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An integrated ISM fuzzy MICMAC approach for modelling the supply chain knowledge flow enablers

Vishal Ashok Bhosale* and Ravi Kant

Department of Mechanical Engineering, S.V. National Institute of Technology, Surat, India

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The aim of this study is to identify supply chain knowledge flow enablers (SCKFEs) to inspect interrelationships among these enablers and classify these enablers into driving power and dependence power using an integrated interpretive structural modelling (ISM) and fuzzy Matriced Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) methodology. While the ISM methodology analyses the interactions among the SCKFEs, fuzzy MICMAC analysis is employed to obtain insights into the dependencies among the SCKFEs. A total of 34 SCKFEs were identified through the literature review and expert opinion. As an example, an Indian manufacturing organisation is selected that is willing to adopt the successful knowledge flow for improving supply chain (SC) performance to overcome the intense competition among the SC versus SC. The research shows SCKFEs having high driving power and low dependence have strategic importance because of their driving nature, while the SCKFEs having high dependence and low driving power are more performance orientated. Therefore, it is the responsibility of SC executives to address the high driving power SCKFEs for the enhancement of SC performance. This categorisation provides a useful tool to top management to differentiate between independent and dependent SCKFEs and their mutual relationships, helping them focus on those key SCKFEs that are most significant. This gives a clear picture to SC practitioners and decision-makers about number of SCKFEs, interrelationship and dependencies existing among them.

Keywords: knowledge flow; supply chain; SCKFEs; ISM; fuzzy MICMAC

1. Introduction

In today's business world, to survive worldwide competitive rivalries and superior performance among organisations, supply chain (SC) is widely considered as an important element (Ketchen and Giunipero 2004). The nature of competition in the present era is not among organisations, but rather among SCs (Myers and Cheung 2008). A SC is a group of organisations working collectively on a network that continually needs to develop its operations and capabilities, both upstream and downstream, from raw material to end user (Mentzer, Flint, and Hult 2001). Knowledge with the SC has become a decisive factor for SC performance improvement. The management and use of knowledge for better SC management are a challenge for every organisation. The success of any SC depends on the flow of knowledge across the chain. Knowledge sharing, knowledge flows and knowledge transfer have been used and discussed interchangeably (Gupta and Govindarajan 2000; Alavi and Leidner 2001). Here, knowledge sharing, knowledge flows and knowledge transfer are exchangeable to disseminate knowledge throughout the SC. Knowledge flow is a process which involves both the sharing of knowledge by the knowledge source and the acquisition and application of knowledge by the recipient (Davenport and Prusak 1998). Knowledge flow among organisations would assist the entire SC to maximise total revenue and improve SC efficiency (Li and Ding 2012). A SC is a functional chain structure which combines suppliers, manufacturers, distributors and retailers, until the end users as a whole (Oke, Prajogo, and Jayaram 2013). An efficient knowledge flow is important to coordinate these SC partners (Huang and Lin 2010). The knowledge flow in SC comprises knowledge acquisition, assimilation and sharing (Swaminathan and Tayur 2003; Li and Ding 2012). While concerning existing economic breakdowns with exorbitant competitive circumstances in fast-changing complexity of overseas markets, the ability of the organisations' knowledge sharing is becoming a key element in improving performance of SC, to enhance decision-making and to maintain a competitive edge (Davis and Spekman 2004).

Organisations are facing common challenges with SC operations, namely; short time to market, reduce bullwhip effects, manufacturing cost, out-of-stocks, excess inventories, new product failure rates and increased product markdowns (Myers and Cheung 2008). The knowledge flow in SC has numerous benefits, namely: improvement in

*Corresponding author. Emails: vbhosale214@gmail.com, d13me006@med.svnit.ac.in

coordination and decision-making (Huang and Lin 2010), better utilisation of resources, increased productivity and encouraging cooperation between SC partners (Bandyopadhyay and Pathak 2007), increase mutual learning among SC partners (Wang et al. 2008) and improve SC integration and transferability (Khalfan et al. 2010). The knowledge flow makes SC more agile, adaptable, aligned and transparent, so that the organisation will enhance production planning, understanding of market trends and product development (Lee 2004). It can improve the response speed of the market, meet customer demand, shorten delivery time and reduce cost (Li and Ding 2012). Knowledge sharing integrates industry and academia. It provides information and wisdom to gain profits as well as constantly educate and train employees and partners (Kurtz et al. 2012). In addition, manufacturing firms demand that their SC partners implement knowledge flow to improve SC's coordination and product delivery (Zhang et al. 2012). Hence, organisations may be forced to adopt the latest and advanced techniques for effective knowledge flow for effective SC.

SCs are very complex inter-dependable structures due to the multitude of participating suppliers, service providers and customers. Organisations need to embrace efficient knowledge flow in order to better handle SC complexity (Myers and Cheung 2008). Organisations that can make full use of their collective expertise and knowledge are likely to be more innovative, efficient and effective in the marketplace (Grant 1996; Argote et al. 2000). Effective performance and growth in knowledge-intensive organisations require integrating and sharing highly distributed knowledge (Cai et al. 2013). Also, the knowledge flow between organisations can help firms find solutions and minimise problems associated with processes within SCs. The implementation of knowledge flow in the chain is widely supported by the SC knowledge flow enablers (SCKFEs). Many researchers have discussed the various SCKFEs which help an organisation achieve better organisational performance. Successful adoption of knowledge flow in SC requires the identification of the interrelationship among various SCKFEs and SCKFEs having a strong driving and dependence power.

Thirty-one SCKFEs have been selected using Delphi method. The intention of the Delphi method is to achieve a convergence of the experts' opinion. Delphi method has key features such as anonymity between experts, iteration and controlled feedback and finally the statistical group response. Different researchers have considered various SCKFEs, according to their perception, level of impact for different theoretical basis of knowledge flow in SC process with a mixed extent of emphasis and coverage. Hence, these SCKFEs were brought on common platform. SCKFEs have been analysed using the ISM and fuzzy MICMAC approach to identify interrelationships of various SCKFEs and their driving power and dependencies. ISM is a well-established methodology for identifying relationships among specific items which define a problem or an issue (Warfield 1974; Sage 1977). The opinions from a group of experts were used to develop the relationship matrix later used in the development of the ISM model.

Three questions have been posed while creating theoretical foundations for knowledge flow in SC. What are SCKFEs? How are they interrelated? And what type of dependencies exists between them?

This paper has three main objectives:

(1) to identify the SCKFEs through the literature review and expert opinion.
(2) to identify the interrelationships among the SCKFEs.
(3) to classify the enablers on the basis of their driving power and dependence power, and to find out the most influencing factors.

The rest of the paper is organised as follows. Section 2 presents literature review of various enablers followed by the problem description in Section 3. Section 4 explains the application of integrated ISM and fuzzy MICMAC methodology. The key findings from the ISM and fuzzy MICMAC method and analysis are discussed in Section 5. Section 6 represents conclusion including limitations and future research.

2. Literature review

Fifty SCKFEs were identified from the literature. An occurrence list based on the literature review was prepared. Some of them were similar in meaning and hence they were eliminated at the initial stage. Sixteen experts from academia and industry having an experience of more than 15 years each in concerned area are selected and the occurrence list of SCKFEs was put in front them. Then, based on experts' opinion and occurrences in literature, 31 SCKFEs were finalised for this study (Table 1). Some SCKFEs are extracted from the work of those who have generally explored enablers of knowledge flow in SC or have addressed a particular barrier in detail. Lawson and Potter (2012) have demonstrated a theoretical model exploring inter-organisational knowledge transfer across the SC. Zhao and Lavin (2012) identified knowledge flow enablers, namely: trust, communication, supplier flexibility and relationship. These enablers stimulate the flow of knowledge from the supplier to the customer. The knowledge is basically classified into two types: explicit and tacit (Nonaka and Takeuchi 1995). Explicit knowledge is transferred by codification of knowledge and person-to-person online discussion. On the other hand, tacit knowledge is not easy to articulate but it can be assimilated by long experience (Cabrera and Cabrera 2002). The socio-political factors such as trust and relative power among SC partners are the important factors for leading organisations to enter into knowledge sharing (Ke and Wei 2007). Trust enables better knowledge flow in the dyadic buyer–supplier relationship (Cai et al. 2013). Face-to-face interaction between two organisations foster better knowledge flow resulting in a reduction in cost and more timely delivery across the SC (Maçada et al. 2013).

The review of the literature indicates a growing interest in applying knowledge flow in SC. Knowledge flow treats knowledge as an asset and distributes it in a systematic way to achieve SC performance and competitiveness. But only a few SC members benefit from the effective knowledge flow. Knowledge flow adoption between groups with dissimilar purposes and dissimilar practices is difficult within an organisation or between trading partners belonging to the same SC (Marra, Ho, and Edwards 2011). Further, incomplete understanding of SCKFEs causes difficulty in knowledge flow adoption in SC. In view of this, it is helpful to identify SCKFEs to simplify knowledge flow adoption in SC. The identified SCKFEs are explained as follows.

(1) *Transferability of Knowledge:* Knowledge complexity considerably affects the dissemination of knowledge. Knowledge source may not convey knowledge in a proper way. For better understanding and exchange purpose, knowledge should be clear and transferable (Lawson and Potter 2012; Lane, Koka, and Pathak 2006).
(2) *Updated Knowledge:* SC should adopt upgraded knowledge, assimilate it and apply it for effective knowledge flow in order to avoid confusion caused by outdated knowledge (Mishra and Bhaskar 2011). Organisation's suppliers and customers are the most common source of new knowledge (Song and Di Benedetto 2008; Filieri and Alguezaui 2012). New knowledge from suppliers and customers may bring a number of benefits to the SC members. Updated knowledge enables individuals to learn from best practice, thereby increasing the stock of knowledge held within the organisation, speeding up the process of new products in line with customer needs (Kogut and Zander 1992).
(3) *Top Management Support:* Any knowledge flow initiative will encounter some form of employee resistance; hence, awareness and involvement of top management are key drivers. Top management involvement ensures financial resources and leads to a more positive impact on improving supplier performance (Kayakutlu and Büyüközkan 2010). TMS ensures the training, empowerment and support needed to promote a desired culture. It also establishes a knowledge structure and support system that enhances and facilitates sharing and application of knowledge (Huang and Lin 2010).
(4) *Strategic Planning:* Knowledge leaders allow their SC participants to create, share and use strategic planning to improve coordination, SC structure and decision-making. They also permit sharing of resources and competencies to ultimately achieve a rise in knowledge flow utilisation within the SC (Wu 2008). Strategic planning combines aspects of business strategy formulation with aspects of tactical SC planning which can make both approaches far more valuable to the planning effort than either would be alone (Sodhi 2003).
(5) *Integration of Knowledge:* Integration of knowledge is bringing diverse knowledge from multiple sources to bear on a complex problem or task (Liu et al. 2014). Singh and Power (2014) found three innovative knowledge-sharing constructs, namely: internal knowledge integration, knowledge integration with customers and knowledge integration with suppliers. These constructs are strongly interrelated, providing a case for knowledge-based integration of organisations with their trading partners. Moreover, customer's and supplier's knowledge can be integrated through information technology (IT) infrastructure (Chen, Preston, and Xia 2013).
(6) *Knowledge Flow Methodology:* Dyer and Singh (1998) demonstrated that knowledge transfer between manufacturers and their SC partners is enhanced by implementing inter-organisation knowledge flow methodology. SC knowledge flow methodology is the way through which knowledge is distributed and shared among members of SC. It is promoted by unique routines, techniques and tasks (van Hoof 2014). Knowledge flow methodology is a guideline for knowledge flow with specific components such as phases, tasks, methods, techniques, routine and tools (Singh and Kant 2008; Li and Hu 2012). It enhances cross-enterprise knowledge trading among members of the SC to improve SC's coordination and product quality.
(7) *Relative Power:* The relative power of an organisation is highly associated with the extent of interdependencies within the SC partners (Cai et al. 2013). Relative power is defined as the dependency of one organisation on another for a service or product that could, otherwise, not be undertaken (He, Ghobadian, and Gallear 2013). Power is used to achieve effective management of inter-organisational information management and knowledge sharing (Maçada et al. 2013). Cox (1999) argued that if SC partners understand power within the SC, a party which holds more power perceives the great potential benefits of knowledge sharing with its trading partners. It may exercise its power and request them to share proprietary knowledge (Ke and Wei 2007).

(8) *Motivation of Source and Recipient organisations:* The act of knowledge flow within SC partners is dependent on the motivation of source and recipient organisations (McLaughlin 2010; Marwick 2001). SC members must be motivated to share knowledge across the organisation and within the network (Christopher and Gaudenzi 2009). Proper effort should be made to motivate sharing by source and recipient organisations for effective knowledge flow in SC (Lin and Lee 2005).

(9) *Strategic Relationship:* Strategic relationships between SC partners are developed through long-term relationships (Oke, Prajogo, and Jayaram 2013; Paulraj and Chen 2007). Strategic relationship is the agreement among SC partners to augment knowledge flow process, to achieve smooth SC. Building strategic relationships with key SC partners will enhance the exchange of knowledge with such firms (He, Ghobadian, and Gallear 2013).

(10) *Employee Training and Site Observation:* Tacit knowledge is more difficult to codify and articulate. It is hard to transfer. Practical experience is necessary to disseminate tacit knowledge (Samuel et al. 2011). This type of knowledge is anchored in a social context, and is intimately attached to the personal experience of the possessor, which complicates its formalisation and communication processes tremendously (Nonaka and Takeuchi 1995). Tacit knowledge is often provided by learning-by-doing and experimenting in traditional dissemination approaches (Stone 2006; van Hoof 2014). Also, cross training, professional development programmes and site observations for employees are crucial to knowledge dissemination (Nagati and Rebolledo 2013; Yang et al. 2013).

(11) *Continuous Communication:* Continuous communication is vital to assist knowledge flow in SC organisations (Harrington 2001; Al-Karaghouli et al. 2013). Tacit knowledge is especially transferred through face-to-face communication between upstream and downstream organisations since it is embedded into the practices and communications of individuals (Nagati and Rebolledo 2013; Yang 2012; Maçada et al. 2013). Two-way communication can deliver important market information, and can enhance operational efficiency and customer responsiveness (Paulraj, Lado, and Chen 2008). Naturally, these activities are conducive to knowledge sharing between the buyer and supplier (Liu et al. 2012).

(12) *Personalisation:* Personalisation refers to human-based information processing activities such as brainstorming sessions to periodically identify and share knowledge (Jennex 2005). Personalisation interconnects the knowledge workers, groups and organisations through networks to find, understand and internalise the knowledge through managed conversation (Brown and Duguid 2000; Yang 2012). Personalisation is basically suited to those companies which face unique problems that depend on workers' expertise and tacit knowledge (McLaughlin 2010). In most situations, knowledge seekers/customers come with an unpredictable set of queries. This happens mostly with organisations which have different customers in different domains. The knowledge seeker needs the right person who has the know-how (Hansen, Nohria, and Tierney 1999).

(13) *IT Infrastructure:* Advanced IT infrastructures have a significant contribution in best-in-class organisations through access of a real-time knowledge flow across all participating members of SCs (Al-Mutawah, Lee, and Cheung 2009). Organisations which adopt 'visible technologies', in their SC system, for real-time customer and demand data are three times more successful than laggard organisations (Myers and Cheung 2008). These technologies allow buyers and sellers to share knowledge more easily across borders. Organisations continue to make significant investments in IT infrastructure, facilitating knowledge flow and information flow across SCs to maintain competitive advantage (Ke et al. 2009; Samuel et al. 2011). The buyer and supplier dyad can achieve a reduced cycle time, lowered operational cost and improved product quality due to a simultaneous access to the required information. As a result, the unit cost of the product and manufacturing overhead costs are reduced (Yang 2012).

(14) *Codification:* Explicit knowledge tends to be codifiable, more precisely and formally articulated and easily understood (Lee 2004; Cai et al. 2013). It is supported by collaborative alliance and IT infrastructure to share the codified documentation (Nonaka and Konno 1998; Yang 2012). In knowledge-intensive work environments, workers need task-relevant knowledge and documents to support their execution of tasks. Thus, pattern-based approaches like codification help workers to effectively fulfil their needs of knowledge while performing tasks (Liu, Lin, and Chen 2013a).

(15) *Organisational Learning:* Organisational learning is a process by which an organisation acquires and transfers knowledge, understanding, know-how, techniques, practices and modifies its behaviour to reflect new knowledge and insights (Wu 2008). New ideas and insights are essential if learning is to take place. Sometimes, they are created as a whole new concept, through flashes of insight; sometimes, they come from other organisations. Whatever their source, these ideas are the trigger for organisational improvement (Garvin, Edmondson, and Gino 2008). Organisational learning is based on sharing of individuals' mental models to construct a shared meaning. Individual learning requires a conversion to become organisational learning.

(16) *Operational Coordination:* Knowledge sharing within SC seems to be associated with increased operational coordination (Christopher and Gaudenzi 2009). Suppliers can develop relationships with some of their customers to acquire new knowledge about production techniques or management practices such as the Kanban system, statistical process control, process improvement activities and preventive maintenance methods. Operational coordination facilitates organisations to exchange decisions rights, knowledge and resources with SC partners, which, in turn, enhances the knowledge sharing among SC (Liu et al. 2013b). The decision right is the right/power to make a decision in that organisation. It reduces bullwhip effect by monitoring initial response, coordination and communications among SC partners.

(17) *Retentive Capacity:* The retention of knowledge is the extraction of tacit knowledge from a person who will retire or wants to leave, and storing it in the organisational memory. Organisational memory refers to 'stored information from an organisation's history that can be brought to bear on present decisions' (Walsh and Ungson 1991). Much of the time organisations fail to retain critical skills, capabilities, experience and knowledge of the employees. A common approach to retaining knowledge is to capture and store departing employees' information and knowledge through interviews and documentation, so that it can be made explicit to others and used again at a later date (Mishra and Bhaskar 2011; Sambrook 2005).

(18) *Trust:* SC knowledge sharing is based on mutual trust among organisations (Li and Ding 2012). Trust in knowledge sharing is a very important factor in fulfilling one's unique value (Mayer and Gavin 2005). A trusting relationship fosters cooperation and open communication rather than competition and opportunism, and is likely to lead to knowledge exchange among business partners. When trust exists, the buyer and supplier are more likely to be open and receptive to seamless knowledge sharing (Jean, Sinkovics, and Hiebaum 2014; Yang 2012).

(19) *Absorptive Capacity:* Absorptive capacity is a critical factor in organisation's knowledge transfer. The knowledge acquiring organisation requires an absorptive capacity to identify key information, understand the competitive importance of the knowledge and apply it to facilitate inter-organisational knowledge flow (Jharkharia and Shankar 2004; Cheng, Yeh, and Tu 2008). Lane, Koka, and Pathak (2006) described absorptive capacity as an organisation's ability to identify, assimilate and exploit knowledge from the environment. Efficient absorptive capacity stimulates the speed of knowledge transfer, and decreases cost of knowledge transfer in an organisation (Cummings and Teng 2003; Minbaeva et al. 2003).

(20) *Source Credibility:* Source credibility and trustworthiness make it easy to share explicit and tacit knowledge with SC partners (Raymond et al. 2007; Petruzzelli et al. 2010), since source credibility assures the knowledge receiver that the knowledge they are accessing is genuine and validated through previous use (Inkpen 1997). Knowledge source should be accurate and definite. Knowledge quality and source credibility depend on accurate and unambiguous knowledge quality, so that there is no hesitation by receivers to access knowledge (Cheng, Yeh, and Tu 2008).

(21) *Collaborative Alliance:* SC collaboration is an effective way to transfer knowledge and skills among organisations. Collaboration is defined as a bilateral effort by SC trading partners for accessing, synthesising and deploying knowledge to achieve goals that would otherwise be difficult to achieve (Chong et al. 2009; Zacharia, Nix, and Lusch 2011; Chong and Bai 2014). Collaborative alliance facilitates knowledge transfer and interactive learning processes across the SC partners and coordinates the knowledge flow and product flow in the buyer and supplier exchanges (Caridi, Cigolini, and DeMarco 2005; Green and Inman 2005; Yang 2013). A collaborative environment among SC partners is essential for meeting the diverse demands of the market which they serve (Chong et al. 2009).

(22) *Organisational Culture:* Organisational culture improves the interaction between individuals, teams and communities (Armbrecht et al. 2001; Sambasivan, Loke, and Abidin-Mohamed 2009; Yang et al. 2013). Organisational culture is a system of shared assumptions, values and beliefs, which governs how people behave in organisations. Mutual trust between employees improves organisational culture to share knowledge (Donate and Guadamillas 2010). Better organisational culture fosters more effective communication among SC partners. An organisational culture that promotes open communication should share knowledge easily. In contrast, organisational culture that promotes closed communication would demonstrate secrecy and value power in knowledge (Hofstede et al. 1990).

(23) *Common Language and Terminology:* Common language is a major factor that is to be considered in the concept of knowledge flow. The need for improved knowledge flow between the buying and supplying organisations' staff calls for the development of a common language and terminology (Finestone and Snyman 2005). Mature SCs use common language and terminology for face-to-face interaction across SC members (Herrgard 2000; Cheung, Myers, and Mentzer 2010). Understanding and teaching tacit and explicit knowledge become easy in common language and terminology (Alguezaui and Filieri 2010).

(24) *Organisations' Reputation*: The creation of a 'good' reputation is an important step for achieving effective knowledge transfer among SC partners (Christopher and Gaudenzi 2009). Currently, organisations are extremely exposed to various threats which can damage their reputation and hence a need arises to manage vulnerability. Organisations have to face threats like negative word-of-mouth, coming from dissatisfied employees and customers because of their expectations and needs regarding quality, price, service, safety, transparency and ethics. An organisation's reputation is decided by the level to which it fulfils stakeholders' expectations through an organisation's performance and behaviour (Atkins, Bates, and Drennan 2006; Taewon and Amine 2007; Christopher and Gaudenzi 2009).

(25) *SC Partner Goal:* Organisations with similar philosophies and goals have a greater tendency to share knowledge (Myers and Cheung 2008). The relationship among SC partners becomes fragile if the operations among the SC are not aligned with common integrated goals (Kayakutlu and Büyüközkan 2010). Goal alignment of SC partners results in better decision-making compared to partners with no goal alignment. Parallel philosophies and goals emphasise cooperation (Inkpen and Tsang 2005). They help SC partners enhance their individual competitive positions as well as their joint competitive position; this, in turn, increases the willingness to share ideas and knowledge (Zhang et al. 2012).

(26) *SC Structure:* SC structure is the combination of suppliers, manufacturers, distributors, retailers and end users. It is used as an enabler of knowledge flow in terms of coordination and supervision within the SC organisation. It also helps enable SC organisational policies, reward systems and incentives to ultimately achieve knowledge flow in SC (Bock, Zmud, and Kim 2005; Oke, Prajogo, and Jayaram 2013).

(27) *Recognition:* Recognition provides power to the employees of the SC to feel proud and important (McDermott and O'Dell 2001). It is considered as one of the most powerful criteria in an SC to motivate its employees to share knowledge (Zhuge and Guo 2007). Recognition is beneficial to retain knowledge experts in the organisation and to encourage people to share knowledge.

(28) *Sense of Self-Worth:* The sense of self-worth of the individual is the tendency to establish and maintain a positive self-image or to believe in oneself (Bock, Zmud, and Kim 2005). Self-worth and trust encourage people to contribute knowledge. It is maintained by trust between the SC members (Kuo 2013).

(29) *Availability of Time and Space:* Availability of time and space fosters internal communication and inter-organisational collaboration, which motivate workers to share ideas and experience in addition to the generation of a cooperative relationship among workers (Cross and Sproull 2004). Knowledge diffusion through face-to-face interaction and the absorption of knowledge require time and space for both individual and organisational forms of knowledge (Herrgard 2000; Cheng, Yeh, and Tu 2008).

(30) *Willing to Share Knowledge:* Some persons are happy to take care of the needs of others, and share knowledge altruistically (Davenport and Prusak 1998). If suppliers are willing to share their knowledge, the SC as a whole benefits (Lawson and Potter 2012; Simonin 2004). Knowledge sharing is a synergistic process; an idea is presented before employees and the employees will get a benefit from this knowledge and the idea can be reformed further (Capó-Vicedo, Mula, and Capó 2011). Willingness to share knowledge acts as an enabler of knowledge flow in the organisation (Hence Kuo 2013).

(31) *Rewards and Incentives:* Rewards and incentives provide a spur or zeal in the employees to implement their ideas for new opportunities and to motivate positive social interaction (Lin and Lee 2005). Most of the time, team members hesitate to take part in knowledge sharing (Zhuge and Guo 2007). Proper organisational policies like rewards and incentives are stimuli that encourage people to share knowledge (Kuo 2013). Organisations in a collaborative alliance within networks share their knowledge with other parties if incentives are provided (Jahani, Ramayah, and Effendi 2011; van Hoof 2014; Li and Ding 2012; Yang 2013).

3. Problem description

This section examines an example of a well-known Indian automobile brake manufacturing organisation. It was established in 2005, and it currently has more than 6000 employees. About 10% of the employees are engineers and SC executives that are engaged in SC development activities. The primary goal of the organisation is global expansion so as to establish a presence in the countries where the group's main clients have production plants, so that its products may be supplied more rapidly and more efficiently. There is a need to adopt successful knowledge flow within the organisation in order to improve SC performance to overcome the intense competition within the SCs of two different organisations to hold the same business. Need to adopt knowledge flow in SC stimulates SC executives of the organisation to identify SCKFEs and to analyse the interaction and interdependencies among these SCKFEs.

4. Integrated application of ISM and fuzzy MICMAC methodology to the case illustration

ISM and fuzzy MICMAC method enables study of the diffusion of impacts through reaction paths and loops for developing a hierarchy of the SCKFEs. Identification of relationships among SCKFEs using ISM approach is based on consensus of expert views. The ISM methodology is employed to study and analyse the interactions among the SCKFEs. The classification of SCKFEs according to their driving power and dependence power has been carried out using fuzzy MICMAC. The flowchart of given method is shown in Figure 1. Many researchers have used integration of ISM and fuzzy MICMAC analysis in various areas such as logistics, SC and risk management. (Table 2).

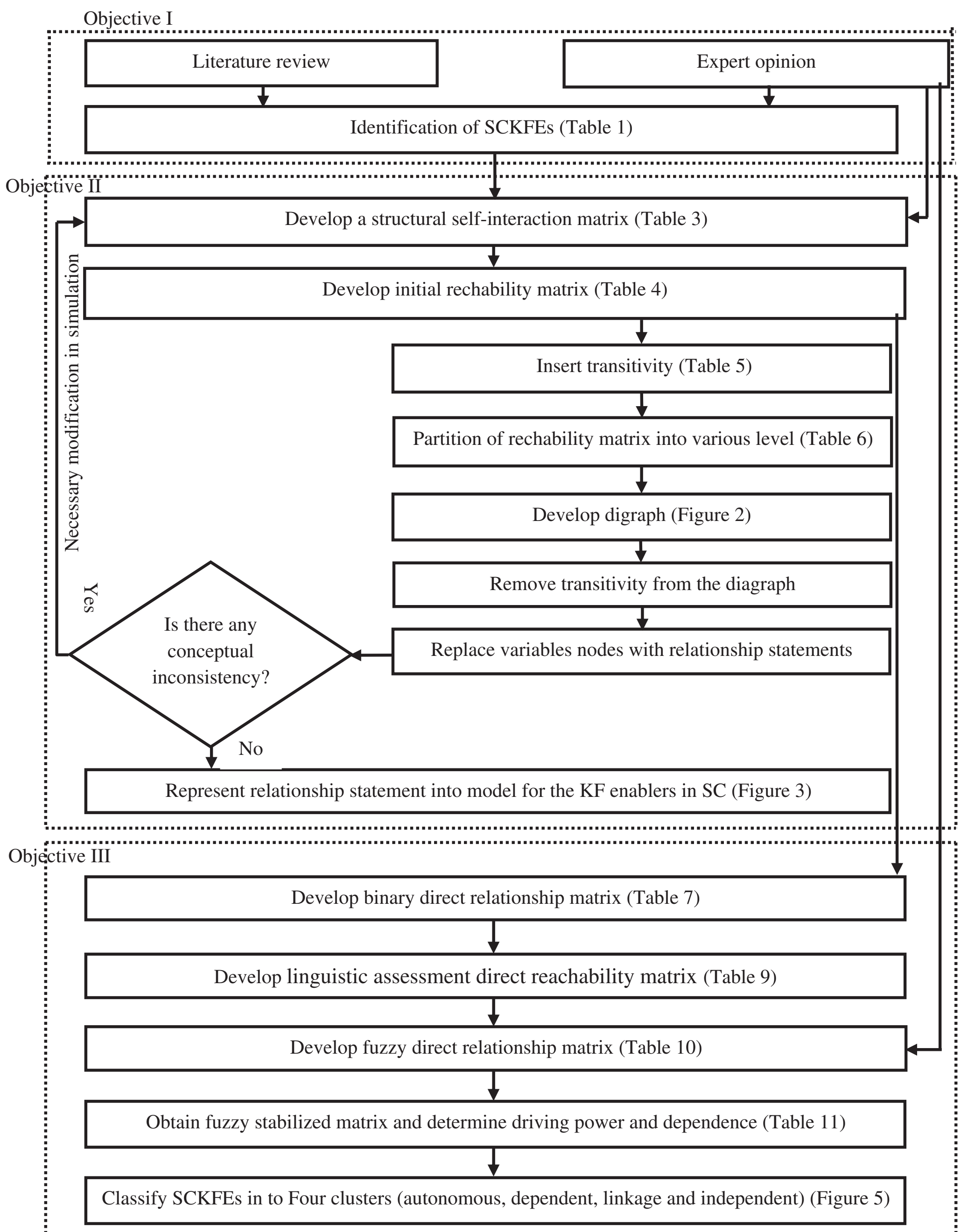

Figure 1. Flow chart for the integrated ISM and FMICMAC methodology.

Table 1. SCMKFEs and literature support.

Major enabler	Sub-enabler	Authors
Characteristics of the knowledge transfer	Transferability of knowledge (SCKFE1)	Lawson and Potter 2012; Lane, Koka, and Pathak 2006;
	Updated knowledge (SCKFE2)	Filieri and Alguezaui 2012; Lawson and Potter 2012; Song and Di Benedetto 2008;
Strategic	Top management support (SCKFE3)	Huang, Stewart, and Chen (2010); Kayakutlu and Büyüközkan 2010; Tseng 2008; Davenport and Prusak 1998;
	Strategic planning (SCKFE4)	Wu 2008; Sodhi 2003;
	Integration of knowledge (SCKFE5)	Chen, Preston, and Xia 2013; Singh and Power 2014;
	Knowledge flow methodology (SCKFE6)	van Hoof 2014; Li, Tarafdar, and Rao 2012; Singh and Kant 2008; Dyer and Singh 1998;
	Relative power (SCKFE7)	Cai et al. 2013; Maçada et al. 2013; Ke and Wei 2007; Cox 1999;
	The motivation of source and recipient firms (SCKFE8)	McLaughlin 2010; Christopher and Gaudenzi 2009; Lin and Lee 2005; Marwick 2001;
Knowledge flow mechanism	Strategic relationship (SCKFE9)	He, Ghobadian, and Gallear 2013; Liu et al. 2013c; Oke, Prajogo, and Jayaram 2013; Zhao and Lavin 2012; Paulraj and Chen 2007;
	Employee training and site observation (SCKFE10)	van Hoof 2014; Nagati and Rebolledo 2013; Yang et al. 2013; Stone 2006; Nonaka and Takeuchi 1995;
	Continuous communication (SCKFE11)	Al-Karaghouli et al. 2013; Gambetti and Giovanardi 2013; Machikita and Ueki 2013; Nagati and Rebolledo 2013; Liu et al. 2012; Yang 2012; Harrington 2001; Paulraj, Lado, and Chen 2008;
	Personalisation (SCKFE12)	Yang 2012; McLaughlin 2010; Mobasher, Cooley, and Srivastava 2002; Brown and Duguid 2000;
	IT infrastructure (SCKFE13)	Chong and Bai 2014; Liu, Lin, and Chen 2013a; Tennant and Fernie 2013; Yang et al. 2013; Cervellon and Wernerfelt 2012; Yang 2012; Schober and Gebauer 2011; Al-Mutawah, Lee, and Cheung 2009; Ke et al. 2009; Myers and Cheung 2008; Rodrigues, Stank, and Lynch 2004;
	Codification (SCKFE14)	Cai et al. 2013; Liu, Lin, and Chen 2013a; Yang 2012; Zhuge 2006; Levin and Cross 2004; Nonaka and Konno 1998;
Operational	Organisational learning (SCKFE15)	Lawson and Potter 2012; Wu 2008; Tsang 2002;
	Operational coordination (SCKFE16)	Liu et al. 2013b; Christopher and Gaudenzi 2009;
	Retentive capacity (SCKFE17)	Mishra and Bhaskar 2011; Sambrook 2005;
	Trust (SCKFE18)	Jean, Sinkovics, and Hiebaum 2014; Li and Hu 2012; Yang 2012; Zhang et al. 2012; Inkpen and Tsang 2005; Mayer and Gavin 2005;
	Absorptive capacity (SCKFE19)	Liu et al. 2013b; Cheng, Yeh, and Tu 2008; Lane, Koka, and Pathak 2006; Jordan and Lowe 2004; Cummings and Teng 2003; Minbaeva et al. 2003;
	Source credibility (SCKFE20)	Petruzzelli et al. 2010; Cheng, Yeh, and Tu 2008; Raymond et al. 2007;
Organisational	Collaborative alliance (SCKFE21)	Chong and Bai 2014; Yang 2013; Singh and Power 2014; Zacharia, Nix, and Lusch 2011; Chong et al. 2009; Caridi, Cigolini, and DeMarco 2005; Green and Inman 2005;
	Organisational culture (SCKFE22)	Yang et al. 2013; Sambasivan, Loke, and Abidin-Mohamed 2009; Wu 2008; Armbrecht et al. 2001;
	Common language and terminology (SCKFE23)	Cheung, Myers, and Mentzer 2010; Alguezaui and Filieri 2010; Finestone and Snyman 2005; Herrgard 2000;
	Organisation’s reputation (SCKFE24)	Liu et al. 2013b; Christopher and Gaudenzi 2009; Taewon and Amine 2007; Atkins, Bates, and Drennan 2006;
	SC partners goals (SCKFE25)	Zhang et al. 2012; Kayakutlu and Büyüközkan 2010; Myers and Cheung 2008; Inkpen and Tsang 2005;
	Supply chain structure (SCKFE26)	Pan et al. 2013; Bock, Zmud, and Kim 2005;
Individual	Recognition (SCKFE27)	Zhuge and Guo 2007; McDermott and O’Dell 2001;
	Self-esteem (SCKFE28)	Kuo 2013; Bock, Zmud, and Kim 2005;
	Availability of time and space (SCKFE29)	Cheng, Yeh, and Tu 2008; Cross and Sproull 2004; Herrgard 2000;
	Willing to share Knowledge and experience (SCKFE30)	Kuo 2013; Lawson and Potter 2012; Capó-Vicedo, Mula, and Capó 2011; Simonin 2004; Davenport and Prusak 1998;
	Rewards and Incentives (SCKFE31)	van Hoof 2014; Kuo 2013; Yang 2013; Li and Hu 2012; Jahani, Ramayah, and Effendi 2011; Zhuge and Guo 2007; Lin and Lee 2005

Table 2. ISM and fuzzy MICMAC as reported in literature.

Author	Details
Jharkharia and Shankar (2004)	To evolve mutual relationships among IT-based enablers of SCM
Faisal, Banwet, and Shankar (2006)	To evolve mutual relationships among the enablers of risk mitigation
Raj, Shankar, and Suhaib (2008)	Establish mutual interaction between enablers of flexible manufacturing system and identify the ‘driving enablers’ and the ‘dependent enablers’
Pfohl, Gallus, and Thomas (2011)	To evolve interrelationships among SC risks and to classify the risks according to their driving and dependence power
Diabat et al. (2013)	To analyse the barriers of third-party logistics in manufacturing industries
Gorane and Kant (2013)	Develops relationship between enablers of SC management

4.1 *Interpretive structural modelling*

Interpretive structural modelling (ISM) technique was first proposed by Warfield in 1974 to analyse the relationship between specific items related to a problem. The method is interpretive as the group of experts’ judgement decides whether and how the items are related. It becomes difficult to deal with a system having a complex set of directly or indirectly related enablers. The ISM methodology transforms unclear and poorly articulated models of systems into a hierarchy of system variables to represent the visible and well-defined models (Warfield 1974; Sage 1977). The main limitations of the ISM method which may influence the final result are as follows:

- Any biasing done by the judging person.
- Person’s expertise and experience with the particular industry sector will affect the relation among the variables.
- ISM does not assign any weight to the variables.

Following are the steps of ISM methodology.

(1) Identification of SCKFEs: Identify and list the SCKFEs which are relevant to the problem through literature review and select the SCKFEs using Delphi method.
(2) Contextual Relationship: Establish a contextual relationship among SCKFEs and prepare a structural self-interaction matrix (SSIM) based on pairwise comparison of elements of the system under consideration. The relations may be of several types like comparative, influence, neutral and temporal relations (Austin and Burns 1985; Warfield 1994).
(3) Reachability Matrix: Develop a matrix from the SSIM by replacing symbols with binary digits (0 and 1) and check transitivity (i.e. if variable P is related to variable Q and variable Q is related to variable R, then variable P is necessarily related to variable R).
(4) Carry out the partitioning to find various levels of the model from the reachability matrix obtained in Step 3.
(5) Draw a directed graph by means of nodes and single/double-ended arrow lines and remove the transitive links from diagraph (see Figure 3) based on the relationships given in the reachability matrix. Later, convert the resultant diagraph into an ISM model by replacing enabler nodes with statements.

4.1.1 *Structural self-interaction matrix*

Through an extensive literature review and expert opinion from academics and industries, 31 SCKEFs (see Table 1) were identified. Twelve experts from the case organisation and four experts from academia were consulted. The twelve experts from the case organisation consisted of three senior SC management executives, three knowledge management/IT representatives, three suppliers and three customers. Each selected expert has more than 15 years of experience and is well acquainted with issues of knowledge flow in SC. The Delphi method was used to select the most preeminent enablers in the area of KF in SC. Linstone and Turoff (1979) defined ‘Delphi technique as a well-known group decision-making method involving a structured interaction among a panel of experts which anonymously tries to reach consensus on the significant features of a certain topic’. Delphi method was used by various authors to select the criteria like the barriers of knowledge transfer (Sun and Scott 2005), knowledge management effectiveness variables (Anantatmula and Kanungo 2005) and the enablers of SC management (Gorane and Kant 2013).

The steps followed in Delphi method are as given below (Wang and Lin 2008; Agell et al. 2015).

Table 3. Structural self-interaction matrix.

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
SCKFE1	A	A	A	A	A	A	A	V	A	A	A	A	X	A	V	V	V	A	A	A	A	A	A	A	A	A	A	A	A	A
SCKFE2	A	A	A	A	A	A	A	V	A	A	A	X	V	A	V	V	V	A	A	A	X	A	A	A	A	A	A	A	A	
SCKFE3	V	V	V	V	V	V	O	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	O	V	O	V	V	V		
SCKFE4	O	V	V	V	O	V	O	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	O	V	O	V	V			
SCKFE5	A	V	V	A	A	A	A	V	V	A	A	V	V	A	V	V	V	A	A	A	V	A	A	A	A	A				
SCKFE6	O	V	V	O	O	O	O	V	V	O	V	V	V	O	V	V	V	V	V	V	V	V	O	O	O					
SCKFE7	O	V	V	V	O	O	A	V	V	V	V	V	V	V	V	V	V	V	O	V	V	O	A	V						
SCKFE8	A	V	V	X	A	A	A	V	V	X	V	V	V	X	V	V	V	V	O	V	V	O	A							
SCKFE9	O	V	V	V	O	O	A	V	V	V	V	V	V	V	V	V	V	V	O	V	V	O								
SCKFE10	O	V	V	O	O	A	O	V	V	O	V	V	V	O	V	V	V	V	X	V	V									
SCKFE11	A	A	A	A	A	A	A	V	A	A	A	X	V	A	V	V	V	A	A	A										
SCKFE12	A	V	V	A	A	A	A	V	V	A	X	V	V	A	V	V	V	X	A											
SCKFE13	O	V	V	O	O	A	O	V	V	O	V	V	V	O	V	V	V	V												
SCKFE14	A	V	V	A	A	A	A	V	V	A	X	V	V	A	V	V	V													
SCKFE15	A	A	A	A	A	A	A	X	A	A	A	A	A	A	X	X														
SCKFE16	A	A	A	A	A	A	A	X	A	A	A	A	A	A	X															
SCKFE17	A	A	A	A	A	A	A	X	A	A	A	A	A	A																
SCKFE18	A	V	V	X	A	A	A	V	V	X	V	V	V																	
SCKFE19	A	A	A	A	A	A	A	V	A	A	A	A																		
SCKFE20	A	A	A	A	A	A	A	V	A	A	A																			
SCKFE21	A	V	V	A	A	A	A	V	V	A																				
SCKFE22	A	V	V	X	A	A	A	V	V																					
SCKFE23	A	O	O	A	A	A	A	V																						
SCKFE24	A	A	A	A	A	A	A																							
SCKFE25	O	V	V	V	O	O																								
SCKFE26	O	V	V	V	O																									
SCKFE27	X	V	V	V																										
SCKFE28	A	V	V																											
SCKFE29	A	X																												
SCKFE30	A																													
SCKFE31																														

Table 4. Initial reachability matrix.

	1	2	3	…	…	…	29	30	31
SCKFE1	1	0	0	…	…	…	0	0	0
SCKFE2	1	0	0	…	…	…	0	0	0
SCKFE3	1	1	0	…	…	…	1	1	1
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
SCKFE29	1	1	0	…	…	…	1	1	0
SCKFE30	1	1	0	…	…	…	1	1	0
SCKFE31	1	1	0	…	…	…	1	1	1

Step 1: A list of all SCKFEs identified from the literature is issued to experts. Some SCKFEs were similar in meaning and hence they were eliminated by experts at initial stage.
Step 2: The individual opinions (in the form of value) were recorded by the facilitator provided to coordinate the opinions in such a way that the experts do not know the opinion of another expert, and these values were aggregated by facilitator, hence trying to reduce the bias.
Step 3: Aggregated values are shown to each expert and asked to re-access the initial values in the view of aggregated opinion.

Through the multiple iterations of Steps 2 and 3, consensus of the experts values is achieved (Gumus 2009). The outcome of the Delphi process was a set of 31 SCKFEs.

For analysing the contextual relationship among different SCKFEs, a structural self-interaction matrix sheet without notation was administered to each expert. The results were then discussed with the experts, and a final matrix was achieved, reflecting the experts' consensus based on their judgement.

For analysing SCKFEs in developing SSIM, the following four symbols have been used to denote the direction of relationship among enablers (*i* and *j*).

(1) V: Factor *i* will lead to Factor *j* (i.e. if enabler *i* influences or reaches to enabler *j*).
(2) A: Factor *i* will be achieved by Factor *j* (i.e. if enabler *j* reaches to enabler *i*).
(3) X: Factor *i* and Factor *j* will help achieve each other.
(4) O: Factor *i* and Factor j are not related.

The following will explain the use of the symbols V, A, X and O in SSIM (Table 3).

- Symbol V is assigned to cell (3, 5) because SCKFE3 influences or reaches to SCKFE5.
- Symbol A is assigned to cell (5, 27) because SCKFE27 influences the SCKFE5.
- Symbol X is assigned to cell (8, 28) because SCKFE8 and SCKFE28 influence each other.
- Symbol O is assigned to cell (9, 31) because SCKFE9 and SCKFE31 are unrelated.

4.1.2 *Initial reachability matrix*

The SSIM has been converted into a binary matrix, called initial reachability matrix (see Table 4) by transforming V, A, X and O by 1 and 0 as per given case. The substitution of 1 and 0 is as per the following rules.

- If the (*i*, *j*) entry in the SSIM is V, then the (*i*, *j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry becomes 0.
- If the (*i*, *j*) entry in the SSIM is A, then the (*i*, *j*) entry in the reachability matrix becomes 0 and the (*j*, *i*) entry becomes 1.
- If the (*i*, *j*) entry in the SSIM is X, then the (*i*, *j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry also becomes 1.
- If the (*i*, *j*) entry in the SSIM is O, then the (*i*, *j*) entry in the reachability matrix becomes 0 and the (*j*, *i*) entry also becomes 0.

Table 5. Final reachability matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SCKFE1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE2	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0
SCKFE3	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
SCKFE4	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
SCKFE5	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	1	1	0	0	0	0	1	1	0
SCKFE6	1	1	0	0	1	1	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE7	1	1	0	0	1	0	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1*	1	0	0	0	1	1	1	0
SCKFE8	1	1	0	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0
SCKFE9	1	1	0	0	1	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0
SCKFE10	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE11	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0
SCKFE12	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE13	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE14	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE18	1*	1	0	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0
SCKFE19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE20	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0
SCKFE21	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0
SCKFE22	1	1	0	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0
SCKFE23	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0
SCKFE24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SCKFE25	1	1	0	0	1	0	1	1	1	0	1	1*	0	1*	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0
SCKFE26	1	1	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
SCKFE27	1*	1	0	0	1*	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1*	1	0	0	1	1	1	1	1
SCKFE28	1	1	0	0	1*	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0
SCKFE29	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	1	1	0
SCKFE30	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	1	1	0
SCKFE31	1	1	0	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1

*Transitivity

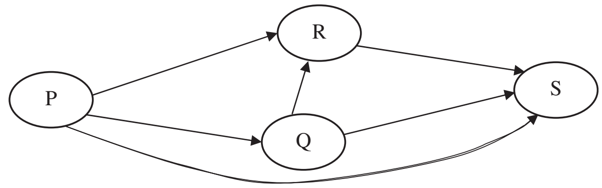

Figure 2. Transitivity graph.

Table 6. Partition of reachability matrix showing all iterations and levels of the SCKFEs.

	Reachability set	Antecedent set	Intersection set	Level
1	1, 19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31	1, 19	II
2	2, 11, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31	2, 11, 20	III
3	3	3	3	X
4	4	3, 4	4	IX
5	5	3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 31	5	V
6	6	3, 4, 6	6	VIII
7	7	7, 9, 25	7	VIII
8	8, 18, 22, 28	3, 4, 7, 8, 9, 18, 22, 25, 26, 27, 28, 31	8, 18, 22, 28	VII
9	9	9, 25	9	IV
10	10, 13	3, 4, 6, 10, 13, 26	10, 13	VII
11	2, 11, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31	2, 11, 20	III
12	12, 14, 21	3, 4, 6, 7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 31	12, 14, 21	VI
13	10, 13	3, 4, 6, 10, 13, 26	10, 13	VII
14	12, 14, 21,	3, 4, 6,7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 31	12, 14, 21,	VI
15	15, 16, 17, 24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	15, 16, 17, 24	I
16	15, 16, 17, 24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	15, 16, 17, 24	I
17	15, 16, 17, 24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	15, 16, 17, 24	I
18	8, 18, 22, 28	3, 4, 7, 8, 9, 18, 22, 25, 26, 27, 28, 31	8, 18, 22, 28	VII
19	1, 19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31	1, 19	II
20	2, 11, 20	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31	2, 11, 20	III
21	12, 14, 21	3, 4, 6, 7, 8, 9 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 31	12, 14, 21	VI
22	8, 18, 22, 28	3, 4, 7, 8, 9, 18, 22, 25, 26, 27, 28, 31	8, 18, 22, 28	VII
23	23	3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 23, 25, 26, 27, 28, 31	23	IV
24	15, 16, 17, 24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	15, 16, 17, 24	I
25	25	25	25	X
26	26	3, 4, 26	26	VIII
27	27, 31	3, 27, 31	27, 31	VIII
28	8, 18, 22, 28	3, 4, 7, 8, 9, 18, 22, 25, 26, 27, 28, 31	8, 18, 22, 28	VII
29	29, 30	3, 4, 5, 6,7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 29, 30, 31	29, 30	IV
30	29, 30	3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 18, 21, 22, 25, 26, 27, 28, 29, 30, 31	29, 30	IV
31	27, 31	3, 27, 31	27, 31	VIII

4.1.3 *Final reachability matrix*

From the initial reachability matrix, the transitivity of the matrix was checked to establish the final reachability matrix (see Table 5). The transitivity of the relationships is a basic assumption made in the ISM method. Transitivity can be explained as shown in Figure 2: if SCKFE P is related to SCKFE Q (i.e. pRq) and SCKFE Q is related to SCKFE R

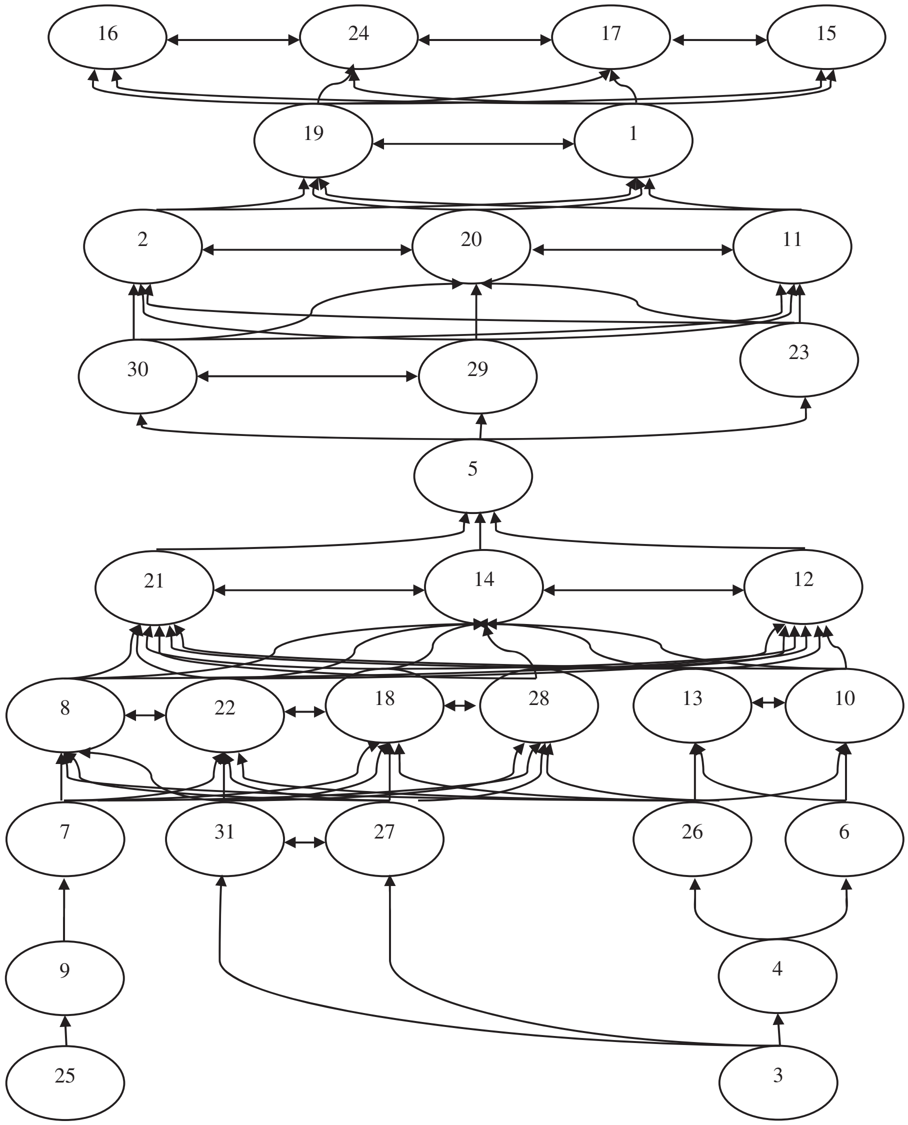

Figure 3. Diagraph depicting the relationship among the SCKFEs.

(i.e. qRr), then SCKFE P is necessarily related to SCKFE R (i.e. pRr). Similarly, if SCKFE P relates to SCKFE S (pRs) and SCKFE Q relates to SCKFE S (qRs), then SCKFE P is necessarily related to SCKFE S (i.e. pRs). Thus, after imposing the transitivity relationships denoted by 1*, the final reachability matrix is developed as shown in Table 5.

4.1.4 *Level partitions*

Level partitions are made to determine the hierarchy of the elements. From the final reachability matrix, the reachability set and antecedent set for each SCKFEs are found. The reachability set consists of the SCKFE itself and the other SCKFEs on whom it may impact. For every column which contains '1' and '1*' in the row of considered SCKFE (i), the SCKFE represents that column is included in the reachability set. Similarly, the antecedent set consists of SCKFE itself and the SCKFEs which may aid in attaining it. For every row which contains '1' and '1*' in the column of considered SCKFE (i), the SCKFE that row represents is included in the antecedent set. Then, the intersection of these sets is derived for all SCKFEs. Based on the intersection of these sets, SCKFEs are identified for which the reachability and intersection sets are same. These have been considered to be the top-level SCKFEs in the ISM hierarchy (Sage 1977). The top-level SCKFEs in the hierarchy would not help achieve any other SCKFEs above its own level. Once the top-level SCKFEs are identified, the same are removed from the next iteration and a similar procedure leads to final iteration leading to the lowest level (see Table 6).These levels help in building the diagraph and the final model.

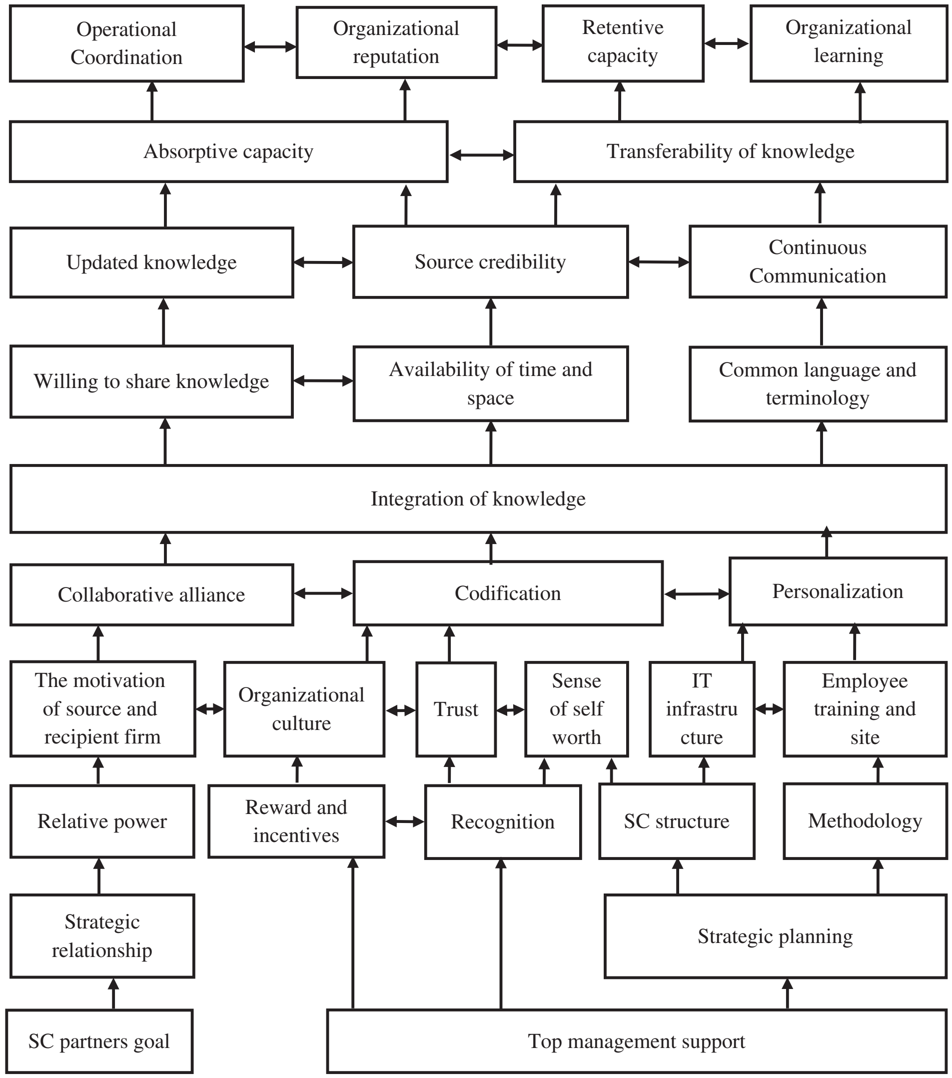

Figure 4. ISM-based model of SCKFEs.

Table 7. Binary direct reachability matrix.

	1	2	3	…	…	…	29	30	31
SCKFE1	0	0	0	…	…	…	0	0	0
SCKFE2	1	0	0	…	…	…	0	0	0
SCKFE3	1	1	0	…	…	…	1	1	1
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
SCKFE29	1	1	0	…	…	…	0	1	0
SCKFE30	1	1	0	…	…	…	1	0	0
SCKFE31	1	1	0	…	…	…	1	1	0

4.1.5 *Building the ISM model*

Based on the level partitions of the factors and the final reachability matrix (Table 5), the structural model is generated. If there is a relationship among the SCKFEs *i* and *j*, this is shown by an arrow which points from *i* to *j*. This graph is called a directed graph, or digraph (Figure 3). By removing the transitivities among the SCKFEs, the digraph is finally converted into the ISM-based model as shown Figure 4.

4.2 *Fuzzy MICMAC analysis*

Duperrin and Godet (1973) developed the MICMAC as a systematic analysis of complex issues. The results of ISM are used as an input to fuzzy MICMAC analysis to identify the driving and dependence power of SCKFEs. MICMAC is an indirect classification method to critically analyse the scope of each element.

The conventional MICMAC analysis considers only binary type of relationships, but here we use fuzzy set theory (FST) to increase the sensitivity of MICMAC analysis. In fuzzy MICMAC, an additional input of possibility of interaction among the elements is introduced. The analysis can be further improved by considering the strength of relationships instead of the mere consideration of relationships so far. From Table 4, we can say that the relationship among SCKFE 31 and SCKFE 2, SCKFE 31 and SCKFE 29, SCKFE 31 and SCKFE 30 have equal importance and denoted by 1. But actually, the relationship among these SCKFEs cannot always be equal. Some relations may be strong, some may be very strong and some relations may be weak.

4.2.1 *Binary direct relationship matrix*

A binary direct reachability matrix (BDRM) is obtained by examining the direct relationship among the SCKFEs in the ISM as given in Table 4. From Table 4, the diagonal entries are converted to zero. The BDRM hence derived is shown in Table 7.

4.2.2 *Development of linguistic assessment direct reachability matrix (LADRM)*

Fuzzy set allows the gradual assessment of the membership of elements in the set, described with the help of membership function valued in the real unit interval [0, 1]. Triangular function is defined by a lower limit l, an upper limit r and a value m, where $l < m < r$. The points l, m and r represent the x coordinates of the three vertices of $\mu_{\tilde{A}}(x)$ in a fuzzy set A. A triangular fuzzy number 'A' is shown as a triplet (l, m, r) as in Figure 5. The membership function '$\mu_{\tilde{A}}(x)$' is defined by the following equation.

$$\mu_{\tilde{A}}(x) = \begin{bmatrix} 0 & x < l \\ \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{r-x}{r-m} & m \leq x \leq r \\ 0 & x > r \end{bmatrix}$$

Table 8 gives the linguistic scale for the evaluation of alternatives. The fuzzy MICMAC can analyse the possibility of interaction defined by qualitative consideration on linguistic variables, no influence (No), very low influence (VL), low influence (L), medium influence (M), high influence (H), very high influence (VH) and Complete influence (C) as shown in Table 8.

The opinion of the same academicians and industry experts is taken to rate the relationship among two SCKFEs. The values for the relationship among two SCKFEs are then superimposed on the BDRM to obtain a linguistic assessment direct relationship matrix (LADRM). The LADRM is given in Table 9.

Since the form of fuzzy numbers is not suitable for matrix operations, defuzzication is needed for further aggregation.

Defuzzication is a method converting fuzzy numbers into a crisp number as shown in fuzzy direct reachability matrix (FDRM) (see Table 10). Convert the fuzzy values into crisp values using the best non-fuzzy performance (BNP) value. The defuzzified value of a fuzzy number can be obtained from following equation.

$$\mathrm{BNP}_{ij} = \frac{[(r-l) + (m-l)]}{3} + l$$

4.2.3 *Fuzzy MICMAC-stabilised matrix*

The FDRM is taken as the base to start the process. The matrix is multiplied repeatedly until the hierarchies of the driver power and dependence stabilise. The multiplication process follows the principle of fuzzy matrix multiplication (Kandasamy 2007). Fuzzy matrix multiplication is basically a generalisation of Boolean matrix multiplication. According to FST, when two fuzzy matrices are multiplied, the product matrix is also a fuzzy matrix. Multiplication follows the given rule:

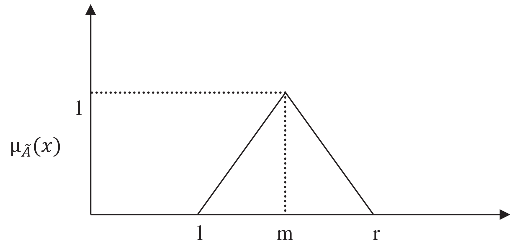

Figure 5. Triangular fuzzy number.

Table 8. The fuzzy linguistic scale.

Linguistic variable	Triangular fuzzy number
No influence (No)	(0, 0, 0)
Very low influence (VL)	(0, 0.1, 0.3)
Low influence (L)	(0.1, 0.3, 0.5)
Medium influence (M)	(0.3, 0.5, 0.7)
High influence (H)	(0.5, 0.7, 0.9)
Very high influence (VH)	(0.7, 0.9, 1)
Complete influence (C)	(1, 1, 1)

Table 9. Linguistic assessment direct reachability matrix.

	1	2	3	…	…	…	29	30	31
SCKFE1	0	0	0	…	…	…	0	0	0
SCKFE2	H	0	0	…	…	…	0	0	0
SCKFE3	M	M	0	…	…	…	M	M	VH
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
SCKFE29	H	H	0	…	…	…	0	0	0
SCKFE30	L	M	0	…	…	…	H	H	0
SCKFE31	L	M	0	…	…	…	H	H	0

Table 10. Fuzzy direct reachability matrix.

	1	2	3	…	…	…	29	30	31
SCKFE1	0	0	0	…	…	…	0	0	0
SCKFE2	0.7	0	0	…	…	…	0	0	0
SCKFE3	0.5	0.5	0	…	…	…	0.5	0.5	0.9
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
SCKFE29	0.7	0.7	0	…	…	…	0	0	0
SCKFE30	0.3	0.5	0	…	…	…	0.7	0.7	0
SCKFE31	0.3	0.5	0	…	…	…	0.7	0.7	0

$$C = A, B = \max k\left[\left(\min \left(a_{ik}, b_{kj}\right)\right] \text{ where } A = [a_{ik}] \text{ and } B = [b_{kj}]$$

A stabilised matrix is shown in Table 11. The driving power of the SCKFE in fuzzy MICMAC is derived by summing the entries of possibilities of interactions in the rows, and the dependence of the SCKFE is determined by summing the entries of possibilities of interactions in the columns.

Table 11. Fuzzy Micmac-stabilised matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Dri.
SCKFE1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0	0	2.5
SCKFE2	0.7	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0.7	0.7	0.7	0	0.7	0.7	0	0	0	0.7	0	0	0	0	0	0	0	5.6
SCKFE3	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.5	23.9
SCKFE4	0.9	0.9	0	0	0.9	0.9	0	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0	0.9	0.9	0.9	0	21.6
SCKFE5	0.9	0.9	0	0	0	0	0	0	0	0	0.9	0	0	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0.9	0.9	0	0	0	0	0.9	0.9	0	10.8
SCKFE6	0.9	0.9	0	0	0.9	0	0	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0	0.9	0.9	0	16.2
SCKFE7	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	18
SCKFE8	0.9	0.9	0	0	0.9	0	0	0	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	17.1
SCKFE9	0.9	0.9	0	0	0.9	0	0.9	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	18.9
SCKFE10	0.9	0.9	0	0	0.9	0	0	0	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0	0.9	0.9	0	15.3
SCKFE11	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.7	0	0.7	0.7	0	0	0	0.7	0	0	0	0	0	0	0	5.6
SCKFE12	0.9	0.9	0	0	0.9	0	0	0	0	0	0.9	0	0	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0	0.9	0.9	0	13.5
SCKFE13	0.9	0.9	0	0	0.9	0	0	0	0	0.9	0.9	0.9	0	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0	0.9	0.9	0	15.3
SCKFE14	0.9	0.9	0	0	0.9	0	0	0	0	0	0.9	0.9	0	0	0.9	0.9	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0	0.9	0.9	0	13.5
SCKFE15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	2.7
SCKFE16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0.9	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	2.7
SCKFE17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0	2.7
SCKFE18	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	17.1
SCKFE19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	2
SCKFE20	0.7	0.7	0	0	0	0	0	0	0	0	0.7	0	0	0	0.7	0.7	0.7	0	0.7	0	0	0	0	0.7	0	0	0	0	0	0	0	5.6
SCKFE21	0.9	0.9	0	0	0.9	0	0	0	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0	0.9	0.9	0	0	0.9	0.9	0	0	0	0	0.9	0.9	0	13.5
SCKFE22	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0.9	0.9	0.9	0	17.1
SCKFE23	0.7	0.7	0	0	0	0	0	0	0	0	0.7	0	0	0	0.7	0.7	0.7	0	0.7	0.7	0	0	0	0.7	0	0	0	0	0	0	0	6.3
SCKFE24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7
SCKFE25	0.9	0.9	0	0	0.9	0	0.9	0.9	0.9	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	19.8
SCKFE26	0.9	0.9	0	0	0.9	0	0	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0	19.8
SCKFE27	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0.9	0.9	0.9	0.9	18.9
SCKFE28	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0.9	0.9	0	17.1
SCKFE29	0.9	0.9	0	0	0	0	0	0	0	0	0.9	0	0	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0.9	0	0	0	0	0	0.9	0	9
SCKFE30	0.9	0.9	0	0	0	0	0	0	0	0	0.9	0	0	0	0.9	0.9	0.9	0	0.9	0.9	0	0	0	0.9	0	0	0	0	0.9	0	0	9
SCKFE31	0.9	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0.9	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0.9	0.9	0.9	0.9	0	18.9
Dependence	21.7	21	0	0.9	16.2	1.8	1.8	9.9	0.9	4.5	21	15.3	4.5	15.3	25.4	25.4	25.4	9.9	22.2	21	15.3	9.9	17.1	25.4	0	1.8	1.8	9.9	18	18	1.4	

5. Findings and discussions

Thirty-one SCKFEs have been identified from the literature and expert discussion. The interrelations among the various SCKFEs were obtained from academicians and a group of industry experts. With the help of ISM methodology, the model was developed. It has been observed from Figure 4 that the top management support's and SC partners' goal is at the first level of the ISM model. Top management support and SC partner's goal assist in making proper strategic planning and development of a strategic relationship. The strategic planning and strategic relationship are constituted at the level IX of ISM model. The level VIII constitutes relative power, reward and incentives, recognition, SC structure and methodology. Reward and incentives are obtained via recognition and vice versa. The motivation of source and recipient organisation, organisational culture, trust, sense of self-worth, IT infrastructure and employee training and site observation constitutes level VI of the ISM model. Healthy organisational culture motivates source and recipient organisation with building trust and sense of self-worth. The motivation of source and recipient organisation, organisational culture and trust together improve the collaborative alliance and codification of knowledge. Similarly, IT infrastructure and employee training and site observation lead to personalisation which improve knowledge flow in SC. Collaborative alliance leads to integration of knowledge with the help of the motivation of source and recipient organisations. Organisational culture and trust are advantageous to encourage codification of knowledge, as it integrates dispersed knowledge from multiple sources, while IT infrastructure and employee training and site observation mutually support each other. These factors would lead to personalisation of knowledge and further promote integration of knowledge. Willingness to share knowledge, availability of time and space and common language and terminology comprise level VI. Willing to share knowledge and availability of time and space are interrelated as one leads to another. Updated knowledge, source credibility and continuous communication are also mutually related and are situated at level III. Updated knowledge and source credibility are promoted by willing to share knowledge and availability of time and space. Continuous communication is increased by common language and terminology within the organisation. Absorptive capacity and transferability of knowledge are interrelated and are placed at II level. Absorptive capacity is augmented through updated knowledge and source credibility. Similarly, transferability of knowledge is achieved by source credibility and continuous communication. All the nine levels will help in obtaining enhanced operational coordination, operational reputation, retentive capacity and organisational learning. The validation of ISM development and fuzzy MICMAC has been conducted with eight experts (SC practitioners – six and academics – two). The model development and fuzzy MICMAC processes have been carried out. It was observed that there is similarity in interrelationships of various SCKFEs, their driving power and dependencies-dependent power.

The second objective was to carry out analysis based upon the driving and dependence power of the SCKFEs and validation of the developed ISM-based model. In fuzzy MICMAC analysis, SCKFEs are classified into four clusters (autonomous, dependent, linkage and independent) (Mandal and Deshmukh 1994) (see Figure 6). The first cluster consists of autonomous SCKFEs (having weak driving power and weak dependence power). A second cluster consists of the dependent SCKFEs (having weak driving power, but strong dependence power). A third cluster consists of linkage SCKFEs (having strong driving power and also strong dependence power). The fourth cluster includes the independent SCKFEs (having strong driving power but weak dependence power). The analysis of fuzzy MICMAC is as follows.

5.1 *Autonomous SCKFEs*

The driving–dependence power diagram (see Figure 6) indicates that there are no autonomous SCKFEs existing in this cluster. Autonomous SCKFEs have weak driving and dependent power. The autonomous SCKFEs are relatively disconnected from the system, as they have only a few links, which may not be strong. Hence, they don't have much influence on the system. The absence of SCKFEs in the first quadrant indicates that all considered SCKFEs are significant, i.e. they are not disconnected from the system. Therefore, among the 31 selected SCKFEs, all SCKFEs have an influence on SC implementation. Hence, top management can't take lightly any of these SCKFEs if they are very serious to make SC successful.

5.2 *Dependent SCKFEs*

Dependent SCKFEs are strongly dependent on other SCKFEs. Transferability of knowledge (SCKFE 1), updated knowledge (SCKFE 2), integration of knowledge (SCKFE 5), continuous communication (SCKFE 11), personalisation (SCKFE 12), codification (SCKFE 14), organisational learning (SCKFE 15), operational coordination (SCKFE 16), retentive capacity (SCKFE 17), absorptive capacity (SCKFE 19), source credibility (SCKFE 20), collaborative alliance (SCKFE 121), common language and terminology (SCKFE 23), organisations reputation (SCKFE 24), availability of

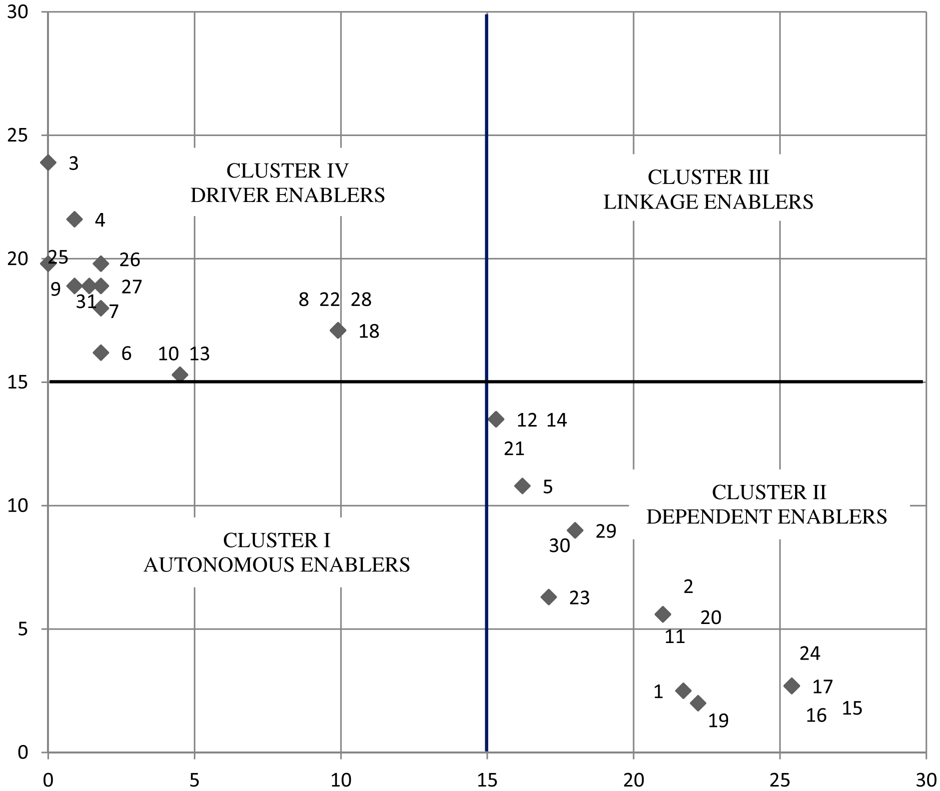

Figure 6. Cluster of SCKFEs.

time and space (SCKFE 29) and willingness to share knowledge and experience (SCKFE 30) have weak driving but have strong dependence power, and are more performance orientated (see Figure 6). They will appear at the top level of the ISM hierarchy (see Figure 4), and are therefore considered important SCKFEs. These enablers have a weak driving power, but strong dependence on other SCKFEs. This indicates that they require all of the other enablers to come together for overcoming the knowledge flow in SC challenges. Their strong dependence indicates that they required all the independent enablers to minimise the impact of dependent enablers on system performance. The model will be very helpful for the organisation which is trying to implement knowledge flow for their SC. Definitely, this model is also helpful for the mature SC wanting to adopt knowledge flow and improve efficiency. Management should therefore accord high priority in executing these SCKFEs. Besides tackling these SCKFEs, management should also understand the dependence of these SCKFEs on the lower level of the ISM.

5.3 *Linkages SCKFEs*

The absence of any linkage SCKFEs in this study indicates that no SCKFEs are unstable among all the 31 SCKFEs chosen in this study (see Figure 6). Linkage SCKFEs are unstable, as any change occurring to these SCKFEs will affect the other SCKFEs and also feedback affects themselves (i.e. on the SCKFEs which are to be changed). Linkage SCKFEs are influenced by lower level enablers and in turn impact other enablers in the model, which may affect the successful knowledge flow in SC either in a positive or negative way. Managers have to take special care in handling such SCKFEs.

5.4 *Independent SCKFEs*

The fourth cluster includes the independent SCKFEs having strong driving power but weak dependence. These SCKFEs are more strategic in orientation. Figure 6 indicates that top management support (SCKFE 3), strategic planning (SCKFE 4), knowledge flow methodology (SCKFE 6), relative power (SCKFE 7), the motivation of source and recipient organisation (SCKFE 8), strategic relationship (SCKFE 9), employee training and site observation (SCKFE 10), IT infrastructure (SCKFE 13), trust (SCKFE 18), organisational culture (SCKFE 22), SC partners goal (SCKFE 25), SC structure (SCKFE 26), recognition (SCKFE 27), sense of self-worth (SCKFE 28) and reward and incentives (SCKFE 31) are the independent SCKFEs. These SCKFEs are indicated as independent and have very strong driving power but weak dependence power and are treated as a 'key SCKFEs' as shown in Figure 6. These enablers can influence other enablers to the maximum extent in the system so that they are cautiously handled. Also, these enablers are placed in the root level of ISM hierarchy as shown in Figure 4. These are significant enablers and always push the organisation to implement knowledge flow in SC; that's why, they are the root cause of all SCKFEs. It has been observed that these SCKFEs help achieve SCKFEs which appear at the top of ISM hierarchy (see Figure 4). Therefore, management should work out strategies to facilitate these independent SCKFEs for successful SC in an organisation. Those SCKFEs possessing higher driving power in the ISM should be adopted initially because there are few other dependent SCKFEs being affected by them.

6. Conclusion

The example organisation considered in this work wants to establish effective knowledge flow in SC in order to use timely and accurate information, collaborating with suppliers and integrating all SC requirements over intense competition. It is essential for an organisation to focus on knowledge flow across the SC processes if the organisation wants to improve its SC performance. Knowledge flow in SC develops the system and elevates it to the next maturity level. It will stimulate SC executives of the organisation to analyse the interaction among SCKFEs in SC. From an extensive literature review and a discussion with the expert team, 31 SCKFEs are identified and finalised for this study. Although a large amount of literature is available on SCKFEs, no study has been carried out to understand the interactions among these SCKFEs using ISM and fuzzy MICMAC analysis. The major contribution of this research work lies in the development of contextual relationships among identified SCKFEs through a systematic framework. The present research work provides an ISM-fuzzy MICMAC-based model to understand the relationships among identified SCKFEs.

ISM methodology is used to develop a map of the complex relationships among various SCKFEs for effective knowledge flow in SC. Through the ISM-based hierarchical model, it is observed that the SCKFEs' operational coordination, organisational reputation, retentive capacity and organisational learning exist at the top level in the ISM hierarchy. Top management support and SC partners' goals are at the base of this model. Policy-makers should give appreciable consideration to the SCKFEs that exist at the base of the hierarchy. The awareness about these SCKFEs will improve the performance of the SC in the organisation. The results of the ISM are used as an input to the fuzzy MICMAC analysis to identify the driving power and dependence of SCKFEs. The organisation should give more focus towards analysing the driving SCKFEs so as to manage the dependent SCKFEs for a successful implementation of knowledge flow in SC.

The empirical research presented in this paper investigates and identifies the SCKFEs that influence the effectiveness of knowledge flow in SC operations. SC executives, decision-makers, academic researchers and industrial practitioners may be able to understand the very complex interrelationship of SCKFEs through visualisation of relations. Hence, knowledge flow is a common requirement in manufacturing organisations to align their SC partners such as suppliers, manufacturers, distributors and retailers to implement common processes.

The exploratory nature and study of a single example firm are the major limitations of this research. Any bias in judging the person may influence the final result. A person's perception of the relation among the variables will affect the relation among the variables. In future research, quantification of these SCKFEs and their interrelationships may be done by carefully adopting SWOT analysis, analytical hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) methodwithin multiple industrial sectors. Also, statistical validation of this model may be carried out with the help of a questionnaire-based survey concentrating upon a specific sector. The structural equation modelling (SEM) or systems dynamics modelling (SDM) may be used to test the validity of the suggested model.

Disclosure statement

No potential conflict of interest was reported by the authors.

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