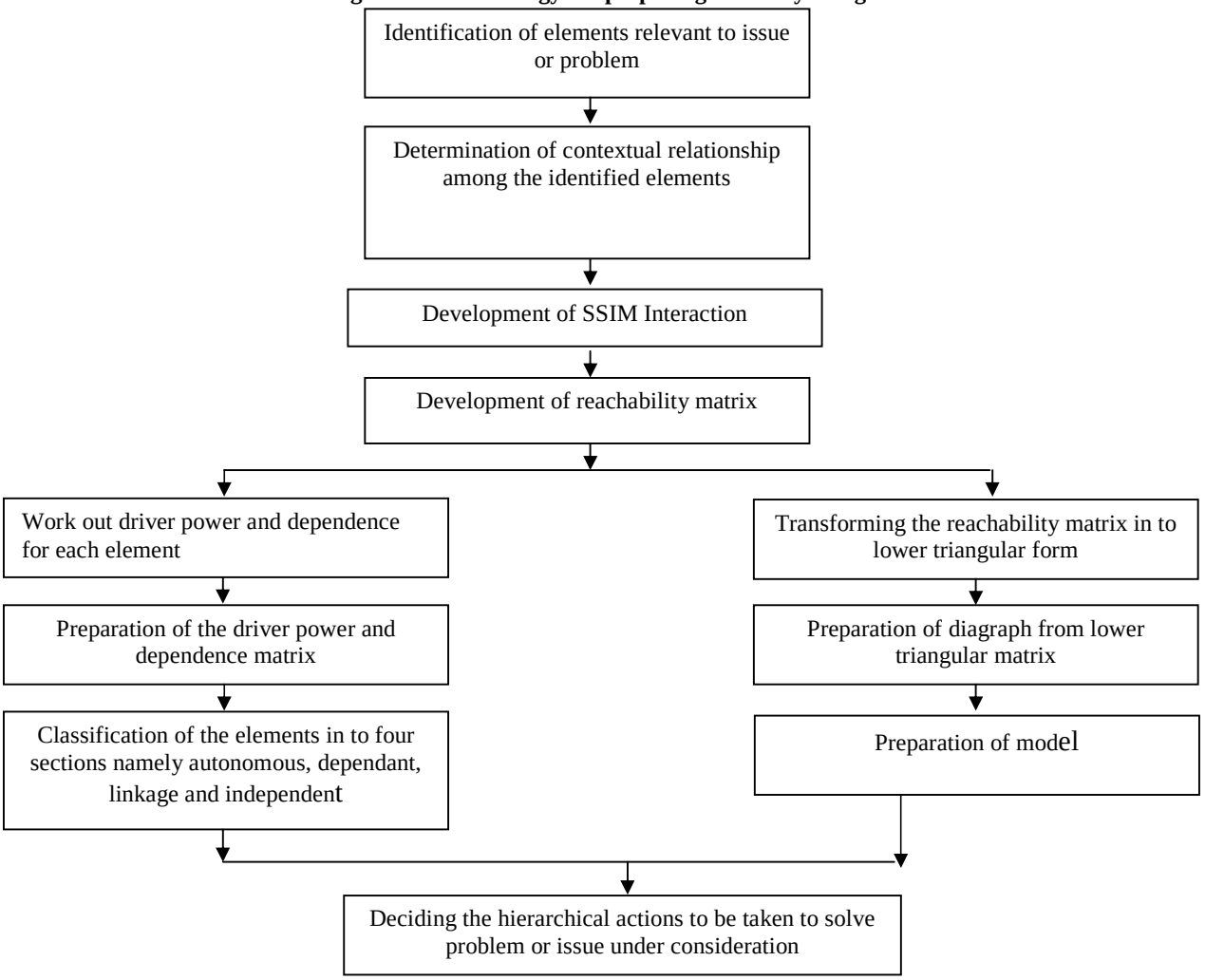
Table 4-Summary of references under the detailed classification scheme for basic papers in ISM

S. No	Authors and year of publication	Issues addressed/conclusions
1	Malone (1975) [20]	Presents brief overview of ISM
2	Warfield J (1976) [13]	Introduced ISM and he provided detailed descriptions and operating procedures
3	Linstone H (1979) [21]	Paper states that ISM is an appropriate tool for modeling when the variables are subjective.
4	Lendris G B (1980)[22]	ISM is a potential tool for modeling a system for the large number of variables.

group-solving technique like brain storming and nominal group technique or by conducting a survey or from the literature [8], [13], [23], and [6] , [18] and[23] have used Delphi for identifying the elements. Whereas [8], [4], [10], [25] etc have used literature survey and [7] [24] have used an industrial survey for identification of elements.

3. In this step, contextual relationship among the identified variables is determined. For developing a contextual relationship group solving technique or a group of experts should be used. The pairs of elements are compared graphically or in a relation matrix, using a contextual relationship, which is mostly a verb or a verb phrase. Typical generic verbs are “influences” or “causes” and verb phrase are “leads to” “is more important than” are used for comparing pairs of elements. Following the selection of the contextual relationship, a graphic representation of the mental model is constructed.
4. The contextual relationship diagram provides a visual means of mapping out the causal and/or associated relationships in the development of a coherent theory. Developing a structural self-interaction matrix (SSIM) of elements, which indicates pair-wise relationship between elements of the system
5. Developing a reachability matrix from the SSIM, and checking the matrix for transitivity. Transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A is necessarily related to C.
6. Partitioning of reachability matrix in to different levels.
7. Based on the relationships given above in the reachability matrix a directed graph (DIGRAPH) is drawn and transitive links are removed.
8. Constructing the ISM model and it should be checked for conceptual inconsistency, and necessary modifications should be made. Final ISM model is presented for solving the problem under consideration.

Figure 3- Methodology for preparing model by using ISM



S. No	Sub-classification	References	Deployed ISM to study
1	ISM in vendor management	Jitesh Thakkar, [52]	Buyer-supplier relations are evaluated by using integrated ISM and graph theoretic matrix: The case study of Indian automotive SMEs
		Illyas R. [37]	For developing interventional road map for creating a flex-lean-agile value chain by outsourcing
		Yan D [9]	Developed a model of vendor managed inventory
		Anukul M [23]	Developed a model for "vendor selection criteria". ISM has been carried out to develop a hierarchy of criteria to be considered for selecting the vendors.
		Ya-Ti Lin [38]	ISM is used to provide an understanding of the casual interrelationship in the complex vendor performance evaluation frame work. This study is conducted for Taiwan's semiconductor industry.
2	ISM in Risk Management of Supply chain	Mohmad [25]	To study information risks management in supply chains
		Faisal M.N [6]	In this research ISM based approach is used for modeling the enablers and barriers for supply chain risk mitigation.
		Devinder K [39]	Mapping supply chains on risk and customer sensitivity dimensions
3	ISM in IT enabled Supply chain Management	M.Khurana [40]	ISM and fuzzy MICMAC have been used to identify and classify the key criterion of information sharing enablers that influence trust in a supply chain management
		Jitesh T [4]	Used ISM for modeling the enablers for adoption and implementation of IT in Indian SMEs.
		S. P .Sarmah, [16]	Developed some models on value of information sharing in SCM.
		Sanjay J [24]	Applied ISM methodology for understanding and establishing the relationship among the barriers for IT enabled supply chain management. This study is conducted for identifying the barriers for IT enabled supply chain for large industries like, Auto industries, FMCG and process industries.
		Jharkharia, S [7]	ISM is used to understand mutual influences of the enablers and also to identify those enablers which support other enablers ("driving enablers") and those which are most influenced by others ("dependent enablers").
4	ISM in performance measurement of supply chains	Charan P [19]	Analyzed the Interactions among variables of supply chain performance measurement system for implementation
		Parakshit Charan [41]	The ISM is used to determine the key supply chain performance measurement systems implementation variables on which top management must focus to improve effectiveness and efficiency of supply chains
5	ISM in reverse logistics	V.Ravi [8]	ISM based approach has been employed to model the reverse logistics variables typically found in computer hardware supply chains.
6	ISM in supply chain of service industry	V.R.Pramod [15]	In this research ISM based approach is used for understanding the Inhibitors of a telecom service supply chain. The study is conducted for a leading telecom service provider operating in various global regions having their head quarters in India.
		Rohit Joshi, [42]	Used ISM for modeling the inhibitors for Indian cold chain like perishable goods
7	ISM in supply chain integration	Rajesh K. Singh [31]	Interpretive structural modeling is used to identify for modeling the enablers of coordination in a supply chain.

Table 5-Summary of references under the detailed classification scheme for ISM and SCM

4.2 ISM Methodology in Supply Chain Management

Supply chain management is a set of approaches, which integrates suppliers, manufacturers, logistics and customers for improving the performance of the individual companies and the supply chain as whole [3]. The objective of literature review in this classification is to investigate the application of ISM in SCM, SCI and IT adoption for SCI.

4.2.1 ISM in Vendor Management

Various criteria for vendor selection are classified by [23] depending on their driving and dependence powers by using ISM methodology. ISM has been carried out to develop a hierarchy of criteria to be considered for selecting the vendors. Vendor managed inventory is a supply initiative where supplier assumes the responsibility of tracking and replenishing a customer's inventory [26]. An ISM model of vendor-managed inventory is developed by [9]

4.2.2 ISM in Supply Chain Risk Management

Faisal et al. [6] employed ISM for modelling the enablers and barriers for supply chain risk mitigation. Mohmad et al [25] applied ISM for studying the variables of information risks management in supply chains.

4.2.3 ISM in Supply Chain Performance Measurement

There are many variables, which affects the performance of the supply chains. Charan et al. [19] analyzed the variables of supply chain performance by using ISM.

4.2.4 ISM in Reverse Logistics

Reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value or proper disposal [27]. It is a process whereby supply chains can become more environmental friendly through recycling, reusing, and reducing the amount of materials used [28]. [8] Have studied the interrelationship among reverse logistics variables typically found in computer hardware supply chains. The variables of reverse logistics have been classified depending on their driving and dependence power for the hierarchical actions by the top management for productivity improvement of a computer hardware supply chains.

4.2.5 ISM in Supply Chain Integration & IT Enabled SCM

Successful SCM requires the integration of various value chain entities to create cooperative and collaborative environments, which facilitate smooth flow of information, materials and money [29]. An integrated supply chain removes the barriers of communication and eliminates redundancies through coordinating, monitoring and controlling processes [30]. Lee and Whang [30] outlines three dimensions of supply chain integration: information, coordination and organizational linkage. Rajesh [31] used ISM to identify for modelling the enablers of coordination in a supply chain. Information sharing among partners is a basic enabler for the effective management of a supply chain. Sarmah et al. [16] used ISM and fuzzy MICMAC to identify and classify the key criterion of information sharing enablers that influence trust in a supply chain management.

SCI is greatly facilitated by recent advances in IT [32]. The emergence of the computers, the explosion of the internet and World Wide Web helped the industries to integrate their supply chains in real time for coordinating the various flows in a supply chain [7]. However, the deployment of IT tolls for integrating the supply chains is not free from barriers [24] [36]. These barriers not only effect the process of IT in supply chain integration but also influence one another [24] effecting each other and leading to poor SCI.

Sanjay and Ravi [24] identified the barriers and applied ISM methodology for understanding and establishing the relationship among the barriers for IT enabled supply chain management. This study is conducted for large industries like, Auto industries, FMCG and process industries. Sanjay and Ravi [24] have deployed ISM to develop a model for IT enabled SCI to classify depending on the driving and dependence power for the IT enablement of a supply chain so that management may effectively deal with these barriers.

Jitesh [4] used ISM to understand mutual influences of the IT enablers for Indian SMEs. He used ISM for modelling the IT enablers for Indian Manufacturing SMEs to identify the enablers which support other enablers ("driving enablers") and those which are most influenced by others ("dependent enablers"). The researcher used literature survey for identifying the IT enablers for Indian SMEs.

Authors [24] and [4] did not address the barriers of SMEs for using the IT in supply chain integration in their research for developing a model by using ISM. As the barriers encountered for IT enabled SCI are different for SMEs because of their differences in the size and nature of the business [4], [33] and [34], there is a need to study the interrelationship among the barriers for adopting the IT in SMEs for integrating their supply chains.

4.3 ISM Methodology in the Areas Other Than SCM

In this section, application and development of ISM in the areas other than supply chain management are discussed. The objective of literature review in this classification is to investigate the application of ISM in SMEs and IT adoption by Manufacturing SMEs. Researchers have adopted ISM in the areas like: to study the objectives of waste management in India: A futures enquiry, to identify and for quantifying interactive risks for an insurance firm [10] for modelling the benefits of collaborative ICT adoption for building project management [14], [35] used ISM for modelling the barriers of six-sigma implementation by establishing relationship among the barriers. Silpa et al.[11] used for identifying and establishing the relationship among the critical factors influencing standards compliance and their level of influence in a food industry of a developing country like in India.

Asif et al. [12] employed for establishing the relationship for modelling the barriers for

environment-conscious manufacturing. A detailed review of the literature under this classification is shown in the Table 5.

5.0 Conclusions

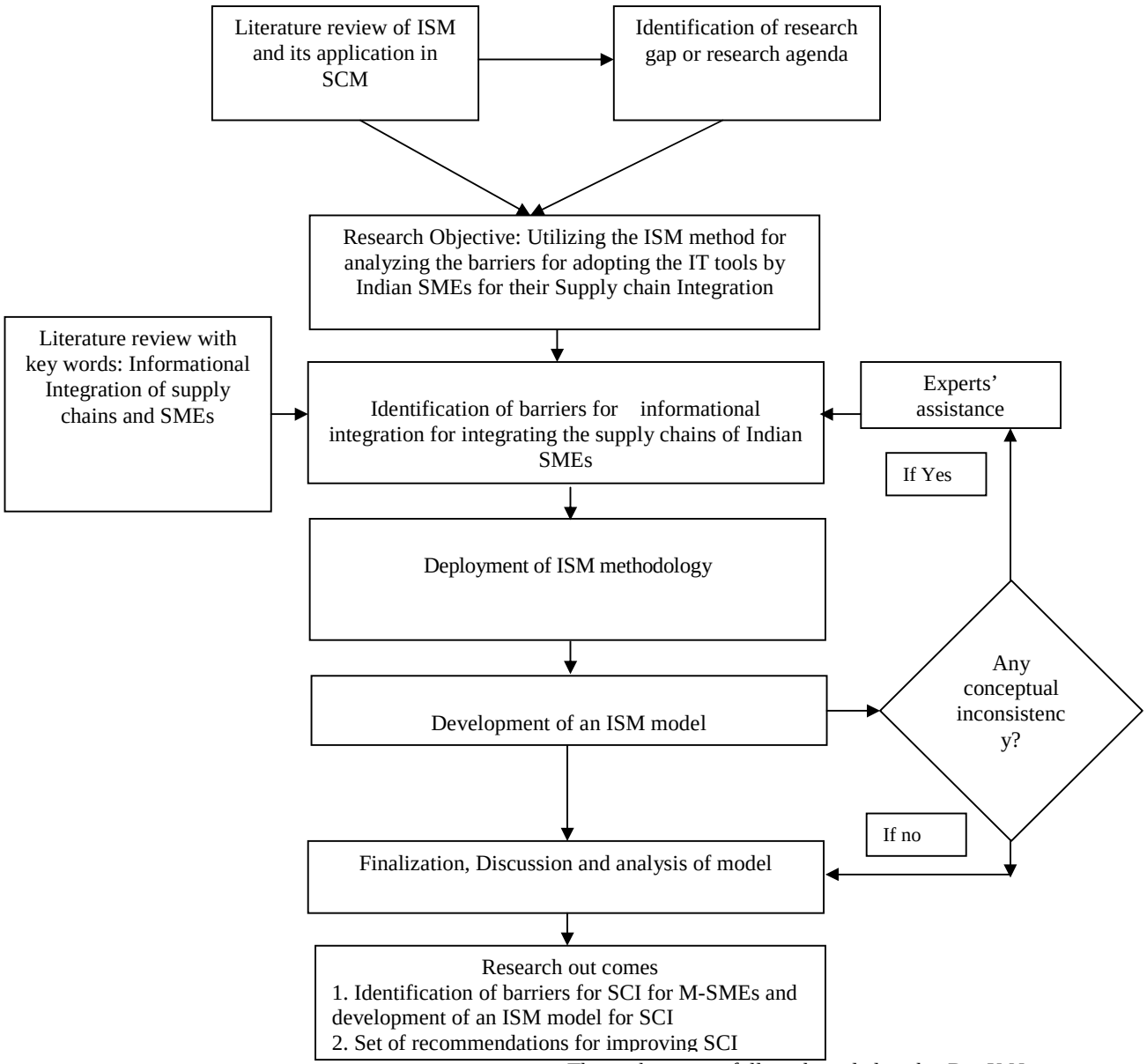
In this paper, an attempt has been made to review the literature for deployment of ISM in SCM. Although literature survey is not exhaustive, it serves as a comprehensive base for identifying the agenda and provides a clear guidance to academicians and researchers in developing, defining and identifying their research agenda for applying ISM methodology in a systematic and convincing manner. Besides, the following are comments that derived from the literature review:

- ISM transforms unclear, poorly articulated mental models of systems in to visible, well-defined models, which will be useful for to address the problem under consideration.
- By using ISM, an overall hierarchy of variables can be portrayed in a graphical model for a hierarchical action for solving the issue or problem under study.

S.No	Sub-classification	Authors	Issues addressed
1	Objectives of Waste Management	H.D.Sharma, [18]	ISM has been carried out to develop a hierarchy of actions required achieve the future objectives of waste management in India.
2	Service Industries	Rick [10]	ISM based approach is used to identify and for quantifying interactive risks for an insurance firm.
3	Education	Alexia G [43]	"Teacher effectiveness" as system is examined by using ISM
4	Project Management	Ahuja V (2009)	ISM based approach is used for modeling the benefits of collaborative ICT adoption for building project management
5	Software Outsourcing Business	Wang M[44]	ISM based approach is used for analyzing and establishing the total risk structure for the software outsourcing project.
6	Banking Business	Khodakaram [45]	ISM based approach used for modeling and for analyzing the relationship among the "critical success factors" in banking process re-engineering. This study is conducted for Iranian banks.
7	Risks In Public-Private-Partnership Projects	K.C. Iyer [35]	In this research ISM based approach used for prioritizing the risks in Public-Private-Partnership projects.
8	Six-Sigma Implementation	Asish S[46]	ISM is used for modeling the barriers of Six -sigma implementation by establishing relationship among the barriers. The result provides insight in to the effective approach to counter these barriers.
9	Food Industry	Silpa S [11]	ISM is used for identifying and establishing the relationship among the critical factors influencing standards compliance and their level of influence in a food industry of a developing country like in India.
10	Environment Conscious Manufacturing	Asif H [12]	ISM is used for establishing the relationship for modeling the barriers for environment-conscious manufacturing.
11	Energy Conservation	Saxena, J.P [47]	ISM is applied for modeling the variables of energy conservation in the Indian cement industry.
12	Innovation Process	Yrd D S [48]	ISM is applied for modeling and establishing the relationship among the barriers encountered in innovation process in Turkey's condition. The developed model will helps in solving the innovation barriers.
13	Knowledge Management	Singh, M.D [49] & M.D.Singh [50]	Interpretive structural modeling for knowledge management in engineering industries.
15		Reza S [51]	Deployed ISM for establishing relationships among knowledge management (KM) criteria that will ensure an essential foundation to evaluate KM outcomes in Malaysian organizations.

Table 5-Summary of references under the detailed classification scheme for ISM and general areas

Figure 4: Flow chart of the proposed research



From the foregoing discussion on the literature review, it can be concluded that ISM is not used for understanding the barriers of Indian manufacturing SMEs for supply chain integration.

We propose to use this ISM methodology for modelling the barriers of supply chain integration in Indian Manufacturing SMEs for integration of their supply chains. Figure 4 depicts flow chart for proposed research. The proposed research in this paper will add onto contribution of authors [4] and [24] who has ventured in studying the ISM for modelling supply chain management of Indian industries in general and specifically to Indian SMEs.

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