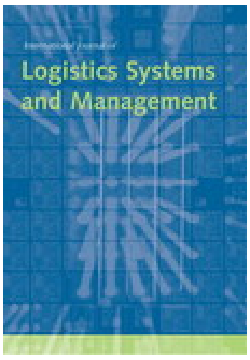


International Journal of Logistics Systems and Management

ISSN online: 1742-7975 - ISSN print: 1742-7967
https://www.inderscience.com/ijlsm

Analysis of the enablers of supply chain digitalisation in the electronics industry: an interpretive structural modelling approach

T.S. Deepu, V. Ravi

DOI: 10.1504/IJLSM.2021.10038493

Article History:

Received:	05 July 2020
Accepted:	22 January 2021
Published online:	26 January 2023

Analysis of the enablers of supply chain digitalisation in the electronics industry: an interpretive structural modelling approach

T.S. Deepu and V. Ravi*

Department of Humanities,
Indian Institute of Space Science and Technology,
Thiruvananthapuram, Kerala, India
Email: tsdeepu@gmail.com
Email: ravi.iist.isro@gmail.com
*Corresponding author

Abstract: Supply chain digitalisation has great advantages. In spite of a large number of studies, there is a lack of literature to identify and address the key enablers to be considered for supply chain digitalisation. In this study, 13 key enablers for integration of supply chain through digitalisation in an electronic supply chain in Indian context are identified and shortlisted in consultation with the experts from industry and academia. Interpretive structural modelling has been used for understanding of the hierarchical and contextual influences among the identified key enablers for supply chain digitalisation. Results of the model indicate that prior to taking a decision on supply chain digitalisation, companies have to identify the key enablers and its impact on digitalisation process. Policy decision-makers could use the results of this study to identify the key enablers and their interrelationship for taking effective decision for supply chain digitalisation process.

Keywords: supply chain digitalisation; SCD; interpretive structural modelling; ISM; digitalisation enablers; MICMAC approach; electronics industry.

Reference to this paper should be made as follows: Deepu, T.S. and Ravi, V. (2023) 'Analysis of the enablers of supply chain digitalisation in the electronics industry: an interpretive structural modelling approach', *Int. J. Logistics Systems and Management*, Vol. 44, No. 1, pp.105–131.

Biographical notes: T.S. Deepu received his Master's in Business Administration from the VLB Institute of Management, Bharathiar University, Coimbatore, India. He is currently working in the Indian Space Research Organisation (ISRO) at its headquarters in Bangalore, India. He is having an experience of more than 15 years in the area of supply chain management at various functional levels. He is a Certified Supply Chain Management Professional (CII-SCM Pro.) by the Confederation of Indian Industries. He is currently pursuing his doctoral research from the Department of Humanities at Indian Institute of Space Science and Technology, Thiruvananthapuram, India. His area of interest includes supply chain integration, digitalisation and logistics management.

V. Ravi is currently working as an Associate Professor in the Department of Humanities at Indian Institute of Space Science and Technology, Thiruvananthapuram, India. He received his BTech in Mechanical Engineering from the University of Calicut, India, MS (by research) in Industrial Management from Indian Institute of Technology, Madras, India and PhD in

Operations Management from Indian Institute of Technology, Delhi, India. His areas of interest include reverse logistics and supply chain management. His publications have appeared in *Technological Forecasting and Social Change*, *Computers and Industrial Engineering*, *International Journal of Productivity and Performance Management*, *International Journal of Production Research*, among others. His biography has appeared in the 28th edition of *Marquis Who's Who in World* in 2011.

1 Introduction

The need for developing a responsive and innovative supply chain (SC) has made supply chain management (SCM) operations as a dominant topic of research among academicians and practitioners (Ayoub et al., 2017). Accordingly, supply chain integration (SCI) has become the central concept of SCM. The scope of SCI covers entire functions and scope ranging from supplier to customer including the internal integration process. The two major components of an integrated SC are flow of goods and information (Fayezi et al., 2017). The application of information and communication technology (ICT) tools for planning, forecasting and scheduling activities will bring in more efficiency, visibility, accountability and transparency in SC.

Integration process can be defined based on the cooperation, coordination and collaboration efforts made by SC partners for enhancing SC efficiency (Zhu et al., 2018). Integration of processes facilitates easy flow of materials and goods from the suppliers to the end customers at the right place and at the right time (Basheer et al., 2019). ICT tools helps in real time sharing of information across the SC network for on time decision making. It results in cost reduction and also in maintaining optimum inventory (Kwak et al., 2018).

Supply chain digitalisation (SCD) assumes importance from the concept of SCI. Organisations can reap benefits through proper integration by managing the data effectively using powerful digital technologies and methods (Pappas et al., 2018). The adoption of advanced technologies leads to automation and exchange of data across the SC, which leads to Industry 4.0 (Sprovieri, 2019). The advancements in digital technologies together with high expectations from SC partners have necessitated the requirement for a highly integrated SC. The studies have found out that SCI through digitalisation is considered as one of the major factors that enhances SC performance. The drivers and enablers affecting the process of SCI have been investigated, with little consensus on the process of integration of SC through digitalisation (Hausberg et al., 2019).

The integration process works on the basis of shared decision making, open communication, collaboration, shared vision, technology and trust among the partners (Flynn et al., 2010). Integration of SC can be done effectively by using information technology (IT). The process of SCD has in fact become an enabler for organisations.

The impact of emerging technologies in SC is transforming the businesses (Ivanov et al., 2019). Effective cooperation of SC partners in adopting technology for digitisation helps in building an end-to-end SC expeditiously. Application of advanced technologies allows the companies to gain competitive advantage through higher revenue and value addition (Buyukozkan and Gocer, 2018). Literature reveals that there is a lack of knowledge in the procedure to be adopted for effective implementation and utilisation of digital technologies. The automation and integration process through digitalisation has caused the fear of loss of jobs as the leading companies are utilising artificial intelligence and robotics to manage their day to day activities. However, the development in SC on account of the digitalisation process allows the organisation to manage the SC activities remotely (Lyall et al., 2018).

In the recent times, the process of SCD has emerged as a strategic topic for professionals and academicians in logistics and SCM communities. Ageron et al. (2020) have highlighted the requirement of further research in the area of SCD, in mobilising various theoretical frameworks and combining qualitative and quantitative methods. Their study also stated that future research should be directed towards developing conceptual models and theoretical frameworks, original practices, case studies and projects for digital SC, that could assist managers in taking effective decision on digitalisation.

The establishment of collaborative practices across SC has gained significance in the context of SCI in recent years. However, the studies pertaining to address the enablers affecting SCI through digitalisation are rarely found in literature. Although literature reveals various ways and approaches for assessing the possibilities of digital SC, little research has been done on developing a model and framework for assessing the key enablers of SCD. This study intends to fill this research gap by proposing a conceptual framework bringing out the relationship among the key enablers of SCD. The objectives of this paper are as follows:

1. to develop a conceptual framework for the key enablers of SCD
2. to identify and analyse the key enablers and its influence on SCD process
3. to validate the SCD framework developed using interpretive structural modelling (ISM) and matriced' Impacts croises-multiplication applique' and classment (MICMAC) analysis.

This study is timely and relevant in the digital world, which leads to development of smart SC. The outcome of research provides further inputs on the key enablers to be considered while proceeding with digitalisation. The managers can consider and give due weightage for the enablers as identified for effective digitalisation.

This paper is further structured as follows. Section 2 provides a review of the existing literature in SCI through digitalisation and enablers of SCD followed by Section 3 on the research gap and problem description. The research methodology used in the study is presented in Section 4 followed by results and discussion in Section 5. Conclusions, theoretical and managerial implications and limitations and future scope of the study are presented in Section 6.

2 Literature review

Literature review with respect to SCI through digitalisation and enablers for SCD process are presented in this section.

2.1 SCI through digitalisation

SCI has emerged as a dominant theme especially due to digitalisation. SCI is defined as alignment, linkages and coordination of processes, people, information, knowledge, strategies, and communication across the SC amongst all points of contact and making the efficient and effective movement of materials, information, money and knowledge as needed by the customer (Stevens and Johnson, 2016). IT adoption process has gained significance due to advancement in digital technologies (Khemili and Belloumi, 2018). SCI works on the basis of shared decision making, open communication, collaboration, shared vision, technology and trust among the partners. The real time connectivity across SC partners facilitates easy access of data for quick and effective decision making. The connection between cyber-physical production systems and machines by storing data in the cloud, i.e., industrial internet of things (IoT) is gaining prominence (Boyes et al., 2018). Flexibility in operations and reduced cycle time are the core components of digitalisation of SC (Stank et al., 2019).

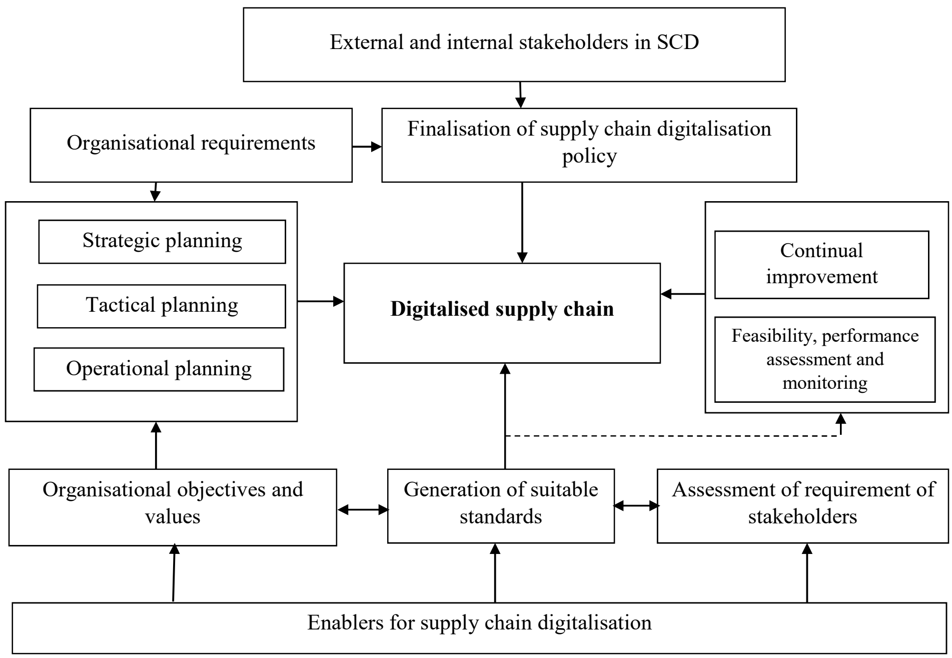
SCI process has three levels of facilitators like information integration, coordination and information sharing and organisational relationship linkage. Information integration is the major component of SCI process which is applicable to all business organisations. The future lies in the fact as to how digital transformation of SC will be managed (O'Marah et al., 2017). It demands addressing the factors like resource sharing, long-term relationship, integration of planning and functional areas, ensuring availability of resources including IT systems to facilitate effective integration through digitalisation. Digital technologies help in real time transmission of information and supports knowledge management practices (Wilkesmann and Wilkesmann, 2018). Application of advanced technologies allows the companies to gain competitive advantage through higher revenue and value addition (Buyukozkan and Gocer, 2018).

Mahindroo et al. (2018) have investigated the application of selected information systems constructs for value creation. They have found that information systems play a crucial role in enhancing overall performance of SC and highlighted the impact of information system on each of the constructs individually on the economic and operational performance of SC. Yadav et al. (2020) have developed an outline of various criterion for selection of appropriate 3PL service providers and highlighted the relevance of enhancing sustainability of IoT-based agriculture SC by outsourcing of logistics activities.

The IT enabled SC helps in enhancing performance, competitiveness, collaboration, flexibility and cost reduction. The real time connectivity ensures the integration of all functional areas of the SC right from sourcing, manufacturing and delivery to the end users. Recent studies in the area of IT implementation reveals about the benefits firms can gain through proper digitalisation (Khan and Wisner, 2019). The implementation process requires support and commitment from the top management based on clear organisational objectives and investment justifications.

Integration of SC is a building block consisting of joint collaborative network, coordination, shared vision, information and technical infrastructure among the SC partners (Flynn et al., 2010). In the globalised and highly competitive world, SC strategies and objectives shall be aligned with the business objectives to achieve maximum benefits. It adds value to the customer by gaining customer satisfaction and market share. The three main pillars of SCI framework are information integration, coordination and resource sharing and organisational relationship linkage. Big data (BD) plays a crucial role in enhancing business value. Brinch et al. (2020) have identified the firm level capabilities required to create value from BD and have identified major capabilities as related to IT, performance, processes, strategic, human and organisational practices. There is a positive relationship between SCI and performance of the firm by involving information, operational and relational integration. A research framework for enablers of SCD is shown in Figure 1.

Figure 1 A research framework on enablers in SCD



SCD process should consider requirements of all SC partners. The organisational requirements specific to the nature of business and the transactions involved are to be given due weightage. In order to achieve the targeted results, implementation process should be considered by taking into account of the strategic, tactical and operational objectives of the firm. Further, the key enablers that are to be considered for the process of digitalisation needs to be identified. Based on the enablers identified, the process of digitalisation can be triggered by considering the organisational objectives and values, generation of suitable standards and assessment of the requirement of stakeholders. All these dimensions are to be considered and the implementation process is to be planned considering the time required in achieving the set targets. Further, feasibility, performance assessment and monitoring of the proposed digitalised SC should be completed. Continuous monitoring of the process and implementation will result in identifying the areas where modifications are required, which results in continual improvement.

Ishtiaque et al. (2020) have developed a model that assists in understanding the relationships among ICT, operational responsiveness, integrative capabilities and dimensions of performance. They opine that the effective way to gain operational performance is by improving integrative capabilities through investment in ICT. SC responsiveness shall be configured from customer facing to supplier facing through integration. Dunke and Nickel (2020) investigated the use of collaborative IT applications in improving intra-organisational logistics processes. They found that vast improvements in logistics functions is attained using collaborative IT applications in track and tract IT solutions. Rached and Bahroun (2020) highlighted the need to raise awareness among SC partners for sharing of information by assessing the value in both upstream and downstream in a divergent SC. They found that maximum benefit was gained in warehouse aspect and suggested to implement revenue sharing contract for motivating and sharing information among SC partners. Gholipour et al. (2020) developed a bi-objective mixed linear integer programming model for designing a green SC network under certainty in case of automotive SC.

Fatorachian and Kazemi (2021) highlighted the potential impact of Industry 4.0 due to technological advancements in enhancing business process and SC performance. They found that the adoption of Industry 4.0 enabling technologies facilitates SCI and information sharing, which brings transparency throughout the SC. Further, Industry 4.0 enhances overall operational functions through integration process, digitisation and automation by bringing novel analytical capabilities.

The application of IT assists in accessing real time information which is one of the key factors in managing and designing digital SC. Advanced digital technologies and tools can be used in managing various SC functions through proper implementation and monitoring. Digital technologies and its applications in SC has revolutionised the traditional concept of SCM.

2.2 Enablers for SCD

The success of SCI through digitalisation depends on the procedure adopted for implementation by giving due significance to the key enablers affecting the process. A new business model can be developed by using advanced technologies. Sestino et al. (2020) have investigated the role of IoT and BD in managing the digital transformation. They have found that IoT and BD are the reengineering factors for business processes. Lechler et al. (2019) have stressed the need of investigation on the emerging aspects of processing data in real world context.

Attaran (2020) has highlighted the role of role of digital technologies in enabling, enhancing and streamlining transformation of SC. Marmolejo-Saucedo and Hartmann (2020) in their research have found that companies adopting technological advancements, as Industrial revolution 4.0 will be able to survive in competitive business environments. They also stated that digital transformation of SC requires proper organising and planning of activities to meet various operational functions.

Gupta et al. (2020) have identified and prioritised key digitisation and IT enablers enhancing SC performance. They have highlighted the relevance of digitisation and IT enablers by organisations to enhance SC performance. Nunez-Merino et al. (2020) have investigated the key aspects and implications of relationships between information and digital technologies of Industry 4.0 and lean SCM. The details of key enablers of SCD identified in this research are shown in Table 1 followed by a brief description of each of them.

Table 1 Enablers of SCD

Sl. no.	*Enablers*	*Relevant literature*	*Remarks*
E1	Involvement and support from top management	Wei et al. (2020), Gawankar et al. (2020)	All activities can be initiated only based on commitment and support from top management.
E2	Cutting edge IT infrastructure and technology	Malyavkina et al. (2019), Hofmann et al. (2019)	Application and use of most advanced technology enhances SC performance.
E3	Proper information security	Schniederjans et al. (2020), Mosteanu (2020)	Assurance of proper data security and privacy enhances the digitalisation process.
E4	Long, medium and short-term planning	Guo et al. (2020), Kumar et al. (2021)	Effective planning will result in proper implementation.
E5	Investments of funds and availability	Xing et al. (2019), Cagle (2020)	Investments for acquiring IT infrastructure and other aspects affect the process.
E6	Corporate culture among partners	Zangiacomi et al. (2020), Shao et al. (2021)	SC partners culture and attitude influence effectiveness of digitalisation.
E7	Trust among SC partners	Lind and Schupp (2020), Jabbar et al. (2020)	Trust ensures cooperation and communication.
E8	Data management on real time basis	Kenge and Khan (2020), Maheshwari et al. (2020)	Analysis of data can be done on real time basis for digitalisation.
E9	Profitable information sharing model with SC partners	Sundram et al. (2020), Li et al. (2020)	Increases financial performance through sharing of knowledge, information and skills.
E10	Information sharing	Ageron et al. (2020), Coronado Mondragon et al. (2020)	Facilitates effective integration and decision making.
E11	Risk management and strategies	Ivanov and Dolgui (2020a), Yang et al. (2020)	Helps in effective SCM by mitigating the risks.
E12	Cooperation and support from SC partners	Dubey et al. (2020), Ebinger and Omondi (2020)	Increases the responsiveness and efficiency of SC.
E13	Extended enterprise	Ivanov and Dolgui (2020b), Wong et al. (2020)	Maximises the value across the SC.

2.2.1 Involvement and support from top management

The top management plays a crucial role in improving company's SC performance. Coordination and collaboration can be enhanced with the help of top management support and commitment. Success of any strategic program finalised by the organisation depends on the extent of top management support and commitment. The involvement of top management is required at all implementation stages of the project life cycle, i.e., from the initial board level discussions till the go-live of the system. Thus, the involvement and support from the top management is very crucial for initiating and implementing digitalisation.

2.2.2 Cutting edge IT infrastructure and technology

IT is a key driver for enhancing SC efficiency. IT system helps in collaborative planning of SC and enhances SC performance. In order to integrate SC, an efficient IT system is crucial. Information system also plays a vital role in tracking and tracing of products. Advanced digital technologies and well-equipped IT infrastructure is one of the key enablers for the digitalisation process.

2.2.3 Proper information security

Organisations should evolve strategies and procedures to improve security and privacy of information transmitted across the SC. Data transmitted in SC should be compliant with the regulations and have enough security measures for transmission of information. Data privacy is to be ensured based on compliance with the regulations while interconnecting across the SC. SCI process should consider main aspects like security, privacy, interoperability, regulatory and legal compliance, in which, information security should be given due significance being a key enabler.

2.2.4 Long, medium and short-term planning

Collaboration among partners in SC is a significant factor in achieving successful SCI. Suitable collaborative planning strategies helps in maximising the interest of organisation, rather than individual interests. The success of long, medium and short-term planning in SC depends upon the level of information sharing. IT systems help in long, medium and short-term planning of processes and thus enhance the SC performance.

2.2.5 Investment of funds and availability

The process of IT enablement, adoption of advanced technologies, hiring of technology savvy employees and training of employees requires high investments. Due to the high costs and financial commitment involved, most of the organisations are reluctant to commit key resources. Lack of convincing justifications for high investment also affects the decision making process for digitalisation. Thus, decisions on investments of funds and its availability is another enabler that affects the digitalisation process.

2.2.6 Corporate culture among partners

The planning and integration of SC activities should be done by considering the requirements of SC partners towards achieving long-term goals. Organisational culture affects the policies on various aspects that assumes significant for organisations in the long-term. Prevailing culture in the organisation is one of the enablers that affect the process of digitalisation.

2.2.7 Trust among SC partners

SC can be effectively integrated if enough security and trust is established across SC partners. The utilisation and sharing of resources like information, knowledge and skills decides the success of SCI. The real strength of SC linkage depends upon the extent of trust, communication, cooperation and adaptation among the SC partners.

2.2.8 Data management on real time basis

Proper analysis of SC data helps in enhancing the business processes. Data management on real time basis facilitates rapid access to information for effective decision making. Data analytics has the potential to transform traditional SCM practices by providing insights for improvement of processes and operational efficiencies. Accordingly, based on the benefits that can be reaped from data management, they act as one of the key enablers for the digitalisation process.

2.2.9 Profitable information sharing model with SC partners

Effective utilisation and sharing of resources like information, knowledge and skills results in better SC performance and leads to higher profit. Success of SCI depends upon the sharing model among SC partners in the dynamic business environment. It results in better financial performance by improving the effectiveness of decision making in business processes. The overall reduction in SC cost results in performance enhancement by way of higher profit margins and enables better integration of SC through digitalisation.

2.2.10 Information sharing

Information sharing and integration are correlated with SC performance measures. The two major stages of SCI are degree of information sharing and decision making. Intelligent value chain networks help in sharing of information among SC partners and industry on real time basis. SC can be integrated effectively by information sharing through advanced digital technologies, which acts as a key enabler for the digitalisation process.

2.2.11 Risk management and strategies

The risk mitigation strategies should be reviewed and updated on a regular basis for effective risk management. SC is prone to many risks due to the drastic changes in the business world. Hence, the strategy has now shifted from risk avoidance to risk management. All related activities in the SC should be planned accordingly to mitigate the risk and its effective management.

2.2.12 Commitment among SC partners

The commitment and mutual trust among SC partners assists in managing SC relationships effectively. SC partners will try to maximise the individual interests instead of the collaborative interests. Integration among the SC partners within an organisation can be achieved through its designed IT strategies. Effective and strong communication among SC partner's increases responsiveness of employees and efficiency of the SC.

2.2.13 Extended enterprise

The concept of extended enterprise becomes vital in gaining competitive advantage through collaborative relationship among SC partners. Due to mutual interconnection among the businesses, proper functioning of one business will assist other business also to flourish. This results in the collaborative approach of working together, wherein each organisation is more than a single entity. The external partners in the extended enterprise play a major role in organisation's success. Decision makers are shifting away from the traditional form of SC and its infrastructure towards a digitally enabled and fully integrated SC leading to an extended enterprise.

3 Research gaps and problem description

The role and process of digitalisation in SC is yet to be fully explored through proper understanding of SCD process. Hence, more insights and research to understand the enablers influencing SCD deserves attention. The existing studies on integration of SC through digitalisation are generic in nature without focusing on a particular industry. The existing literature also lacks study on SCD and identification of key enablers and its prioritisation for effective integration. In order to integrate the SC effectively through digitalisation, a study on analysis of the key enablers affecting integration process is necessitated. This gap has motivated us to conduct a study in this area with specific emphasis to electronics SC. A research framework for study on enablers of SCI through digitalisation is shown in Figure 1.

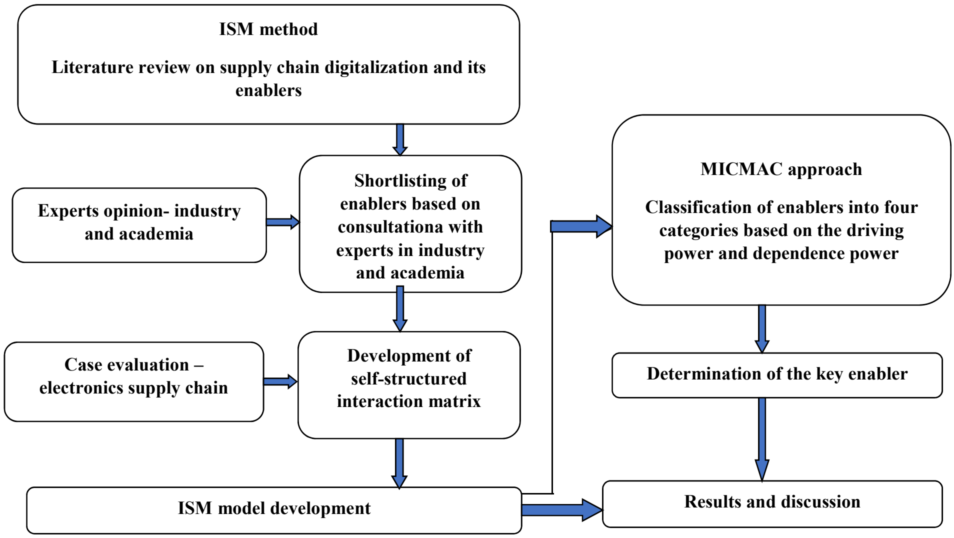
It provides guidance to the professionals and managers in the field of SC by providing insights for effective integration of the SC through digitalisation. The research also addresses the relevance of considering the key enablers for SCD with respect to an electronics SC, which have not been considered in earlier research.

4 Research methodology

In this paper, analysis of the key enablers is done by using ISM method. Application of ISM method helps in identifying the prominent influential relations among the key enablers facilitating effective SCD.

The key enablers were identified from literature review and based on consultation with the experts in industry and academia. Accordingly, 13 major enablers were shortlisted which are to be considered while proceeding with SCI through digitalisation so as to gain maximum benefits. ISM method and MICMAC analysis technique is used to categorise the major enablers. A flow chart for the methodology for ISM and MICMAC approach is given in Figure 2.

Figure 2 Flowchart for methodology for ISM and MICMAC approach (see online version for colours)



4.1 Interpretive structural modelling

ISM is an interactive learning process in which a set of elements are structured into a comprehensive systematic model wherein both dissimilar and directly related elements are involved. The multilevel structural model developed by using ISM depicts a sub-systems level representation of a complicated system, thereby imposing order and complexity of the relationships among the elements of a system. The basis for development of ISM method was presented by Warfield (1974) to analyse the complex socioeconomic systems and has been used for policy analysis. Later, the method was used for research in analysing factors influencing building energy performance, assessing retailer responsiveness, SC complexity drivers and SC sustainability (Xu and Zou, 2020; Sharma et al., 2020; Piya et al., 2020; Chand et al., 2020).

ISM method has the following steps:

Step 1 Shortlisting of the variables that are affecting the system.

Step 2 The contextual relationship among the variables identified in Step 1 is found.

Step 3 Pairwise relationship among the variables of the system is developed in the form of a structural self-interaction matrix (SSIM).

Step 4 Transitivity of the matrix is checked based on the reachability matrix developed from SSIM. The basic assumption made in ISM is the transitivity of the contextual relation. Transitivity rule states that if variable A is related to variable B and variable B is related to variable C, then variable A is necessarily related to variable C.

Step 5 Partitioning of the reachability obtained in Step 4 into different levels.

Step 6 A diagraph is developed based on the reachability matrix and considering the contextual relationships by removing the transitive links.

Step 7 The diagraph developed as above in Step 6 is converted into an ISM by replacing variable nodes with statements.

Step 8 Conceptual inconsistency is checked by reviewing the ISM model developed in Step 7and necessary modifications are made. Finally, a model is drawn representing relationship among the enablers for SCD.

4.2 ISM model development – case evaluation

The proposed ISM model developed is applied in a case study and is discussed in this section. The case study is performed on an MNC, XYZ Company, which is one of the prominent companies in the electronic industry dealing with electronic consumer products and services in India. This company is considered for the study to take advantage of their expertise and experience in the field, which ensures the credibility of the case study design. The company is rapidly growing in the electronics industry with a very vast range of products and services. It includes home appliances, electrical installation systems and home automations. The organisation has a very widely spread SC network in India. However, advancement in digital technologies and its applicability in SCI can bring in much more benefits compared to the existing system are not yet considered by the company. Hence, on a long-term perspective, suitable provisions for effective management of the SCI by means of digitisation of the activities across the software platform can be considered. It also enables the procedure to be followed for integration of SC using advanced digital technologies. The experts in the company were consulted and the enablers identified were evaluated. The experts consulted were senior managers who are having an industrial experience of over 25 years in electronics industry responsible for activities of IT and operations management in the firm. The academic expert was an associate professor in a reputed university engaged in researches for over twenty years in various areas of operations and SCM. He was also associated with many industrial consultancies related to automation of SC projects. All these experts in the study were quite experienced and familiar with digital transformations of SCs happening in electronic industries. The data collected was recorded and categorised to found out the key enabler in integration of SC through digitalisation:

Step 1 The key enablers affecting the SCD process was finalised by taking into account of the opinion from two experts in the electronic firm and one expert from academia. The influence of enablers and its relation to the process of SCD and the relevant literature are detailed in Table 1.

Step 2 The contextual relationship among the enablers identified in the process of SC studied by two experts from industry and one expert from the academia. All the potential influential relations and its interpretations were identified and analysed through brainstorming sessions.

Step 3 The influential relations among the key enablers are marked in the matrix in binary form. The matrix formed is the direct reachability matrix as shown in Table 4. The element in the matrix represents the direct influential relation among the key enablers.

Step 4 The significant transitive relations among the enablers form the interpretive logic is to be identified. All the significant transitive relations shall then be updated in the direct relation matrix by indicating all the transitive relations to form the final reachability matrix. The final reachability matrix thus formed is shown in Table 5.

Step 5 Further, the level partition is done by following Steps 1 to 8 as mentioned in Section 4.2 and the enablers are placed level wise indicating the influences among them. The reachability of the elements, its antecedents and the intersection sets were sorted at each level and the procedure is repeated as shown in Tables 6 to 11.

Step 6 After forming the level partitions, digraphs are drawn by representing the most relevant influence relations. The relations among the enablers can be identified from the final reachability matrix and interpretive logic of the relations. The digraph formed accordingly is shown in Figure 3.

Figure 3 An ISM-based model for enablers in SCD

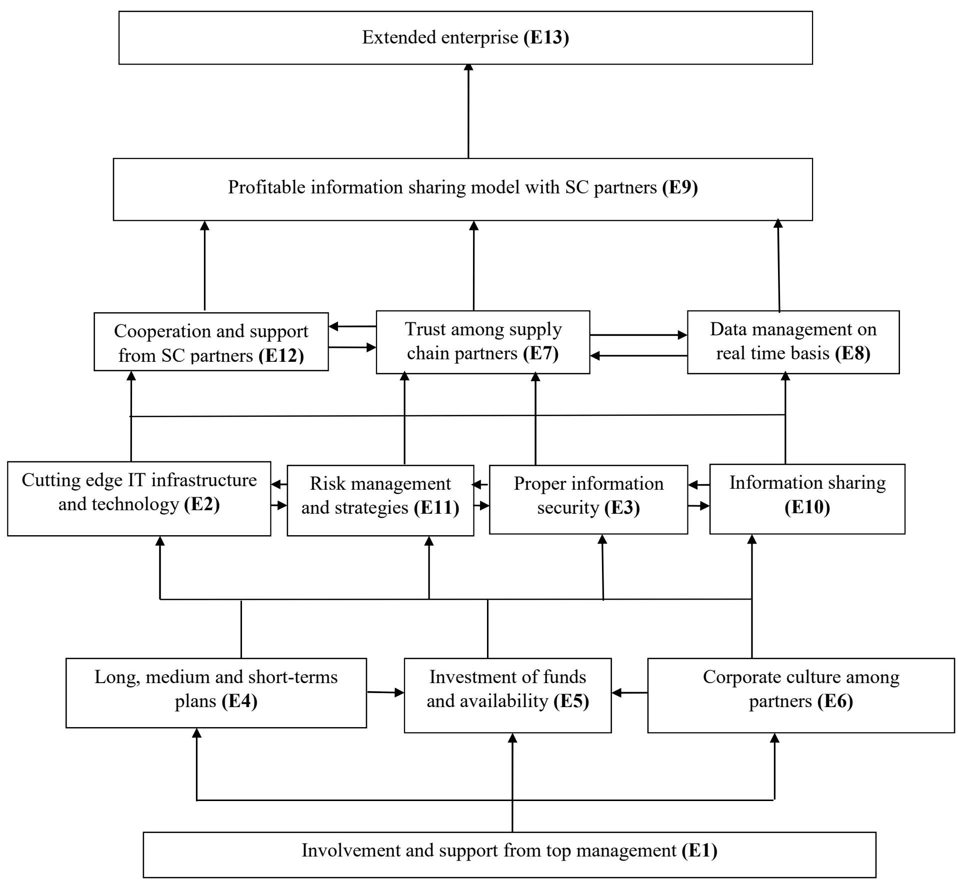


Table 2 Structural self-interaction matrix

Sl. no.	*Enabler*	*Enabler description*	*E13*	*E12*	*E11*	*E10*	*E9*	*E8*	*E7*	*E6*	*E5*	*E4*	*E3*	*E2*
1	E1	Involvement and support from top management	V	V	V	V	V	V	V	V	O	O	V	V
2	E2	Cutting edge IT infrastructure and technology	V	V	V	V	V	V	V	O	A	A	X	
3	E3	Proper information security	V	V	V	V	V	V	V	A	A	A		
4	E4	Long, medium and short-term planning	V	V	V	V	V	V	V	O	X			
5	E5	Investments of funds and availability	V	V	V	V	V	V	V	O				
6	E6	Corporate culture among partners	V	V	V	V	V	V	V					
7	E7	Trust among supply chain partners	A	A	V	V	V	V						
8	E8	Data management on real time basis	A	A	V	V	V							
9	E9	Profitable information sharing model with SC partners	A	A	V	V								
10	E10	Information sharing	A	A	V									
11	E11	Risk management and strategies	A	A										
12	E12	Cooperation and support from SC partners	X											
13	E13	Extended enterprise												

4.3 Structural self-interaction matrix

The contextual relationship among the enablers are identified based on expert's opinion. The relationship among the variables (*i* and *j*) are marked by using the symbols V, A, X and O. In case variable, *i* will lead to variable *j*, it is denoted by V; variable *j* leading to variable *i* is denoted by A; variable *i* and *j* leading to each other is represented by X and where variable *i* and *j* are unrelated, it is denoted by O.

An SSIM is developed based on the contextual relationships between the variables and is shown in Table 2. In Table 2, the variable E1 leads to variable E13 so it is marked by V in the cell, likewise variable E2 leads to variable E5 and denoted by A in the cell. Variable E2 and E3 lead to each other, hence represented by X. Variable E4 and E6 do not lead to each other, so it is marked as O.

4.4 Initial reachability matrix

The initial reachability matrix is calculated based of the SSIM formulated and converting into a binary matrix by substituting the symbols V, A, X and O by 1 or 0 as the case may be by applying the rules, as in Table 3.

Table 3 Rule for construction of initial reachability matrix

Sl. no.	*Value in SSIM*	*Value in reachability matrix*	
	(i, j)	*(i, j)*	*(j, i)*
1	V	1	0
2	A	0	1
3	X	1	1
4	O	0	0

Table 4 Initial reachability matrix

	E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E12*	*E13*
E1	1	1	1	1	1	1	1	1	1	1	1	1	1
E2	0	1	1	0	0	0	1	1	1	1	1	1	1
E3	0	1	1	0	0	0	1	1	1	1	1	1	1
E4	0	1	1	1	1	0	1	1	1	1	1	1	1
E5	0	1	1	1	1	1	1	1	1	1	1	1	1
E6	0	1	0	0	1	1	1	1	1	1	1	1	1
E7	0	0	0	0	0	0	1	1	1	0	0	1	1
E8	0	0	0	0	0	0	1	1	1	0	0	1	1
E9	0	0	0	0	0	0	0	0	1	0	0	0	1
E10	0	1	0	0	0	0	1	1	1	1	1	0	1
E11	0	1	0	0	0	0	1	1	1	1	1	0	1
E12	0	0	0	0	0	0	1	1	1	0	0	1	1
E13	0	0	0	0	0	0	0	0	0	0	0	0	1

By applying these rules, an initial reachability matrix for the key enablers for integration of the SC through digitalisation is drawn and shown in Table 4.

4.5 Final reachability matrix

By taking into account of the transitivity rule, the final reachability matrix (Table 5) is made from the initial reachability matrix. The transitivity rule states that, if a variable 'X' is related to 'Y' and 'Y' is related to 'Z', the 'X' is necessarily related to 'Z'.

Table 5 Final reachability matrix

Enablers	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E12*	*E13*	*Driving power*
E1	1	1	1	1	1	1	1	1	1	1	1	1	1	*13*
E2	0	1	1	0	0	0	1	1	1	1	1	1	1	*9*
E3	0	1	1	0	0	0	1	1	1	1	1	1	1	*9*
E4	0	1	1	1	1	1	1	1	1	1	1	1	1	*12*
E5	0	1	1	1	1	1	1	1	1	1	1	1	1	*12*
E6	0	1	1	1	1	1	1	1	1	1	1	1	1	*12*
E7	0	0	0	0	0	0	1	1	1	0	0	1	1	*5*
E8	0	0	0	0	0	0	1	1	1	0	0	1	1	*5*
E9	0	0	0	0	0	0	0	0	1	0	0	0	1	*2*
E10	0	1	1	0	0	0	1	1	1	1	1	1	1	*9*
E11	0	1	1	0	0	0	1	1	1	1	1	1	1	*9*
E12	0	0	0	0	0	0	1	1	1	0	0	1	1	*5*
E13	0	0	0	0	0	0	0	0	0	0	0	0	1	*1*
Dependence power	*1*	*8*	*8*	*4*	*4*	*4*	*11*	*11*	*12*	*8*	*8*	*11*	*13*	

The driving power and dependence of each enabler is shown in Table 5. The driving power of each enabler is the total number of enablers into which it is having influence. The dependence power means the total number of enablers which is influencing it. In MICMAC analysis, the driving power and dependence powers are used for classification into four groups; autonomous, dependent, linkage and independent variables.

4.6 Level partitions

From the final reachability matrix, the reachability set and antecedent set (Warfield, 1974) for each enabler is found. The intersection set of these sets for all the enablers are determined by giving top-level variable in the ISM model, wherein the reachability and intersection sets are the same. Table 6 has come out with the E13 at level I. The level of each enabler is found out through continuous iteration process, which helps in building the diagraph and the final ISM model.

Table 6 Level partitions for enablers: Iteration-I

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1	1	
2	2, 3, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
3	2, 3, 7, 8, 9, 10, 11, 12, 13,	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
4	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 4, 5, 6	4, 5, 6	
5	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 4, 5, 6	4, 5, 6	
6	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 4, 5, 6	4, 5, 6	
7	7, 8, 9, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	
8	7, 8, 9, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	
9	9, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	9	
10	2, 3, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
11	2, 3, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
12	7, 8, 9, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	7, 8, 12	
13	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	13	*I*

Table 7 Level partitions for enablers: Iteration-II

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1	1	
2	2, 3, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
3	2, 3, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
4	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
5	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
6	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
7	7, 8, 9, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	
8	7, 8, 9, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	
9	9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	9	*II*
10	2, 3, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
11	2, 3, 7, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
12	7, 8, 9, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	7, 8, 12	

Table 8 Level partitions for enablers: Iteration-III

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	1	1	
2	2, 3, 7, 8, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
3	2, 3, 7, 8, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
4	2, 3, 4, 5, 6, 7, 8, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
5	2, 3, 4, 5, 6, 7, 8, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
6	2, 3, 4, 5, 6, 7, 8, 10, 11, 12	1, 4, 5, 6	4, 5, 6	
7	7, 8, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	*III*
8	7, 8, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	*III*
10	2, 3, 7, 8, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
11	2, 3, 7, 8, 10, 11, 12	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	
12	7, 8, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12	7, 8, 12	*III*

Table 9 Level partitions for enablers: Iteration-IV

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 2, 3, 4, 5, 6, 10, 11	1	1	
2	2, 3, 10, 11	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	*IV*
3	2, 3, 10, 11	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	*IV*
4	2, 3, 4, 5, 6, 10, 11	1, 4, 5, 6	4, 5, 6	
5	2, 3, 4, 5, 6, 10, 11	1, 4, 5, 6	4, 5, 6	
6	2, 3, 4, 5, 6, 10, 11	1, 4, 5, 6	4, 5, 6	
10	2, 3, 10, 11	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	*IV*
11	2, 3, 10, 11	1, 2, 3, 4, 5, 6, 10, 11	2, 3, 10, 11	*IV*

Table 10 Level partitions for enablers: Iteration-V

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 4, 5, 6	1	1	
4	4, 5, 6	1, 4, 5, 6	4, 5, 6	*V*
5	4, 5, 6	1, 4, 5, 6	4, 5, 6	*V*
6	4, 5, 6	1, 4, 5, 6	4, 5, 6	*V*

Table 11 Level partitions for enablers: Iteration-VI

Sl. no.	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1	1	1	*VI*

4.7 Formation of ISM-based model

The structured ISM model developed from the final reachability matrix is known as diagraph. The transitivity links are removed and the node numbers are replaced by statements and ISM model is developed, which is shown in Figure 3. From Figure 3, it is observed that Involvement and support from top management (E1) is the most significant enabler for integration of SC through digitalisation, as it comes at the base of the ISM hierarchy. Further, extended enterprise (E13) is the top-level enabler in the model.

Figure 4 Driving and dependence power diagram

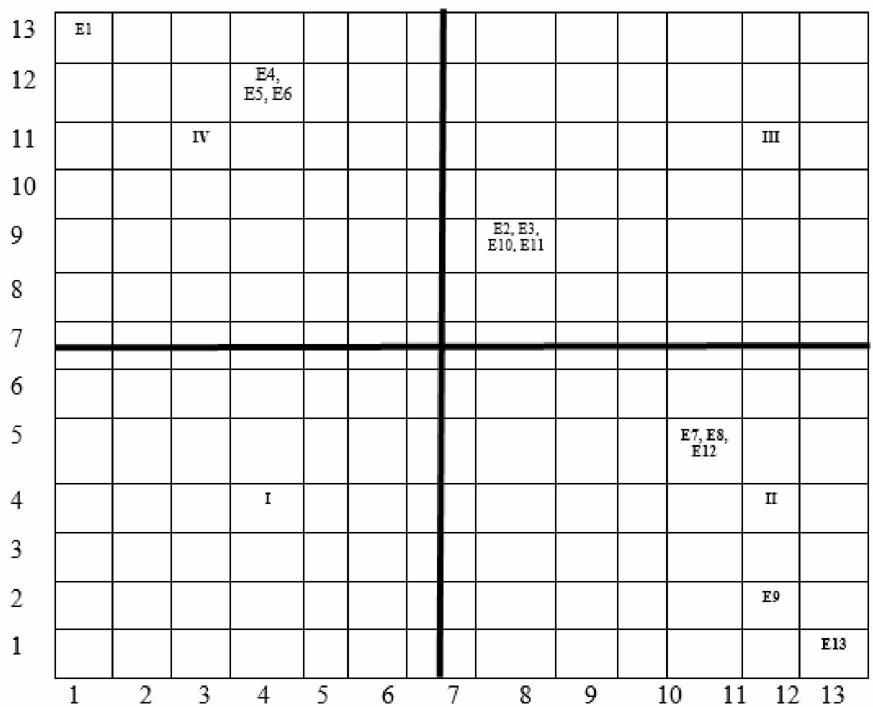


Figure 4: Driving and dependence power diagram

Table 12 Cluster classification based on MICMAC analysis

Sl. no.	*Driving power*	*Dependence power*	*Cluster*
1	Weak	Weak	Autonomous enablers
2	Weak	Strong	Dependent enablers
3	Strong	Strong	Linkage enablers
4	Strong	Weak	Independent enablers

4.8 MICMAC analysis

Matriced' impacts croises-multiplication applique' and classment is abbreviated as MICMAC. Based on the driving power and dependence power of the variables, MICMAC analysis is done (Attri et al., 2020). In MICMAC analysis, enablers will be classified into four clusters, identified as: autonomous enablers, dependent variables, linkage enablers and independent enablers as mentioned in Table 12.

1 Autonomous enablers have weak driving power and weak dependence power. These enablers are relatively disconnected from the system, as they have few links. These enablers are represented in Quadrant-I.

2 Dependent enablers have weak driving power and strong dependence power. These enablers are represented in Quadrant-II.

3 Linkage enablers have strong driving power and dependence power and hence are unstable. Any alterations on these enablers will have an effect on other enablers. These enablers are shown in Quadrant-III.

4 Independent enablers have strong driving power, but weak dependence power. These enablers are shown in Quadrant-IV.

The driving power and dependence power diagram of the enablers of SC constructed is shown in Figure 4. The dependence power is represented in X axis and the Y axis represents the driving power of the respective enablers. Based on the driving power and dependence powers, the enablers identified are classified under the four clusters.

5 Results and discussion

The process of SCD is a challenging task. The key factors influencing transformation from traditional SCM approach to digital one needs due consideration. Thus, an analysis of key enablers affecting digitalisation process is vital. In this study, key enablers influencing SCD in an electronic industry were identified from literature and in consultation with experts from the industry and academia. Further, these key enablers were analysed using ISM method and MICMAC analysis. Findings of this study provide a roadmap by which organisations can smoothly undertake the process of SCD. The major findings of this study based on the ISM model and MICMAC analysis are as follows.

The hierarchical structural model constructed based on the level partitioning of enablers at six levels is shown in Figure 3. The enablers classified at lower level facilitates in achieving effective digitalisation by driving through the enablers positioned subsequently at upper levels. Enablers with high driving power occupy at the lower level, while the enablers with high dependence power occupy at the higher level in the ISM model.

Results indicate that the enabler involvement and support from top management (E1) has appeared at the bottom of ISM model. Thus, it is a key enabler responsible for initiating SCD processes in organisations. Literature indicates that top management involvement and support has a major influence on aspects of SC connectivity and information sharing (Shibin et al., 2020). For the case electronics company, decision taken by top management and the support initiates the process of digital transformation of SC. This enabler has the highest driving power and thus it signifies that it is driving the remaining enablers in the model. Thus, it becomes evident that top management of organisations need to be proactive in initiating the process of digitalisation for achieving success.

The enablers, long, medium and short-terms plan (E4), investment of funds and availability (E5) and corporate culture among partners (E6) have appeared at fifth level in the model. The involvement and support from top management will drive for finalisation of implementation plans and raising funds for digitalisation process. Also, top management has a major role in creating a favourable corporate culture among the partners for achieving the benefits of SCI. Literature indicates that availability of adequate funds (Min et al., 2019), effective planning (Garay-Rondero et al., 2019) and encouraging corporate culture (Ghadge et al., 2020) fosters the process of digitalisation.

Cutting edge IT infrastructure and technology (E2), risk management and strategies (E11), proper information security (E3) and information sharing (E10) have appeared at fourth level in the model. Long, medium and short-terms plans, investment of funds and availability and corporate culture among SC partners would lead to procurement of advanced IT infrastructure and initiating proactive steps related to strategies on risk management and information security. These would strengthen company's infrastructure for effective information sharing (Tsironis et al., 2019).

Cooperation and support from SC partners (E12), trust among SC partners (E7) and data management on real time basis (E8) have appeared at third level in the model. Cooperation and support and trust among partners (Kamble et al., 2020) and data management on real time basis (Kara et al., 2020) will lead to achieve profitable information sharing mode with SC partners (E9). Somjai and Jermsittiparsert (2019) have highlighted the mediating impact of information sharing and its relation with SC capabilities and business performance.

Finally, it is observed that the enabler extended enterprise (E13) is dependent on many of the enablers and has appeared at top of the ISM model. Akyuz and Gursoy (2019) have addressed importance of IT in creation of a process oriented, strategically coupled and value creating networked SCs leading to an extended enterprise. Further, the classification of enablers based on MICMAC analysis is as follows:

- Autonomous enablers: From Figure 4, it is noted that there are no variables found in Quadrant-I. This reveals that all the enablers considered in the study are very significant and plays a crucial role in the process of enabling SCD.
- Dependent enablers: The enablers, trust among SC partners (E7), data management on real time basis (E8), profitable information sharing model with SC partners (E9), cooperation and support from SC partners (E12) and extended enterprise (E13) has come under Quadrant-II. The strong dependence power of these enablers reveals that they are interdependent on other enablers. Akyuz and Gursoy (2020) have highlighted the requirement of building trust, collaboration and support from the SC partners for digital transformation of SC activities. This reveals the importance of giving weightage to trust, cooperation and collaboration among the partners facilitating real time sharing of information without any hindrance.

- Linkage enablers: Cutting edge IT infrastructure and technology (E2), proper information security (E3), information sharing (E10), risk management and strategies (E11) are four enablers that have appeared under Quadrant-III. These enablers possess strong driving and strong dependence powers. Literature reveals that proper IT infrastructure integration and flexibility has a positive impact on organisational performance (Hou, 2020). Munir et al. (2020) investigated the need for having effective SC risk management strategies which affects the operational performance while integrating SC through digitalisation.
- Independent enablers: Involvement and support from top management (E1), long, medium and short-term planning (E4), investments of funds and availability (E5) and corporate culture among partners (E6) are four enablers that have appeared in Quadrant-IV. As these enablers possess strong driving powers, they can be classified as key enablers that need to be addressed for SCD. Wong et al. (2020) have found that the support from top management and financial investments are crucial factors influencing the process of digitalisation. Attaran (2020) has highlighted the significance of planning and its impact on the digital technology enablers during the process of SCD.

6 Conclusions

SCI through digitalisation allows an organisation to become smart enough to cope up with the dynamic changes in the digital era. Digitalisation allows the firms to gain transparency, competitive advantage and better SCM decision making. This research has developed a framework for enablers of SCD. We have also analysed influences and inter relations along the enablers that can assist decision makers while proceeding with the process of SCD.

This research has made some unique contributions. Firstly, it has explicitly analysed the key enablers affecting the process of SCD seen in electronics industry. Secondly, we have used the methodologies of ISM followed by MICMAC analysis. Application of ISM method helps in identifying the contextual relationship among the enablers. MICMAC analysis has been used to investigate the driving power and dependence power of the enablers that facilitates us in identifying key enablers affecting the process of SCD.

The ISM model developed in this research can support decision making process and development of a design for SC through digitalisation. It also provides directions for managers and professionals in the field for decision making processes for SCD. Even though a diversity of integration practices is available, approach of integration through digitalisation process adopted in this study helps the companies to focus on the key enablers effectively. It is found that the process of SCI through digitalisation is multi-dimensional and having several rooted theoretical perspectives. In this paper, we have addressed one of these dimensions by systematically bringing out the major enablers that are to be considered for decision making while integrating SC. This exercise leads to effective digitalisation of SC that enhances the efficiency and competitiveness of a firm.

6.1 Theoretical and managerial implications

The prioritisation and identification of interrelations among the enablers helps in determining the most significant enabler and due weightage can be given to those enablers in the digitalisation process. The establishment of interrelationship among the enablers facilitates the managers to decide on which enablers of digitalisation are to be given more attention at any point of time. This can increase the competitiveness of a firm. The enablers identified in this research are quite generic and with marginal changes can be adopted for other industries as well.

6.2 Limitations of the study and future scope

This study has been conducted specifically in electronics industry and hence, one of the limitations of the study is the industry specific nature. Also, enablers of SCD were identified from the literature and also in consultation with the experts in the firm and academia. Future studies could add more variables at the cost of complexity. Future scope of this study could attempt validation of this model by using structural equation modelling approaches.

References

Ageron, B., Bentahar, O. and Gunasekaran, A. (2020) 'Digital supply chain: challenges and future directions', *Supply Chain Forum: An International Journal*, Vol. 21, No. 3, pp.133–138.

Akyuz, G.A. and Gursoy, G. (2019) 'Strategic management perspectives on supply chain', *Management Review Quarterly*, Vol. 70, No. 2, pp.213–241.

Akyuz, G.A. and Gursoy, G. (2020) 'Transformation of supply chain activities in blockchain environment', in *Digital Business Strategies in Blockchain Ecosystems*, pp.153–175, Springer, Cham. https://doi.org/10.1007/978-3-030-29739-8_8.

Attaran, M. (2020) 'Digital technology enablers and their implications for supply chain management', *Supply Chain Forum: An International Journal*, Vol. 21, No. 3, pp.1–15.

Attri, R., Ashishpal, Khan, N.Z., Siddiquee, A.N. and Khan, Z.A. (2020) 'ISM-MICMAC approach for evaluating the critical success factors of 5S implementation in manufacturing organisations', *International Journal of Business Excellence*, Vol. 20, No. 4, pp.521–548.

Ayoub, H.F., Abdallah, A.B. and Suifan, T.S. (2017) 'The effect of supply chain integration on technical innovation in Jordan', *Benchmarking: An International Journal*, Vol. 24, No. 3, pp.594–616.

Basheer, M., Siam, M., Awn, A. and Hassan, S. (2019) 'Exploring the role of TQM and supply chain practices for firm supply performance in the presence of information technology capabilities and supply chain technology adoption: a case of textile firms in Pakistan', *Uncertain Supply Chain Management*, Vol. 7, No. 2, pp.275–288.

Boyes, H., Hallaq, B., Cunningham, J. and Watson, T. (2018) 'The industrial internet of things (IIoT): an analysis framework', *Computers in Industry*, Vol. 101, pp.1–12, doi:10.1016/j.compind.2018.04.015.

Brinch, M., Gunasekaran, A. and Wamba, S.F. (2020) 'Firm-level capabilities towards big data value creation', *Journal of Business Research*, DOI: 10.1016/j.jbusres.2020.07.036.

Buyukozkan, G. and Gocer, F. (2018) 'Digital supply chain: literature review and a proposed framework for future research', *Computers in Industry*, Vol. 97, pp.157–177, doi:10.1016/j.compind.2018.02.010.

Cagle, M.N. (2020) 'Reflections of digitalization on accounting: the effects of Industry 4.0 on financial statements and financial ratios', in *Digital Business Strategies in Blockchain Ecosystems*, pp.473–501, .Springer, Cham, doi:10.1007/978-3-030-29739-8_23.

Chand, P., Thakkar, J.J. and Ghosh, K.K. (2020) 'Analysis of supply chain sustainability with supply chain complexity, inter-relationship study using Delphi and interpretive structural modeling for Indian mining and earthmoving machinery industry', *Resources Policy*, Vol. 68, 101726, doi:10.1016/j.resourpol.2020.101726.

Coronado Mondragon, A.E., Coronado Mondragon, C.E. and Coronado, E.S. (2020) 'Managing the food supply chain in the age of digitalization: a conceptual approach in the fisheries sector', *Production Planning & Control*, Vol. 32, No. 3, pp.242–255. doi:10.1080/09537287.2020.1733123.

Dubey, R., Gunasekaran, A., Bryde, D.J., Dwivedi, Y.K. and Papadopoulos, T. (2020) 'Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting', *International Journal of Production Research*, Vol. 58, No. 11, pp.3381–3398.

Dunke, F. and Nickel, S. (2020) 'Improving company-wide logistics through collaborative track and trace IT services', *International Journal of Logistics Systems and Management*, Vol. 35, No. 3, pp.329–353.

Ebinger, F. and Omondi, B. (2020) 'Leveraging digital approaches for transparency in sustainable supply chains: a conceptual paper', *Sustainability*, Vol. 12, No. 15, p.6129.

Fatorachian, H. and Kazemi, H. (2021) 'Impact of Industry 4.0 on supply chain performance', *Production Planning & Control*, Vol. 32, No. 1, pp.63–81.

Fayezi, S., Zutshi, A. and O'Loughlin, A. (2017) 'Understanding and development of supply chain agility and flexibility: a structured literature review', *International Journal of Management Reviews*, Vol. 19, No. 4, pp.379–407.

Flynn, B., Huo, B. and Zhao, X. (2010) 'The impact of supply chain integration on performance: a contingency and configuration approach', *Journal of Operations Management*, Vol. 28, No. 1, pp.58–71.

Garay-Rondero, C.L., Martinez-Flores, J.L., Smith, N.R., Morales, S.O.C. and Aldrette-Malacara, A. (2019) 'Digital supply chain model in Industry 4.0', *Journal of Manufacturing Technology Management*, Vol. 31, No. 5, pp.887–933.

Gawankar, S.A., Gunasekaran, A. and Kamble, S. (2020) 'A study on investments in the big data-driven supply chain, performance measures and organisational performance in Indian Retail 4.0 context', *International Journal of Production Research*, Vol. 58, No. 5, pp.1574–1593.

Ghadge, A., Kara, M.E., Moradlou, H. and Goswami, M. (2020) 'The impact of Industry 4.0 implementation on supply chains', *Journal of Manufacturing Technology Management*, Vol. 31, No. 4, pp.669–686.

Gholipour, S., Ashoftehfard, A. and Mina, H. (2020) 'Green supply chain network design considering inventory-location-routing problem: a fuzzy solution approach', *International Journal of Logistics Systems and Management*, Vol. 35, No. 4, pp.436–452.

Guo, H., Yang, Z., Huang, R. and Guo, A. (2020) 'The digitalization and public crisis responses of small and medium enterprises: implications from a COVID-19 survey', *Frontiers of Business Research in China*, Vol. 14, No. 1, pp.1–25.

Gupta, H., Kumar, S., Kusi-Sarpong, S., Jabbour, C.J.C. and Agyemang, M. (2020) 'Enablers to supply chain performance on the basis of digitization technologies', *Industrial Management & Data Systems*, ahead-of-print.

Hausberg, J.P., Liere-Netheler, K., Packmohr, S., Pakura, S. and Vogelsang, K. (2019) 'Research streams on digital transformation from a holistic business perspective: a systematic literature review and citation network analysis', *Journal of Business Economics*, Vol. 89, Nos. 8–9, pp.931–963.

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A. and Prockl, G. (2019) 'Supply chain management and Industry 4.0: conducting research in the digital age', *International Journal of Physical Distribution & Logistics Management*, Vol. 49, No. 10, pp.945–955.

Hou, C.K. (2020) 'The effects of IT infrastructure integration and flexibility on supply chain capabilities and organizational performance: an empirical study of the electronics industry in Taiwan', *Information Development*, Vol. 36, No. 4, pp.576–602.

Ishtiaque, S., Siddiqui, D.A. and Ahmed, W. (2020) 'Impact of technology-based integrated responsive supply chain on operational performance: a case of a volatile market', *International Journal of Logistics Systems and Management*, Vol. 35, No. 3, pp.387–409.

Ivanov, D. and Dolgui, A. (2020a) 'A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0', *Production Planning & Control*, pp.1–14, DOI: 10.1080/09537287.2020.1768450

Ivanov, D. and Dolgui, A. (2020b) 'Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak', *International Journal of Production Research*, Vol. 58, No. 10, pp.2904–2915.

Ivanov, D., Dolgui, A. and Sokolov, B. (2019) 'The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics', *International Journal of Production Research*, Vol. 57, No. 3, pp.829–846.

Jabbar, S., Lloyd, H., Hammoudeh, M., Adebisi, B. and Raza, U. (2020) 'Blockchain-enabled supply chain: analysis, challenges, and future directions', *Multimedia Systems*, pp.1–20, doi:10.1007/s00530-020-00687-0.

Kamble, S.S., Gunasekaran, A. and Sharma, R. (2020) 'Modeling the blockchain enabled traceability in agriculture supply chain', *International Journal of Information Management*, Vol. 52, 101967, doi:10.1016/j.ijinfomgt.2019.05.023.

Kara, M.E., Fırat, S.Ü.O. and Ghadge, A. (2020) 'A data mining-based framework for supply chain risk management', *Computers & Industrial Engineering*, Vol. 139, 105570, 105570. doi:10.1016/j.cie.2018.12.017.

Kenge, R. and Khan, Z. (2020) 'A conceptual study of the supply chain Management 4.0 implementation process', *GSTF Journal of Engineering Technology*, Vol. 10, No. 2, pp.12–16.

Khan, H. and Wisner, J.D. (2019) 'Supply chain integration, learning, and agility: effects on performance', *Journal of Operations and Supply Chain Management*, Vol. 12, No. 1, p.14.

Khemili, H. and Belloumi, M. (2018) 'Cointegration relationship between growth, inequality and poverty in Tunisia', *International Journal of Applied Economics, Finance and Accounting*, Vol. 2, No. 1, pp.8–18.

Kumar, P., Singh, R.K. and Kumar, V. (2021) 'Managing supply chains for sustainable operations in the era of Industry 4.0 and circular economy: analysis of barriers', *Resources, Conservation and Recycling*, Vol. 164, 105215, doi:10.1016/j.resconrec.2020.105215.

Kwak, D-W., Seo, Y-J. and Mason, R. (2018) 'Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains', *International Journal of Operations & Production Management*, Vol. 38, No. 1, pp.2–21.

Lechler, S., Canzaniello, A., Robmann, B., von der Gracht, H.A. and Hartmann, E. (2019) 'Real-time data processing in supply chain management: revealing the uncertainty dilemma', *International Journal of Physical Distribution and Logistics Management*, Vol. 49, No. 10, pp.1003–1019.

Li, J., Chen, C.W., Wu, C.H., Hung, H.C. and Lin, C.T. (2020) 'How do partners benefit from IT use in supply-chain management: an empirical study of Taiwan's bicycle industry', *Sustainability*, Vol. 12, No. 7, p.2883.

Lind, L. and Schupp, F. (2020) 'Towards efficient financial supply chains: how to leverage inter-organizational working capital by digitalizing the financial flows', in *The Nature of Purchasing*, pp.205–232, Springer, Cham.

Lyall, A., Mercier, P. and Gstettner, S. (2018) 'The death of supply chain management', *Harvard Business Review*, Vol. 15, pp.2–4.

Maheshwari, S., Gautam, P. and Jaggi, C.K. (2020) 'Role of big data analytics in supply chain management: current trends and future perspectives', *International Journal of Production Research*, Vol. 59, No. 6, pp.1875–1900, doi:10.1080/00207543.2020.1793011.

Mahindroo, A., Samalia, H.V. and Verma, P. (2018) 'Information systems road map to enhance economic and operational reverse logistics performance', *International Journal of Logistics Systems and Management*, Vol. 29, No. 2, pp.215–240.

Malyavkina, L.I., Savina, A.G. and Parshutina, I.G. (2019) 'Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges', *1st International Scientific Conference 'Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth' (MTDE 2019)*, pp.10–15, Atlantis Press.

Marmolejo-Saucedo, J. and Hartmann, S. (2020) 'Trends in digitization of the supply chain: a brief literature review', *EAI Endorsed Transactions on Energy Web*, Vol. 7, No. 29, 164113. doi:10.4108/eai.13-7-2018.164113.

Min, S., Zacharia, Z.G. and Smith, C.D. (2019) 'Defining supply chain management: in the past, present, and future', *Journal of Business Logistics*, Vol. 40, No. 1, pp.44–55.

Mosteanu, N.R. (2020) 'Challenges for organizational structure and design as a result of digitalization and cybersecurity', *The Business & Management Review*, Vol. 11, No. 1, pp.278–286.

Munir, M., Jajja, M.S.S., Chatha, K.A. and Farooq, S. (2020) 'Supply chain risk management and operational performance: the enabling role of supply chain integration', *International Journal of Production Economics*, Vol. 227, p.107667, DOI: 10.1016/j.ijpe.2020.107667.

Nunez-Merino, M., Maqueira-Marin, J.M., Moyano-Fuentes, J. and Martinez-Jurado, P.J. (2020) 'Information and digital technologies of Industry 4.0 and lean supply chain management: a systematic literature review', *International Journal of Production Research*, Vol. 58, No. 16, pp.5034–5061.

O'Marah, K., Chen, X., John, G., Manenti, P., Morgan, B. and Hull, P.V. (2017) *Future of Supply Chain 2017* [online] https://www.gartner.com/en/documents/3849975/future-of-supply-chain-2017 (accessed 1 July 2020).

Pappas, I.O., Mikalef, P., Giannakos, M.N., Krogstie, J. and Lekakos, G. (2018) 'Big data and business analytics ecosystems: paving the way towards digital transformation and sustainable societies', *Information Systems and e-Business Management*, Vol. 16, No. 3, pp.479–491.

Piya, S., Shamsuzzoha, A. and Khadem, M. (2020) 'An approach for analysing supply chain complexity drivers through interpretive structural modelling', *International Journal of Logistics Research and Applications*, Vol. 23, No. 4, pp.311–336.

Rached, M. and Bahroun, Z. (2020) 'Vertical and horizontal impacts of information sharing on a divergent supply chain', *International Journal of Logistics Systems and Management*, Vol. 35, No. 2, pp.246–272.

Schniederjans, D.G., Curado, C. and Khalajhedayati, M. (2020) 'Supply chain digitisation trends: an integration of knowledge management', *International Journal of Production Economics*, Vol. 220, 107439, doi:10.1016/j.ijpe.2019.07.012.

Sestino, A., Prete, M.I., Piper, L. and Guido, G. (2020) 'Internet of things and big data as enablers for business digitalization strategies', *Technovation*, Vol. 98, 102173, doi:10.1016/j.technovation.2020.102173.

Shao, X.F., Liu, W., Li, Y., Chaudhry, H.R. and Yue, X.G. (2021) 'Multistage implementation framework for smart supply chain management under Industry 4.0', *Technological Forecasting and Social Change*, Vol. 162, 120354, doi:10.1016/j.techfore.2020.120354.

Sharma, D., Taggar, R., Bindra, S. and Dhir, S. (2020) 'Retailer responsiveness: a total interpretive structural modelling approach', *Journal for Global Business Advancement*, Vol. 13, No. 3, pp.336–358.

Shibin, K.T., Dubey, R., Gunasekaran, A., Hazen, B., Roubaud, D., Gupta, S. and Foropon, C. (2020) 'Examining sustainable supply chain management of SMEs using resource based view and institutional theory', *Annals of Operations Research*, Vol. 290, No. 1, pp.301–326.

Somjai, S. and Jermsittiparsert, K. (2019) 'Mediating impact of information sharing in the relationship of supply chain capabilities and business performance among the firms of Thailand', *International Journal of Supply Chain Management*, Vol. 8, No. 4, pp.357–368.

Sprovieri, J. (2019) *Industry 4.0 is Well Underway* [online] http://www.assemblymag.com/articles/94970-industry-40-is-well-underway (accessed 10 January 2020).

Stank, T., Esper, T., Goldsby, T.J., Zinn, W. and Autry, C. (2019) 'Toward a digitally dominant paradigm for twenty-first century supply chain scholarship', *International Journal of Physical Distribution and Logistics Management*, Vol. 49, No. 10, pp.956–971.

Stevens, G.C. and Johnson, M. (2016) 'Integrating the supply chain … 25 years on', *International Journal of Physical Distribution & Logistics Management*, Vol. 46, No. 1, pp.19–42.

Sundram, V.P.K., Chhetri, P. and Bahrin, A.S. (2020) 'The consequences of information technology, information sharing and supply chain integration, towards supply chain performance and firm performance', *Journal of International Logistics and Trade*, Vol. 18, No. 1, pp.15–31.

Tsironis, L.K., Dimitriadis, S.D. and Papathanasiou, J. (2019) 'The essence of supply chain collaboration: a consideration of information sharing types and benefits (SC-Info-Shr)', *International Journal of Decision Sciences, Risk and Management*, Vol. 8, No. 4, pp.292–320.

Warfield, J.W. (1974) 'Developing interconnected matrices in structural modeling', *IEEE Transcript on Systems, Men and Cybernetics*, Vol. 4, No. 1, pp.51–81.

Wei, S., Ke, W., Lado, A.A., Liu, H. and Wei, K.K. (2020) 'The effects of justice and top management beliefs and participation: an exploratory study in the context of digital supply chain management', *Journal of Business Ethics*, Vol. 166, No. 1, pp.51–71.

Wilkesmann, M. and Wilkesmann, U. (2018) 'Industry 4.0 – organizing routines or innovations?', *VINE Journal of Information and Knowledge Management Systems*, Vol. 48, No. 2, pp.238–254.

Wong, L.W., Leong, L.Y., Hew, J.J., Tan, G.W.H. and Ooi, K.B. (2020) 'Time to seize the digital evolution: adoption of blockchain in operations and supply chain management among Malaysian SMEs', *International Journal of Information Management*, Vol. 52, 101997, doi:10.1016/j.ijinfomgt.2019.08.005.

Xing, G., Xia, B. and Guo, J. (2019) 'Sustainable cooperation in the green supply chain under financial constraints', *Sustainability*, Vol. 11, No. 21, p.5977.

Xu, X. and Zou, P.X. (2020) 'Analysis of factors and their hierarchical relationships influencing building energy performance using interpretive structural modelling (ISM) approach', *Journal of Cleaner Production*, Vol. 272, 122650, doi:10.1016/j.jclepro.2020.122650.

Yadav, S., Garg, D. and Luthra, S. (2020) 'Selection of third-party logistics services for internet of things-based agriculture supply chain management', *International Journal of Logistics Systems and Management*, Vol. 35, No. 2, pp.204–230.

Yang, J., Xie, H., Yu, G. and Liu, M. (2020) 'Antecedents and consequences of supply chain risk management capabilities: an investigation in the post-coronavirus crisis', *International Journal of Production Research*, Vol. 59, No. 5, pp.1573–1585, doi:10.1080/00207543.2020.1856958.

Zangiacomi, A., Pessot, E., Fornasiero, R., Bertetti, M. and Sacco, M. (2020) 'Moving towards digitalization: a multiple case study in manufacturing', *Production Planning & Control*, Vol. 31, Nos. 2–3, pp.143–157.

Zhu, Q., Krikke, H. and Caniels, M.C.J. (2018) 'Supply chain integration: value creation through managing inter-organizational learning', *International Journal of Operations & Production Management*, Vol. 38, No. 1, pp.211–229.