An integrated ANP–QFD approach for prioritization of customer and design requirements for digitalization in an electronic supply chain

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Abstract

Purpose – Supply chain efficiency can be enhanced by integrating the activities in supply chain through digitalization. Advancements in digital technologies has facilitated in designing robust and dynamic supply chain by bringing in efficiency, transparency and reduction in lead times. This research tries to identify and prioritize the customer requirements and design requirements for effective integration of supply chain through digitalization.
Design/methodology/approach – The key nine customer requirements and 16 design requirements applicable for an electronics company were shortlisted in consultation with the experts from the company and academia. An integrated analytic network process (ANP) and quality function deployment (QFD) methodology has been applied for prioritizing the customer and design requirements. The relative importance and interdependence of these requirements were identified and a House of Quality (HOQ) is constructed.
Findings – The HOQ constructed has prioritized and identified interrelationships among customer requirements and design requirements for effective supply chain digitalization. These findings could be effectively used by managers for planning the objectives on long-term, medium-term and short-term basis.
Originality/value – This study tries to bridge the gap of identifying and prioritizing the design and customer requirements for effective supply chain integration through digitalization. The results could aid practicing managers and academicians in decision-making on supply chain digitalization process.

Keywords Analytic network process (ANP), Quality function deployment (QFD), Integrated supply chain, Electronics supply chain
Paper type Research paper

1. Introduction

Supply chain management (SCM) has become a dominant topic among academicians and practitioners in the recent years (Ayoub *et al.*, 2017). Further, supply chain integration (SCI) has emerged as a dominant theme for research due to innovation in digital technologies and its immense application in industries. Traditional supply chain (SC) is considered as a rigid mechanism in which the SC processes are handled independently by the partners. The development in SC due to emerging technologies is transforming the businesses activities (Ben-Daya *et al.*, 2019; Ivanovo *et al.*, 2019). The advancement in digital technologies has changed the nature of SC through closer collaboration and integration among partners.

In recent times, information technology (IT) is used by companies for interlinking the flow of information, material and money across the SC. The evolution of Internet has facilitated to access information across the SC on real-time basis. Further, software and applications like Enterprise Resource Planning (ERP) systems have integrated the existing systems in areas such as inventory control, financial accounting, customer relations, etc. The advancements in information and communication technology (ICT) tools have made the SCs more dynamic and efficient. This has facilitated faster and real-time communication among the SC partners.

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The transformation of organizations into digital form is commonly known as Industry 4.0. It includes various types of technologies like Internet of things (IoTs), cloud-based manufacturing, block chain, artificial intelligence and cyber physical systems. Further, in order to assess the readiness of organization for Industry 4.0, the six key ingredients identified are the extent of digitization of SC, level of digitization of organization, readiness of organizational strategy, top management involvement and commitment, employee adaptability with Industry 4.0 and smart products and services (Sony and Naik, 2019). Belinski *et al.* (2020) have categorized the dimensions of Industry 4.0 under three main constructs: learning development, Industry 4.0 structure and technology adoption for easy management and implementation.

The use of digital technology and its ability to transform the information in user friendly format is a major invention for enhancing SC efficiency. Connectivity and information sharing under the mediating effect of top management commitment is positively related to business data and predictive analysis (BDPA) acceptance. Gunasekaran *et al.* (2017) in their study have found that assimilation of BDPA is positively related to supply chain performance (SCP) and organizational performance (OP).

IT has immense significance in overall performance of SC in an organization. The impact of IT attributes depends upon the nature of SC characteristics considered. IT integration is the most prominent attribute mentioned in the literature. IT integration refers to creation of a virtual SC by linking the information systems and sharing of information among SC partners. Seamless integration of partners across the SC is essential to reduce the costs. An efficient SC network can be established by means of implementing most modern information sharing systems and tools. Effective management of SC by using ICT tools aid in utilizing the firm's resource and capacity effectively. CT implementation also helps in redesigning of SC (Lee *et al.*, 2011). The innovations in ICT and its implementation have enabled the creation of effective and efficient information systems for effective management of SCs.

Perez-Lopez *et al.* (2019) have quantified the relationships among variables to be considered for adopting ICT in SC. Seamless integration of partners across the SC is required to reduce manufacturing and transactions costs. Hence, there exists a need to introduce efficient SC network with execution of most modern information sharing systems and tools. In order to facilitate implementation of a robust SC using IT tools, data and information transmitted across among the SC partners is to be maintained in a repository and classified suitably for easy access and processing.

The process of SCI through digitalization involves the extent to which a company adopts digital technologies in their processes for conducting their day to day transactions. Digitalization of SC allows integration of data and information by assisting various functions of SC processes (Mussomeli *et al.*, 2016). Digital technologies help in real-time transmission of information and support knowledge management practices (Wilkesmann and Wilkesmann, 2018). The desire to adopt new technologies will bring in transformational effects on SC (Xue *et al.*, 2013). Application of advanced technologies allows companies to gain competitive advantage through higher revenue and value addition (Buyukozkan and Gocer, 2018). There is a lack of knowledge in the procedure to be adopted for implementation and effective utilization of digital technologies. The development on account of digitalization process allows organizations to manage their SC activities remotely (Lyall *et al.*, 2018).

The integration process has been transformed by the use of IT in SC, facilitating organizations to gain more market share. The process of digitalization of SC has become an enabler. In order to achieve the desired results, it is indispensable for understanding the interrelationships among customer requirements (CRs) and design requirements (DRs) pertinent for digitalization. The influence of big data analytics for enhanced operational performance of organization is stated in the literature by integrating three major fields of management like entrepreneurship, operations management and information systems management. Dubey *et al.* (2020a) have developed a model that describes the role of entrepreneurial orientation on the adoption of big data analytics powered by artificial intelligence and operational performance.

Research in the area of SCI has revealed that value creation can be done through partnership among SC partners (Jajja *et al.*, 2018). The integration process works on basis of shared decision-making, open communication, collaboration, shared vision, technology and trust among the partners (Flynn *et al.*, 2010). A digital supply chain (DSC) can be defined as interorganizational systems that firms implement to digitize the process of transaction and collaboration with their SC partners. (Xue *et al.*, 2013).

Studies on various aspects specific to a functional area or cross functional areas of SCI aiming at performance augmentation are found in the literature. Dimensions and measures relevant to integration of SC on a broad perspective in various contexts are also found. However, the studies pertaining to identifying the CRs and DRs essential for SCI process while adopting advanced digital technologies is not duly found. The lack of such a study in the digitized world needs to be addressed, which contributes to an understanding of various aspects of SCI. To the best of our knowledge, no paper has attempted to study on identifying the CRs and DRs that are to be considered for SCI through the process of digitalization. This study intends to fill this research gap. The study is timely and relevant due to the era of digitalization in SC, which leads to development of smart SC. It also contributes to the theory of SCI and digitalization process by providing insights to researchers in the field. The managers can take into account and weigh up for the CRs and DRs identified for effective integration. Further, based on the nature of industry, the model developed can be adapted by considering the industry-specific CRs and DRs for effective digitalization.

Buyukozkan *et al.* (2018) in their study have found an upsurge in functions and application of digital technologies in various aspects of SC. Thus, an integrated approach in the adoption of digital technologies in SC and its assessment based on analytical network process (ANP) integrated quality function deployment (QFD) will be an appropriate study to bring in better insights. The present study is an attempt in this regard by considering the CRs and DRs of SC digitalization. It would be useful for an organization in finalizing the requirements to be considered at various implementation levels.

This research attempts to propose an information system framework using integrated ANP–QFD approach. SC digitalization can be done effectively by quantifying the processes and requirements needed from both customer and design point of views. Interrelationships among the CRs and DRs can be addressed effectively by using ANP. QFD is one of the methods that have been applied judiciously in case of both manufacturing and service sectors (Fisher and Schutta, 2003).

This study tries to bring insights to the process of SCI through digitalization by developing a framework by using ANP–QFD approach. The main objectives of this research are as follows:

(1) To identify the major CRs and DRs for the process of SCD.

(2) To analyze and prioritize CRs and DRs identified by finding out the extent of interrelationship among the requirements and

(3) To construct a House of Quality that assists in better decision-making in the process of digitalization.

This paper is further organized as follows. The Section 2 deals with literature review on the subject followed by Section 3 detailing the proposed methodology adopted in this study. In Section 4, we applied the proposed methodology to a case electronics company and build the conceptual HOQ for SCI. Section 5 deals with results and discussions, followed by conclusions in Section 6 dealing with theoretical and managerial implications, limitations and future scope of research.

2. Literature review

Literature review with respect to SCI and its importance, SCI through digitalization and CRs and DRs for supply chain digitalization (SCD) are presented in this section.

2.1 Supply chain integration and its importance

SCI aims at streamlining the flow of products, information and funds from suppliers to customers thereby ensuring efficiency and accuracy in SC processes (Sammuel and Kashif, 2013). Diverse outlook and aims of SCI like collaborative advantage (Cao and Zhang, 2010); effective relational governance (Schoenherr and Swink, 2012); IT integration; knowledge exchange and trust (Chen *et al.*, 2016); strategic achievement (Beske and Seuring, 2014); supplier involvement (Alam *et al.*, 2014); SC performance (Flynn *et al.*, 2016); lead time (LaureanoPaiva *et al.*, 2014); Quality (Gonzalvez-Gallego *et al.*, 2015); competitive advantage (Pradabwongetal. (2017); Flexibility (Wong *et al.*, 2017); cost reduction (Tseng and Liao, 2015) are found in literature. SCI process has three levels of facilitators, namely, (1) information integration (2) coordination and information sharing and (3) organizational relationship linkages (Alfalla-Luque *et al.*, 2013).

Autry and Moon (2016) have defined various perspectives and dimensions of SCI. In addition, uncertainty (Flynn *et al.*, 2016); supplier's involvement and relationship (Alam *et al.*, 2014); market complexity (Wong *et al.*, 2015); competitive approach (Cao *et al.*, 2015); organization culture (Yunus and Tadisina, 2016); human capital (Huo *et al.*, 2016); market and technological turbulence (Arora *et al.*, 2016); trust (Abdallah *et al.*, 2017) are the other dimensions and variables driving SCI that are addressed in literature.

Sodhi and Tang (2019) have found out process of disclosing information to the public as a mechanism for providing SC transparency. Dubey *et al.* (2020b) have developed a conceptual model for understanding of application of blockchain technology in the case of humanitarian SC. The model demonstrated that blockchain technology exercises positive and significant influence on operational SC transparency.

The measures of SCI are information sharing and interdependence among SC members (Huang *et al.*, 2014). Information sharing, decision-making at interorganizational level and planning among partners in SC are considered as the key elements (Jayaram *et al.*, 2010). The major dimensions identified for SCI are information sharing and operational coordination (Liu and Qiao, 2014), collaboration and information sharing (Wu *et al.*, 2016) and information and physical integration (Bruque-Camara *et al.*, 2016). Majority of the research papers in the area of SCI have focused on the two dimensions of internal and external integration. Sundarakani *et al.* (2019) have developed a hybrid SC cloud model for integrating the infrastructure, resources and configurations of platforms for creating better flexibility and efficiency in SCM. Queiroz *et al.* (2019) has developed a framework for DSC capabilities consisting of seven basic capabilities and six main enabler technologies.

SCI is an imperative topic considering enormous benefits that organizations can gain from the process. SCI through IT requires money and time to leverage maximum benefits (Chakravorty *et al.*, 2016). SCI involves collaboration of interorganizational and interfunctional practices for enhancing SC performance. SCM provides an integrative thinking to collaborate among the partners for enhancing performance and customer value. SCI also involves flow of materials and information, coordination within partners, decision-making and collaboration which smoothens the processes of SC. Integration of SC refers to the extent to which partners in the SC collaborate to achieve maximum efficiency and performance (Vanpoucke *et al.*, 2017).

2.2 Supply chain integration through digitalization

Advanced digital technologies and tools can be used in managing various SC functions through proper implementation and monitoring of activities. SC in real-time faces tribulations like mismatch between supply and demand, overstocking, stock outs and delay in delivery (Wu *et al.*, 2016). IT has drastically changed the way of defining SCI process as the information can be shared online on real-time basis (Palomero and Chalmeta, 2014). Availability of timely and accurate information to partners facilitates effective coordination of activities and decision-making in SC (Zhou *et al.*, 2014).

Salam (2019) has investigated the impact of manufacturing strategies on Industry 4.0 supplier performance and found that improved quality and flexibility has positive impact on performance of suppliers. Gupta *et al.* (2020) have addressed the orientation of firms in adopting Industry 4.0 and DSC. Hastig and Sodhi (2020) have investigated the readiness of blockchain technology for traceability in business requirements by including all the participants into the system. Existing systems should be integrated with the blockchain-based solution for facilitating effective implementation. Thus, traceability solution for an industry can be hybrid in nature with blockchain as a small but significant component of overall system.

The future of SC distinctly depends on how the digital transformation of SC is managed (O'Marah *et al.*, 2017). The need is for improving SC by shifting the priority from simple cost reduction and optimization of resources to SC restructuring based on technological advancement. It stresses addressing factors like resource sharing, long term relationship and ensuring availability of resources including IT systems to facilitate effective integration through digitalization. SC managers need to examine, control and understand the entire operations in SC by managing the information received from various sources (Ngai and Gunasekaran, 2007; Olson, 2018).

Srinivasan and Swink (2018) have found that demand and supply visibility are associated with the development of analytics capability in a firm. The operational performance of a firm is closely associated with analytics capability. Managers considering investing in analytics capability should carefully evaluate their SC capabilities, organizational abilities and competitive value of sensing and responding to changing market conditions. Zekhnini *et al.* (2020) have developed a framework for SCM 4.0, which decomposes the connection between distinct parts in SC like digitalization, digital technologies and risk management. SCM4.0 considers deployment of modern technologies like IoTs, big data analytics, autonomous robotics, etc.

Digital technologies play a dynamic role in effective SC functioning and enhancing firm's performance (Gurria, 2017; Laaper, 2017). There is a positive relationship between SCI and performance of the firm by comprising information, operational and relational integration (Leuschner *et al.*, 2013). Stroup (2017) has accentuated upon multidisciplinary nature of digitalization. Studies on various aspects of SCI aiming at performance enhancement, dimensions and measures relevant to integration are also found in the literature. Drivers and enablers of SCI have also been investigated with little consensus on the process of SCI through digitalization (Hausberg *et al.*, 2019). Inter-relationships among SC partners are to be established and recognized for effective design, alignment and execution of the strategy. However, on account of advanced digital technologies, the implication and strategies to be framed and the procedure to be followed is not yet addressed.

2.3 CR and DRs for SCD

SCD can be done productively by considering SC requirements and adopting suitable implementation procedures. In order to effectively integrate SC, this paper tries to analyze various CRs and DRs affecting the digitalization process. Literature review has identified various factors of SCI as collaborative planning (Barratt, 2004); competitive capability (Kim, 2009); long-term relationship (Prajogo and Olhager, 2012); dependence and trust with customer and supplier (Zhang and Huo, 2013); SC planning and trust (Laureano-Paiva *et al.*, 2014); SC relationship (Wu *et al.*, 2016); shared IT infrastructure (Bernon *et al.*, 2013); technology adoption (Tseng and Liao, 2015); interorganizational communications (Jacobs *et al.*, 2016) and people involvement (Pradabwong *et al.*, 2017).

Ghosh *et al.* (2019) have investigated the practices and policies that are unique to high-tech manufacturing start-ups in emerging economies and related technologies through Industry 4.0. The three constructs affecting performance and competitiveness of high-tech manufacturing firms are upstream operations issues, production-based issues and downstream operations issues. Kumar *et al.* (2020) have studied the role of ICT in agri-food SC and impact on SCM practices on firm's performance. It is found that ICT and SCM practices are significantly related. Further, SCM practices like information sharing, supplier relationship and logistics integration have a significant and positive impact on organization's performance .

Literature reveals that no prior works found for identifying CRs and DRs influencing the process of SCI through digitalization. Studies on identifying the requirements of SCD in the context of electronics SC have also not received due attention. As the role of digitalization in SC is yet to be fully explored, proper understanding of the process of SCD is necessitated. Hence, more insights and research to understand the CRs and DRs to be considered for SCD merits attention. The key CRs and DRs were identified and shortlisted based on existing literature and in consultation with three experts in the industry and one expert from the academia.

Details of abbreviations used in the study are given in Appendix. Some of the recent studies highlighting the core area in SCD are given in Table 1.

2.4 ANP and QFD in supply chain management

QFD is a quantitative tool that can be used to translate CRs into DRs. The dynamic and diversified requirements of customers' needs to be addressed actively. Customers get utmost

Sl. No	Author and year	Area of study	Remarks
1.	Feibert *et al.* (2017)	Digitalization in shipping SC	Integrated digitalization and business process management perspective for enhancing SCP in shipping companies
2.	Kersten *et al.* (2018)	DSC	New business ecosystems create challenges for all partners and developed a road map for digital SC
3.	Buyukozkan *et al.* (2018)	DSC	Review of DSC and identified its key limitations and prospects of future research studies in this area
4.	Hein *et al.* (2019)	Digital products and services	Technology management, economics and information systems have different perspective on digital platform ecosystems
5.	Sundaram *et al.* (2020)	Digital transformation business models	Studied the need for incorporating digital transformations in business models
6.	Nasiri *et al.* (2020)	Performance in DSC	Smart technologies mediation between digital transformation and relationship performance
7.	Marmolejo-Saucedo *et al.* (2020)	DSC	Studied the evolution of SC in digital context of operational functions
8.	Hennelly *et al.* (2019)	DSC	Production digitalization and its role in performance improvement in SC

Table 1.
Literature review on SCD

value for money, if the CRs are considered. Organizations are adopting QFD to consider the CRs called voice of customer, while designing products and services. The advantages of identifying requirements or expectations prior to design and manufacture results in meeting customer demands to the maximum possible extent. QFD method helps in realistically communicating the requirements of customer at each production levels, starting from marketing, design, quality, manufacturing, sales, after sales service, etc.

The ANP is a multicriteria decision-making (MCDM) methodology that considers the interdependence among various alternatives and criteria. It helps in transforming the qualitative judgment of decision-makers into quantitative values. ANP differs from the analytical hierarchy process (AHP) wherein the later deploys a hierarchical relationship among the criteria, whereas the former enables to identify the interrelationships among the clusters and its elements.

Researchers have applied QFD method in a number of areas. Karsak *et al.* (2002) have used a combination of ANP and zero one goal programming approach in determining technical requirements for designing the product. The requirements of SMEs in SC planning has been addressed through a hybrid QFD, interpretive structural modeling (ISM), zero-one goal programming and ANP approach (Thakkar *et al.*, 2011). Morteza (2013) has addressed SCM design using QFD and ANP approaches. Chang *et al.* (2019) have used a combination of ANP and QFD methodologies for mitigation of bullwhip effect by deploying agility in SC.

2.5 Problem description and gaps in literature

Literature review reveals that proper prioritization and clarity in CRs and DRs affecting SCI using IT is not duly addressed. This study tries to address this gap. The process of adoption of digitalization in SC affects various functional areas like quality, maintenance, inventory management, production planning, etc. The decision on SCD should be taken considering factors like availability of advanced digital technologies, various requirements, its impact and willingness of SC partners to adopt such technologies. Hence, a study on the prioritization of CRs and DRs is much necessitated, as the organizations are competing to transform by adopting DSC.

Literature reveals various ways and approaches for assessing the possibilities of DSC, whereas, little research has been done on developing a framework by considering the CRs and DRs for SCD. This study intends to fill this research gap by prioritizing the CRs and DRs and bringing out the inter-relationships and its effect on SC performance by using an integrated ANP–QFD methodology. Based on advent of advanced technologies and its practical implications, this study has great relevance in the digital era. Hence, identifying the key CRs and DRs, its interrelationship and prioritizing the requirements would facilitate successful digitalization of SC. This study concentrates on the CRs and DRs which are to be considered as a preliminary step for initiating the digitalization process.

3. The proposed ANP–QFD methodology

3.1 Analytic network process

ANP method is used in this study as it is feasible for modeling within complex situations and relations. An advantage of ANP is that it considers all relations and interactions among different levels of decision-making and it also creates a network structure (Saaty, 2004). It also determines the relative importance of criteria and prioritizes alternatives that are available with decision-maker. ANP method is effective in real-world case applications when decision criteria and alternatives are interdependent. It can be applied to find out solutions for real-world problems considering tangible as well as intangible criteria.

3.2 QFD

QFD is a quantitative tool that can be used to translate CRs into DRs. In reality, the demand and requirements of the customers are dynamic and diversified in nature and these needs to be addressed effectively. In order to gain competitive advantage, CRs have to be considered prior to launching products. QFD is a tool that organizations are adopting to consider the requirements of customers called as the voice of the customer (VoC) while designing products and services. The advantage of having the requirements or expectations prior to designing and manufacturing helps them in meeting customer demands as close as possible. QFD has been successfully applied in service sectors like hotels and airline (Zawati and Dweiri, 2016), e-commerce sector (Waterworth and Eldridge, 2010), e-banking (Shahin *et al.*, 2016), web interface (Hamilton and Selen, 2004) and construction sector (Gilbert *et al.*, 2016; Moghimi *et al.*, 2017).

QFD method helps in effectively communicating the CRs at each level of production process initiating from the design, manufacturing, quality, marketing, sales and after sales service. The key benefits of adopting QFD method are as follows.

(1) *Focus on customer*: Focus on customer is given utmost importance in QFD. Organizations are considering the perceived demands and CRs rather than producing and marketing the products which they feel the customer wants.

(2) *Voice of customer:* QFD process involves comparing competitive products in order to design a product that meets the voice of customer. The voice of customers is transformed into technical requirements which provide valuable insights in product development and in rendering service.

(3) *Less development time and cost*: Adoption of the QFD tool results in reducing development time and cost. This is because development of the product is done based on the CRs. A well-tailored QFD methodology helps in effectively using the resources for development of better products and services.

(4) *Structure and documentation*: QFD method provides a well-structured documentation of data collected that helps in product development and decision-making process.

3.2.1 Proposed QFD-based integrated SCM framework. The procedure of adoption and digitalization through QFD has many benefits (Murali *et al.*, 2016). It expedites the design process and brings breakthrough innovation (Vinodh *et al.*, 2008). It also reduces cost, design and rework changes and failure risks (Gonzalez *et al.*, 2004). Application of QFD augments overall operational performance of the firm by meeting the CRs and DRs influencing the process of digitalization. QFD assumes the linear relationships between the CRs and DRs which are considered as an abridged version of the reality. QFD method aggregates both quantitative and qualitative data. QFD process could be improved by integrating quantitative techniques like AHP to minimize subjective weakness (Dai and Blackhurst, 2012). A diagrammatic representation of the HOQ construction using QFD method is shown in Figure 1.

3.3 Integrated ANP approach in QFD

The ANP is a MCDM process that considers the interdependence among various alternatives and criteria. Further, it helps in transforming the qualitative judgment of decision-makers into quantitative values. Chan *et al.* (2019) have used a combination of QFD–ANP approaches to determine the vital agility factors for mitigating the bullwhip effect. The integrated QFD–AHP method through pairwise comparison helps in overcoming disadvantages and reduces the subjectivity bias of decision-makers (Kwong and Bai, 2003). QFD–ANP method used in this study helps to outline and relate CRs and DRs for SCD. The activities can be planned effectively by prioritizing the requirements for effective decision-making.

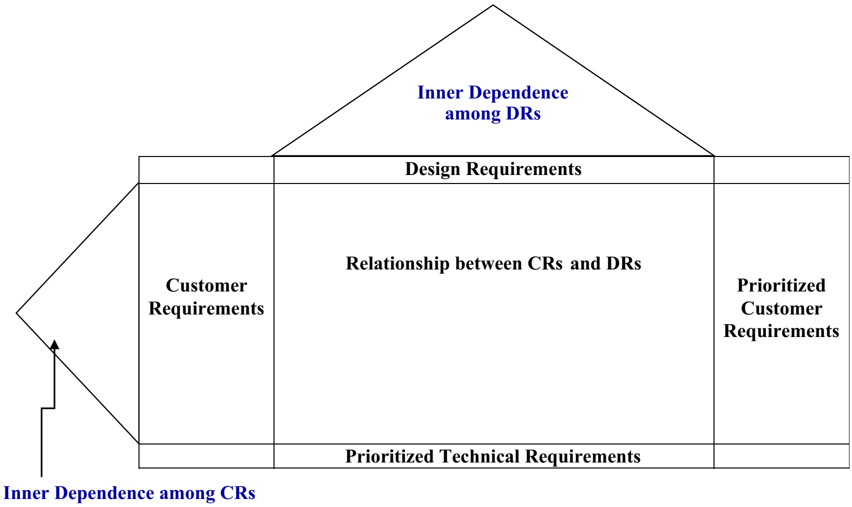


Figure.1.
The House of Quality

3.3.1 Steps to be followed in the proposed ANP–QFD framework. The steps in proposed framework for making the HOQ are given in Figure 2.

3.3.2 Completing HOQ. A HOQ which relates CRs and DRs can be constructed using QFD method. HOQ reflects the prioritization of CRs and DRs so as to meet perceived requirements of the organization contemplated in this study. A four phase model of building a HOQ that conveys voice of customer (WHATs) to design modifications (HOWs) and in meeting customer expectations needs to be developed. The priority of CRs and DRs is determined by formulating the super matrix of HOQ network model which consists of following steps (Buyukozkan *et al.* 2011):

Step 1. Identification of CRs: The CRs are identified from literature review and shortlisted based on opinion of experts in industry and academia through brainstorming sessions.

Step 2. Finalization of DRs: The DRs are finalized by considering the CRs identified in Step 1 above, through brainstorming sessions with the experts in electronics industry.

Step 3. Relative importance of CRs (W_1): The relative importance of CRs is found out by framing a pair-wise comparison matrix among the CRs. .

Step 4. Relationship between CRs and DRs (W_2): In order to develop a HOQ, CRs and DRs are compared and their relative importances are established by forming an interdependency matrix.

Step 5. Establishing inner dependence matrix among CRs (W_3): The CRs identified may have inner dependence and may support or affect the achievement of other CRs. The inner dependence matrix of the CRs is constructed by pair-wise comparison matrix within CRs.

Step 6. Developing inner dependence matrix among DRs (W_4): The inner dependence matrix of DRs is established by constructing pair-wise comparison matrix within the DRs which forms the roof of HOQ, called as correlation matrix.

Step 7. Establish interdependent priority matrix of CRs (Wc): The interdependent priority matrix of the CRs is obtained by using the following relation, $W_C = W_3{*}W_1$.

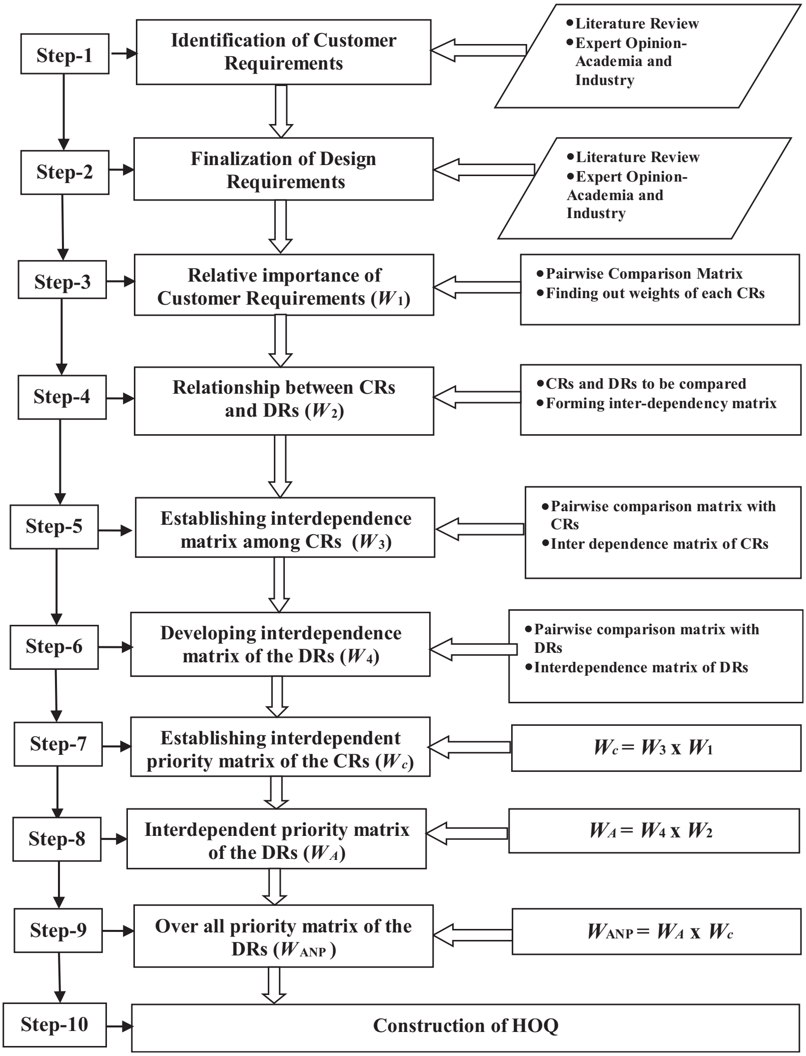


Figure 2.
Steps in the proposed framework for completing HOQ

Step 8. Establish interdependent pri*ority matrix among DRs* (W_A): The interdependent priority matrix of DRs is obtained by using the relation, $W_A = W_4{*}W_2$

Step 9. Finding out the overall priority of DRs: The overall priorities of DRs, reflecting the interrelationships within HOQ, are obtained by using the relation, $W_{\mathrm{ANP}} = W_A{*}W_C$.

4. Illustration of proposed methodology to an electronic company

The methodology proposed in this study is applied in the SC of an XYZ company in electronics industry, which is dealing with consumer electronics having an annual turnover of INR 128bn. The CRs and DRs for the XYZ company are finalized based on literature review and in consultation with experts in the company and academia. The experts identified were chosen based on case study methodology adopted by Bouzon *et al.* (2018) and Seker *et al.* (2017). These experts consulted were senior managers who are having an industrial experience of over 25 years in electronics industry responsible for Information Technology, Product Life Cycle Management and Operations Management in the firm. The academic expert was an Associate Professor in a reputed university engaged in research studies for over 20 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. All these experts were asked to evaluate the CRs and DRs based on their knowledge in the industry and experience.

As the methodology involves construction of matrix for pairwise comparison for each CR and DR, only a limited number of matrices for pairwise comparison of CRs and DRs are shown. However the detailed methodology for calculating the pairwise comparison matrices for each CRs and DRs is explained. The step by step procedure of application of methodology is mentioned as follows.

4.1 Step 1: identification of CRs

In order to build a HOQ, the first step is to identify CRs. In this study, CRs were identified from literature review and refined based on the opinion from experts in electronics industry and academia.

The CRs are identified based on various studies in the area of integration of SC using information systems. Accordingly, the case company identified nine major CRs as follows: (1) Cost, (2) Quality, (3) Flexibility, (4) Data Privacy, (5) Responsiveness, (6) Functional Fit to the System, (7) Vendor Reputation, (8) After Sales Service and (9) Ergonomic design. Details of CRs identified and the relevant literature are given in Table 2.

Ref no	Ref. code	Customer requirements	Relevant literature	Remarks
CR1	CST	Cost	Lapinskaite and Kuckailyte (2014), Wronka (2016)	Overall cost can be reduced by adopting innovative methods
CR2	QLT	Quality	Kushwaha *et al.* (2010), Sharma *et al.* (2012)	Improving quality results in better resource utilization and process efficiency
CR3	FLX	Flexibility	Stevenson *et al.* (2009), Palandeng *et al.* (2018)	Ability to respond quickly to rapid changes
CR 4	DPY	Data privacy	Kolluru and Meredith. (2001), Ulhaq *et al.* (2016)	Data privacy is required for obtaining trust among supply partners
CR 5	RSP	Responsiveness	Hayat *et al.* (2012), Sinha *et al.* (2015)	Responsiveness is the ability to understand market situations and adapt to CRs
CR 6	FFS	Functional fit to the system	Marinagi and Trivellas (2014), Aithal (2016)	Aligning functions to achieve the organizational goals
CR 7	VNR	Vendor reputation	Haridasan and Sudharsan (2018), Yadavalli *et al.* (2019)	Helps in achieving SC objectives
CR 8	AFS	After-sales service	Gaiardelli *et al.* (2007), Gilaninia *et al.* (2012)	Vendor reputation retains customers and increases business volume
CR 9	ERD	Ergonomic design	Farooq and Grudin (2016), Zunjic *et al.* (2018)	Designing and effective implementation using digital technologies

Table 2. CR for SCI through digitalization

4.2 Definitions of CRs

4.2.1 Cost (CR1, CST). Cost analysis is pertinent to find out the impact of processes costs in SC. The available resources of the SC should be used in most efficient way to provide competitive goods and services. The overall cost in SC can be reduced by adopting innovative IT tools (Lapinskaite *et al.*, 2014; Wronka, 2016). Assessing the production and distribution costs enables the management to determine the products which are viable and cost effective. Thus, understanding the costs involved in SC has a significant role in improving company's profit and its viability.

4.2.2 Quality (CR2, QLT). One of the most important factors to be considered by the companies in their relationship between suppliers and customers is quality. Improving the quality of all SC processes results in (1) reduced costs and (2) better resource utilization and increased process efficiency. Firms can gain competitive advantage by providing innovative products and services at better price, quality and on time supply (Kushwaha *et al.*, 2010; Sharma *et al.*, 2012). Firm's performance can be evaluated through the financial and operational performance. Thus, there is a direct and positive relationship between quality and SCM. Based on the dynamic changes that are happening in the SC, quality concept and its implication is gaining relevance. Firms need to adhere to quality policy that meets the CRs and standards for manufacture of products.

4.2.3 Flexibility (CR3, FLX). Flexibility in SC means the potential of the firm to improve efficiency and performance by quickly responding to the rapid changes. A firm's performance depends upon the flexibility dimensions among SC partners (Stevenson *et al.*, 2009; Palandeng *et al.*, 2018). Flexibility is strategically important to SC as it includes operational flexibility, resource flexibility and demand flexibility. The specific interfirm practices used to achieve flexibility and how these affects SC is of greater significance.

4.2.4 Data privacy (CR4, DPY). The dimensions of power distance, uncertainty avoidance and collectivism actively support information protection practices in SCM. Protection of data is necessary while it is transmitted across SC partners and privacy should be ensured. Organizations should evolve strategies and procedures to improve security and privacy of information transmitted across the SC (Kolluru *et al.*, 2001; Ulhaq *et al.*, 2016).

4.2.5 Responsiveness (CR5, RSP). SC responsiveness refers to how rapidly an organization can understand the market situations and adapt to CRs. IT plays a major role in gathering and transmitting information across the SC, which enhances SC responsiveness. Top management plays a major role in ensuring SC responsiveness, as it involves financial investment (Mehrjerdi, 2009; Hayat *et al.*, 2012). Proper planning in SC activities enables the SC to be more responsive and efficient. Responsive SC ensures meeting customer demands and requirements on time.

4.2.6 Functional fit to the system (CR6, FFS). Functional fit to the system is the process of aligning the functions of an organization in achieving organizational goals. This attribute is necessary is to ensure that the customer demands are met to avoid uncertainty, if any. Achieving functional fit to the system ensures trust and mutual cooperation among internal and external SC partners. Maintaining functional fit to the system ensures accurate forecast of the demand and supply, availability of resources, proper designing of SC, alignment of goals resulting in achieving the overall objectives of organization (Gurumurthy *et al.*, 2013).

4.2.7 Vendor reputation (CR7, VNR). The vendors participating in SC plays an important role in achieving SC objective (Hemalatha *et al.*, 2015; Mani *et al.*, 2018). Continuous improvement and development of vendors to meet the requirements of the firm helps in (1) reducing wastages, (2) improving quality and (3) reducing lead time. Reputation of a vendor depends upon the technical competence, financial soundness, production capacity, etc.

4.2.8 After-sales service (CR8, AFS). Customer satisfaction and retention of customers depends upon after sales service indices provided by the firm, namely, product delivery, installation and warranty. In the case of an electronics industry, income earned from repairs and maintenance accounts for a major share in the overall turnover of the company. Providing proper after sales service will help in retaining customers and increases business volume. The feedback received from customers can be used in developing improved products with better quality that suits CRs (Kumar, 2012; Gilanini *et al.*, 2012). Coordination between suppliers and customers are required for managing SC effectively through proper communication and information sharing. Monitoring of after sales service can be met by identifying proper service performance criteria and frequent auditing so as to make corrective measures for providing better service.

4.2.9 Ergonomic design (CR9, ERD). Ergonomic design facilitates in achieving a unified experience through interaction between humans and machines through digital solutions (Farooq and Grudin, 2016). It helps in analyzing the opportunities that enhances the existing design through in-depth integration, resulting in realizing greater competitive advantage. Application of ergonomic principles in SC facilitates solving various problems through designing and effective implementation (Zunjic *et al.*, 2018). Hence the segments of SC in which ergonomics can provide significant contributions should be identified for better integration. The application of ergonomics in SC should be a multidisciplinary approach with specific emphasis on designing of information in compliance with ergonomic principles for quick absorption, understanding and effective execution.

These CRs along with relevant literature are summarized in Table 2. Further, the CRs identified were grouped based on the nature of functions to be performed in the SC like transaction execution, collaboration and decision support (Auramo *et al.*, 2005). This is illustrated in Figure 3.

4.3 Step 2: finalization of DRs

The DRs were identified from literature review and finalized based on expert opinion. Sixteen major DRs identified are (1) Simplification and Standardization, (2) Outsourcing, (3) IT Automation, (4) Quality Standards, (5) Process Management, (6) Research and Development, (7) Knowledge Management, (8) Smart Contracts, (9) E-intermediation, (10) Auditability, (11) IT Integration, (12) Data-Driven Innovation, (13) Intelligent Value Chain Networks, (14) ICT Security, (15) Data and Business Analytics and (16) Design for Manufacturing. Details of the DRs identified and the corresponding literature are given in Table 3.

4.3.1 Simplification and standardization (DR, SMS). Simplification and standardization is the process of adopting standard procedures, materials parts and process in manufacturing of product or providing service. Simplification and standardization procedure has a positive effect on business performance (Sanchez-Rodrıguez *et al.*, 2006) as it facilitates in bulk production. It also helps in coordinating and simplifying processes among SC partners

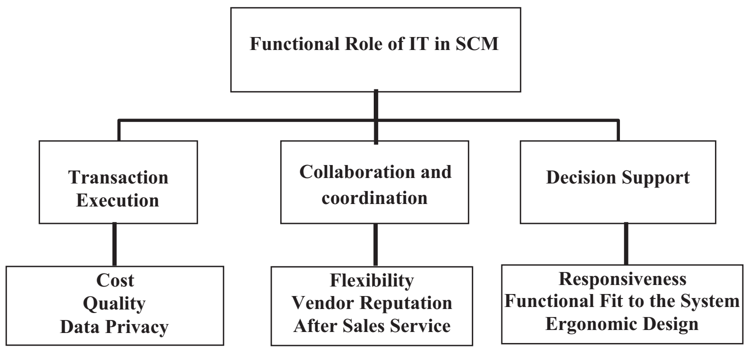


Figure 3.
CRs for SCI through digitalization

Ref no	Ref. code	DRs	Relevant literature	Relevance to SCD
DR1	SMS	Simplification and standardization	Sanchez-Rodrıguez *et al.* (2006), Stajniak and Kolinski (2016)	Positive impact on business performance through coordination and simplifying processes
DR2	OTS	Outsourcing	Tsay *et al.* (2018), Pankowska *et al.* (2019)	Helps to focus on core areas and bring flexibility
DR3	ITA	IT automation	Almuiet and Salim (2014), Kothari *et al.* (2018)	Results in robustness and efficiency by information exchange on real-time basis
DR4	QLS	Quality standards	Sharma *et al.* (2012), Gu *et al.* (2017)	Adds value to products and service
DR5	PRM	Process management	Croxton *et al.* (2001), Lockamy *et al.* (2004)	Assists in measuring performance and continual improvements
DR6	RAD	Research and development	Shahmari Chatghieh *et al.* (2013), Jordan (2014)	Results in evolution of innovative methods for effective SCM
DR7	KLM	Knowledge management	Almuiet and Salim (2014), Perez-Salazar *et al.* (2013)	Includes acquisition, integration, protection and dissemination of knowledge
DR8	SMC	Smart contracts	Law (2017), Schutte *et al.* (2018), Hu *et al.* (2019)	Reduces complexity through automated verification and execution
DR9	EIM	E-intermediation	Wollschlaeger *et al.* (2017), Mostafa *et al.* (2019)	Integrated system of physical and virtual world for communication, computing and control
DR10	AUD	Auditability	LeBaron *et al.* (2017), Daghfous *et al.* (2017)	Independent objective assurance and consulting activity to add value to improve operations
DR11	ITI	IT integration	Marinagi *et al.* (2014), Samadi *et al.* (2016), Pachayappan (2018)	Enhances collaboration and provides timely, accurate and reliable information
DR12	DDI	Data-driven innovation	Padmos (2016), Spanaki *et al.* (2018)	Creates better value by providing reliable inputs in planning and other activities
DR13	IVN	Intelligent value chain networks	Kothari *et al.* (2018), Goswami *et al.* (2013), Hanifan *et al.* (2014)	Provides visibility through real-time continuous synchronization
DR14	ICS	ICT security	Kolluru *et al.* (2001), Ulhaq *et al.* (2016)	Reduces risk of loss of data, misuse, fraud and tampering of data
DR15	DBA	Data and business analytics	Tiwari *et al.* (2017), Mishra *et al.* (2018), Spanaki *et al.* (2018), Roy (2018)	Quick processing of data for effective decision-making and enhancing business process
DR 16	DFM	Design for manufacturing	Srinivasan *et al.* (2018), Bogers *et al.* (2018), Roscoe *et al.* (2019)	Application of digital solutions and integration of product design in the production process

Table 3.
Design requirement used in the study for SCI through digitalization

leading to overall reduction of cost and raw materials (Stajniak and Kolinski, 2016). The effects of information systems and its role in process improvements needs to be considered while proceeding with adoption of simplification and standardization process.

4.3.2 Outsourcing (DR2, OTS). Outsourcing of noncore activities to specialized third parties allows an organization to focus on its core areas. It gives flexibility in operating and maintaining SC (Tsay *et al.*, 2018; Pankowska *et al.*, 2019). IT outsourcing chain partners are mutually dependent due to globalization and rapid innovation in IT. Outsourcing allows firms to concentrate on a narrower range of operations and reduces the need for internal flexibility.

4.3.3 IT automation (DR3, ITA). The process of IT automation can be centralized, distributed and agent based. Internet has allowed collaboration among SC partners to become automated, by providing access to real-time information (Almuiet and Salim, 2014; Kothari *et al.*, 2018). IT automation of SC results in robustness and efficiency through real-time sharing of information across the SC. It helps in planning and collaboration of SC activities and enhances SC performance and efficiency.

4.3.4 Quality standards (DR4, QLS). Quality standards are a prominent factor to be considered in the whole process of SC. The concept of total quality management should be carried out to add value in products and services Sharma *et al.* (2012). Quality is one of the most important factors to be considered by suppliers and customers that enhance customer data base and reputation. The areas of production, delivery and after sales services should be given due priority and monitored by using quality management tools (Gu *et al.*, 2017).

4.3.5 Process management (DR5, PRM). The process management includes implementation of a set of processes to enhance SC performance and efficiency. Effective process management tools can be used for measuring performance and continual improvement efforts (Croxton *et al.*, 2001; Lockamy *et al.*, 2004). It includes defining of the process, measuring and controlling the activities that brings consistency and richness across the organization. Gaining maturity in the process management process will results in continuous improvement and in attaining new maturity levels, i.e. from an internal perspective to an externally focused perspective that results in a higher level of process capability for a firm.

4.3.6 Research and development (DR6, RAD). R&D is a competitive tool that contributes to a great extent in success of a company. The process of R&D requires information related to specific areas in higher level of research and innovation (Shahmari Chatghieh *et al.*, 2013). R&D results in fruition of innovative methods for managing SC processes that result in better performance (Jordan, 2014).

4.3.7 Knowledge management (DR7, KLM). Knowledge management (KM) is one of the strategic activities in SC which includes acquisition of knowledge, integration of knowledge, its protection and dissemination. The era of globalization has necessitated the need for managing information and knowledge to survive in the highly competitive and turbulent environment. Effective knowledge management helps in identifying new trade-offs and developing new models which helps in quick decision-making to gain competitive advantage (Perez-Salazar *et al.*, 2013; Almuiet and Salim, 2014). Knowledge and information being the core areas for effective integration and coordination of SC activities, building effective tools for knowledge management will enhance the firm's capabilities.

4.3.8 Smart contracts (DR8, SMC). Smart contracts are digital agreements that are written in computer code and deployed to the blockchain, where they will self-execute when predetermined conditions are met. They reduce complexity in SC through automated verification and execution of the multiple business transactions involved. It ensures that all the stakeholders have equal access to the information which can be accessed on need base that in turn helps in building trust among the SC partners (Law, 2017; Schutte *et al.*, 2018; Hu *et al.*, 2019). Smart contracts help in bringing in transparency, efficiency and traceability of SC activities. It also helps in evaluating the performance of the contracts on real-time basis.

4.3.9 E-intermediation (DR9, EIM). E-intermediation involves an integrated system for communication, computing and control which integrates the physical and virtual world of an organization. The development of robust communication technologies like cloud computing, mobile Internet and IoTs enables for interaction among the SC partners (Wollschlaeger *et al.*, 2017; Mostafa *et al.*, 2019). Applying the concepts of IoT and Industry 4.0 helps in developing smart products and services.

4.3.10 Auditability (DR10, AUD). Auditing is an independent objective assurance and consulting activity framed to add value to improve the operations in an organization. Auditing helps an organization in achieving the objectives through systematic and well-planned approach to enhance the efficiency of an organization. It also assesses whether the predetermined rules and procedures were deviated from the standards set. Effective auditing adds value to the organization and stakeholders by evaluating the efficiency, economy and effectiveness of activities. The plan, policy and procedures followed in the organization should be examined (LeBaron *et al.*, 2017; Daghfous *et al.*, 2017).

4.3.11 IT integration (DR11, ITI). IT integration is a critical factor to enhance the SC performance. The recent advancements in IT have provided timely, accurate and reliable information for enhancing collaboration and integration among SC partners. It has also improved agility and flexibility among firms (Sabbaghi and Vaidyanathan, 2008). The information should be shared both in upstream and downstream for improving the integration and planning related activities in SC processes (Samadi *et al.*, 2016; Pachayappan, 2018).

4.3.12 Data-driven innovation (DR12, DDI). ICT tools help the organizations in focusing on data-driven decision-making based on the real-time data availability. The innovation based on the data accessed plays a significant role in transforming and enhancing SC functions. Organizations are concentrating more on developing capabilities to access and analyze the data to enhance their technical and organizational capabilities. New digital business models are increasingly more complex and companies that are able to effectively manage that complexity gains competitive advantage (Padmos, 2016). Effective data-driven innovation helps in creating better value by providing reliable inputs in planning the activities of an organization (Spanaki *et al.*, 2018). Companies have to frame and develop data strategies and information and data management disciplines to gain full potential of SCD.

4.3.13 Intelligent value chain networks (DR13, IVN). The significance of collaborative technologies makes improvements in sharing of information, trust and commitment among SC partners. It helps in coordinating of activities to overcome uncertainties by providing visibility of manufacturing process on real time through continuous synchronization between demand and supply. Analysis of the real-time information through intelligent value chain networks helps in meeting the demands of customers. It also reduces manufacturing cost, which is of the top priority of SC relationships (Kothari *et al.*, 2018; Goswami *et al.*, 2013; Hanifan *et al.*, 2014). SC information systems are critical for synchronizing information among SC partners in order to carry out a systematic evaluation and selection of such applications.

4.3.14 ICT security (DR14, ICS). The information that an organization communicates with its SC partners is one of the most critical assets (Kolluru *et al.*, 2001; Ulhaq *et al.*, 2016). The need for securing information should be made aware to all SC partners. It helps in attaining control on the information to be transmitted and accessed across the SC. Organizations should ensure security at sender and receiver level for the information transmitted over a publicly accessible medium such as the Internet. ICT security helps in reducing organizations risk of loss of data, misuse, fraud and tampering of data by providing protection from both external and internal threats.

4.3.15 Data and business analytics (DR15, DBA). Data and business analytics are used for effectively processing different types of data for proper decision-making. Data and business analytics has the potential to outperform and transform traditional SCM practices by providing better insights for improving processes, operational efficiency, cost reduction and quick decision-making (Mishra *et al.*, 2018; Tiwari *et al.*, 2017). It also helps in enhancing the business process and methodology by analyzing the information related to various processes and partners involved in the SC (Spanaki *et al.*, 2018; Roy, 2018).

4.3.16 Design for manufacturing (DR 16, DFM). The process of digital transformation should consider the integration of design for manufacturing to translate the design into a final product. The application of digital solutions and integration of product design in production process adds value. The operational capability in digital manufacturing process needs effective management of knowledge for better performance (Roscoe *et al.*, 2019). Consideration of design for manufacturing during digitalization process by taking into account of information required for manufacturing, usage and delivery results in effective decision-making (Srinivasan *et al.*, 2018). Further, features of products are affected due to uncertainty and designs selected for the production process (Bogers *et al.*, 2018). Hence, design for manufacturing should be given due consideration.

4.4 Step 3: relative importance of CRs (W_1)

The relative importances of CRs are identified by finding out answer to "Which CR should be given more priority while designing a digitally integrated SC and to what extent?" The following eigenvector is calculated by assuming that there is no dependency among the CRs, which is obtained by doing pairwise comparison with respect to the goal of achieving the better design.

$$W_1 = \begin{pmatrix} 0.2913 \\ 0.1994 \\ 0.1478 \\ 0.1216 \\ 0.0776 \\ 0.0663 \\ 0.0337 \\ 0.0304 \\ 0.0319 \end{pmatrix} = \begin{pmatrix} \text{CR 1} & \text{CST} \\ \text{CR 2} & \text{QLT} \\ \text{CR 3} & \text{FLX} \\ \text{CR 4} & \text{DPY} \\ \text{CR 5} & \text{RSP} \\ \text{CR 6} & \text{FFS} \\ \text{CR 7} & \text{VNR} \\ \text{CR 8} & \text{AFS} \\ \text{CR 9} & \text{ERD} \end{pmatrix}$$

4.5 Step 4: relationship between CRs and DRs (W_2)

In this step, interdependence of DRs with respect to each CR is found out, assuming that there is no dependence among the DRs. For example, the calculation of interdependence of DRs with respect to CR; quality is given in Table 4. What is the relative importance of DR3 (IT automation) when compared to DR5 (Process Management)? This comparison results in 3 as depicted in Table 4 Further, degree of relative importance of DRs for the remaining CRs calculated in the same way and is presented in Table 5. The transpose of the data shown in Table 5 will be represented in the body of the HOQ.

	DRs	DR1	DR3	DR4	DR5	DR6	DR8	DR10	DR14	DR15	DR 16	Weight
DR1	SMS	1.00	4.00	5.00	5.00	6.00	8.00	7.00	6.00	2.00	9.00	0.316
DR3	ITA	0.25	1.00	3.00	3.00	3.00	5.00	6.00	6.00	7.00	8.00	0.199
DR4	QLS	0.20	0.33	1.00	3.00	2.00	3.00	3.00	4.00	2.00	8.00	0.115
DR5	PRM	0.20	0.33	0.33	1.00	3.00	2.00	3.00	4.00	3.00	9.00	0.102
DR6	RAD	0.17	0.33	0.50	0.33	1.00	2.00	3.00	3.00	2.00	9.00	0.078
DR8	SMC	0.13	0.20	0.33	0.50	0.50	1.00	2.00	2.00	2.00	4.00	0.051
DR10	AUD	0.14	0.17	0.33	0.33	0.33	0.50	1.00	2.00	2.00	6.00	0.047
DR14	ICS	0.17	0.17	0.25	0.25	0.33	0.50	0.50	1.00	2.00	2.00	0.034
DR15	DBA	0.50	0.14	0.50	0.33	0.50	0.50	0.50	0.50	1.00	2.00	0.043
DR 16	DFM	0.11	0.13	0.13	0.11	0.11	0.25	0.17	0.50	0.50	1.00	0.016

Table 4. Relative importance of the DRs for quality

Table 5.
The column eigenvectors with respect to each CRs

	W_2	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9
DR1	SMS	0.4697	0.3162	0.2687	0.2858	0.3429	0.2733	0.0000	0.3777	0.3041
DR2	OTS	0.2414	0.0000	0.0000	0.1386	0.1496	0.1675	0.3327	0.1721	0.1463
DR3	ITA	0.0000	0.1985	0.2030	0.1903	0.1429	0.1418	0.0000	0.1598	0.1282
DR4	QLS	0.0000	0.1150	0.0000	0.1169	0.1145	0.0000	0.2412	0.1120	0.1074
DR5	PRM	0.0000	0.1022	0.1524	0.0848	0.0822	0.1045	0.0000	0.0578	0.0804
DR6	RAD	0.1211	0.0781	0.1207	0.0000	0.0000	0.0753	0.1726	0.0000	0.0526
DR7	KLM	0.0000	0.0000	0.0000	0.0000	0.0000	0.0498	0.0000	0.0000	0.0349
DR8	SMC	0.0761	0.0512	0.0718	0.0673	0.0589	0.0000	0.1207	0.0719	0.0000
DR9	EIM	0.0000	0.0000	0.0693	0.0000	0.0440	0.0354	0.0000	0.0000	0.0223
DR10	AUD	0.0000	0.0465	0.0000	0.0431	0.0000	0.0000	0.0720	0.0000	0.0000
DR11	ITI	0.0000	0.0000	0.0474	0.0357	0.0248	0.0274	0.0000	0.0000	0.0000
DR12	DDI	0.0000	0.0000	0.0284	0.0000	0.0000	0.0189	0.0390	0.0000	0.0203
DR13	IVN	0.0000	0.0000	0.0236	0.0214	0.0231	0.0163	0.0000	0.0000	0.0140
DR14	ICS	0.0588	0.0338	0.0000	0.0162	0.0000	0.0000	0.0217	0.0260	0.0000
DR15	DBA	0.0000	0.0429	0.0000	0.0000	0.0000	0.0000	0.0000	0.0227	0.0000
DR16	DFM	0.0330	0.0156	0.0146	0.0000	0.0171	0.0134	0.0000	0.0000	0.0134

4.6 Step 5: establishing inner dependence matrix among CRs (W_3)

Further, interdependence among CRs is arrived by finding out the impact of each CR on other CRs by using pairwise comparisons. The CRs which do not have an impact are not included in comparison matrix. For example, the relative importance of cost when compared to responsiveness in achieving quality is mentioned as 5.00 as mentioned in Table 6. Accordingly, eigenvectors obtained from pairwise comparisons for other CRs are mentioned in Table 7. Zero is assigned to the eigenvector weights for CRs that are independent.

Table 6.
The inner dependence of CRs against quality

CRs		CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR 9	Weight
CR1	CST	1.00	5.00	2.00	4.00	5.00	8.00	7.00	6.00	1.00	0.3076
CR3	FLX	0.20	1.00	3.00	2.00	4.00	7.00	8.00	8.00	0.20	0.2073
CR4	DPY	0.50	0.33	1.00	3.00	2.00	8.00	6.00	7.00	0.50	0.1664
CR5	RSP	0.25	0.50	0.33	1.00	2.00	6.00	7.00	6.00	0.25	0.1253
CR6	FFS	0.20	0.25	0.50	0.50	1.00	4.00	3.00	3.00	0.20	0.0736
CR7	VNR	0.13	0.14	0.13	0.17	0.25	1.00	2.00	3.00	0.13	0.0392
CR8	AFS	0.14	0.13	0.17	0.14	0.33	0.50	1.00	3.00	0.14	0.0332
CR9	ERD	0.17	0.13	0.14	0.17	0.33	0.33	0.33	1.00	0.17	0.0281
CR 2	QLT	0.13	0.14	0.17	0.14	0.25	0.33	0.50	0.33	0.13	0.0193

Table 7.
The inner dependence matrix of CRs (W_3)

CRs		CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR 9
CR1	CST	0.0349	0.3076	0.0000	0.5702	0.0000	0.4237	0.5527	0.4484	0.4415
CR2	QLT	0.2706	0.0193	0.2451	0.2786	0.2377	0.2566	0.1966	0.2297	0.2383
CR3	FLX	0.0000	0.2073	0.0524	0.0000	0.2965	0.1337	0.0000	0.0000	0.1316
CR4	DPY	0.3009	0.1664	0.3164	0.0396	0.1834	0.0803	0.1003	0.0000	0.0000
CR5	RSP	0.0000	0.1253	0.1951	0.0000	0.0283	0.0455	0.0724	0.1368	0.0856
CR6	FFS	0.2548	0.0736	0.1298	0.1116	0.0000	0.0273	0.0000	0.0000	0.0450
CR7	VNR	0.0000	0.0392	0.0000	0.0000	0.1155	0.0000	0.0319	0.0839	0.0000
CR8	AFS	0.0752	0.0332	0.0000	0.0000	0.0899	0.0000	0.0461	0.0468	0.0327
CR 9	ERD	0.0637	0.0281	0.0612	0.0000	0.0488	0.0330	0.0000	0.0544	0.0252

4.7 Step 6: Developing inner dependence matrix of the DRs (W_4)

In the next step, dependence among the DRs is determined. For this pairwise comparison among DRs are done to find out the inner dependency. For example, the relative importance of DR1 SMS when compared to DR3 ITA resulting in 7 is illustrated in Table 8. Accordingly, the relative importance of the weights obtained from pairwise comparisons are presented in Table 9.

4.8 Step 7: Establishing interdependent priority matrix of the CRs (Wc)

The interdependent priorities of the CRs are obtained by using the relation $W_C = W_3 \times W_1$.

$$W_c = \begin{pmatrix} 0.2913 \\ 0.1994 \\ 0.1478 \\ 0.1216 \\ 0.0776 \\ 0.0663 \\ 0.0337 \\ 0.0304 \\ 0.0319 \end{pmatrix} = \begin{pmatrix} \text{CR 1} & \text{CST} \\ \text{CR 2} & \text{QLT} \\ \text{CR 3} & \text{FLX} \\ \text{CR 4} & \text{DPY} \\ \text{CR 5} & \text{RSP} \\ \text{CR 6} & \text{FFS} \\ \text{CR 7} & \text{VNR} \\ \text{CR 8} & \text{AFS} \\ \text{CR 9} & \text{ERD} \end{pmatrix}$$

4.9 Step 8: Interdependent priority matrix of the DRs (W_A)

The interdependent priorities of the DRs, W_A are calculated as follows: $W_A = W_4 \times W_2$.

$$W_A = \begin{pmatrix} 0.2089 & 0.1911 & 0.2236 & 0.2288 & 0.2279 & 0.2093 & 0.3590 & 0.2162 & 0.2095 \\ 0.1394 & 0.1013 & 0.0952 & 0.0918 & 0.1106 & 0.0948 & 0.0100 & 0.1137 & 0.0991 \\ 0.1398 & 0.1670 & 0.1383 & 0.1498 & 0.1473 & 0.1147 & 0.1225 & 0.1476 & 0.1260 \\ 0.1596 & 0.1354 & 0.1428 & 0.1542 & 0.1420 & 0.1512 & 0.1588 & 0.1463 & 0.1373 \\ 0.1050 & 0.0943 & 0.0828 & 0.1178 & 0.1152 & 0.0886 & 0.1295 & 0.1172 & 0.0979 \\ 0.0302 & 0.0371 & 0.0344 & 0.0246 & 0.0287 & 0.0363 & 0.0059 & 0.0305 & 0.0332 \\ 0.0249 & 0.0462 & 0.0597 & 0.0302 & 0.0279 & 0.0360 & 0.0420 & 0.0243 & 0.0273 \\ 0.0255 & 0.0166 & 0.0199 & 0.0166 & 0.0198 & 0.0149 & 0.0048 & 0.0187 & 0.0140 \\ 0.0251 & 0.0350 & 0.0382 & 0.0322 & 0.0312 & 0.0298 & 0.0032 & 0.0313 & 0.0276 \\ 0.0000 & 0.0064 & 0.0007 & 0.0023 & 0.0007 & 0.0005 & 0.0028 & 0.0024 & 0.0004 \\ 0.0357 & 0.0467 & 0.0484 & 0.0370 & 0.0358 & 0.0367 & 0.0481 & 0.0345 & 0.0380 \\ 0.0100 & 0.0209 & 0.0273 & 0.0120 & 0.0114 & 0.0216 & 0.0141 & 0.0102 & 0.0162 \\ 0.0205 & 0.0311 & 0.0237 & 0.0243 & 0.0241 & 0.0177 & 0.0317 & 0.0258 & 0.0232 \\ 0.0016 & 0.0104 & 0.0046 & 0.0107 & 0.0092 & 0.0032 & 0.0131 & 0.0093 & 0.0081 \\ 0.0199 & 0.0050 & 0.0049 & 0.0107 & 0.0104 & 0.0161 & 0.0304 & 0.0119 & 0.0135 \\ 0.0190 & 0.0173 & 0.0167 & 0.0189 & 0.0202 & 0.0195 & 0.0245 & 0.0201 & 0.0205 \end{pmatrix}$$

DRs		DR1	DR3	DR5	DR11	DR13	DR14	DR4	DR 16	Weight
DR1	SMS	1.00	2.00	7.00	7.00	7.00	5.00	9.00	8.00	0.3760
DR3	ITA	0.50	1.00	3.00	3.00	4.00	4.00	7.00	4.00	0.2030
DR5	PRM	0.14	0.33	1.00	5.00	4.00	4.00	4.00	6.00	0.1537
DR11	ITI	0.14	0.33	0.20	1.00	2.00	3.00	3.00	3.00	0.0821
DR13	IVN	0.14	0.25	0.25	0.50	1.00	2.00	2.00	7.00	0.0742
DR14	ICS	0.20	0.25	0.25	0.33	0.50	1.00	2.00	3.00	0.0518
DR16	DFM	0.11	0.14	0.25	0.33	0.50	0.50	1.00	2.00	0.0329
DR4	QLS	0.13	0.25	0.17	0.33	0.14	0.33	0.50	1.00	0.0265

Table 8. The inner dependence matrix of DRs with respect to quality standards

Table 9.
The inner dependence matrix of the DRs

DRs		DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9	DR10	DR11	DR12	DR13	DR14	DR15	DR 16
DR1	SMS	0.014	0.454	0.258	0.376	0.336	0.355	0.000	0.308	0.294	0.000	0.265	0.312	0.242	0.306	0.000	0.257
DR2	OTS	0.267	0.030	0.000	0.000	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.207
DR3	ITA	0.212	0.000	0.015	0.203	0.155	0.000	0.340	0.262	0.216	0.398	0.182	0.196	0.187	0.259	0.344	0.150
DR4	QLS	0.145	0.232	0.189	0.026	0.122	0.170	0.210	0.158	0.000	0.296	0.130	0.141	0.146	0.000	0.000	0.090
DR5	PRM	0.091	0.182	0.138	0.154	0.019	0.000	0.000	0.108	0.142	0.160	0.070	0.113	0.094	0.127	0.000	0.076
DR6	RAD	0.056	0.000	0.000	0.000	0.082	0.018	0.154	0.000	0.000	0.000	0.000	0.072	0.082	0.000	0.207	0.054
DR7	KLM	0.000	0.000	0.101	0.000	0.000	0.153	0.018	0.064	0.139	0.077	0.060	0.058	0.059	0.000	0.156	0.044
DR8	SMC	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.069	0.000	0.039	0.000	0.050	0.094	0.000	0.000
DR9	EIM	0.041	0.000	0.064	0.000	0.058	0.000	0.000	0.000	0.018	0.000	0.032	0.037	0.039	0.080	0.000	0.034
DR10	AUD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.000	0.030	0.000	0.106	0.000
DR11	ITI	0.026	0.000	0.051	0.082	0.039	0.124	0.100	0.044	0.044	0.000	0.064	0.000	0.022	0.075	0.000	0.024
DR12	DDI	0.000	0.000	0.042	0.000	0.031	0.077	0.076	0.000	0.032	0.000	0.025	0.018	0.020	0.000	0.070	0.018
DR13	IVN	0.020	0.000	0.033	0.074	0.000	0.051	0.042	0.036	0.025	0.000	0.018	0.000	0.012	0.032	0.064	0.018
DR14	ICS	0.000	0.000	0.018	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.016	0.027	0.000	0.000
DR15	DBA	0.000	0.066	0.000	0.000	0.000	0.029	0.037	0.000	0.000	0.030	0.000	0.033	0.014	0.000	0.026	0.014
DR 16	DFM	0.015	0.036	0.016	0.033	0.022	0.023	0.023	0.000	0.020	0.000	0.015	0.022	0.011	0.000	0.028	0.013

4.10 Step 9: Finding out the overall priority of DRs

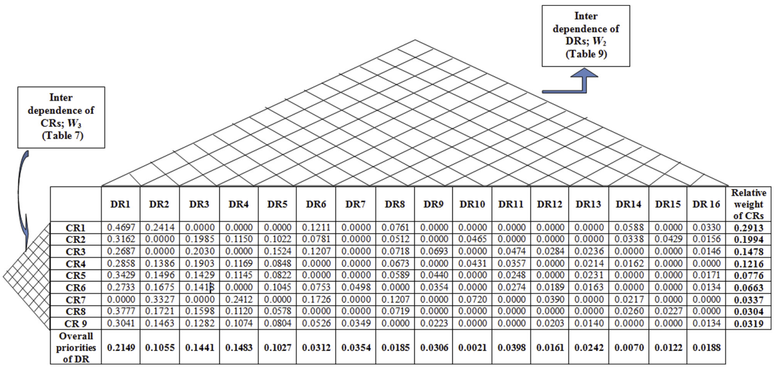
The overall priorities of the DRs (W_{ANP}), reflecting the interrelationships within the HOQ, are obtained by multiplying W_A and W_C.

$$W_{\text{ANP}} = \begin{pmatrix} 0.2149 \\ 0.1055 \\ 0.1441 \\ 0.1483 \\ 0.1027 \\ 0.0312 \\ 0.0354 \\ 0.0185 \\ 0.0306 \\ 0.0021 \\ 0.0398 \\ 0.0161 \\ 0.0242 \\ 0.0070 \\ 0.0122 \\ 0.0188 \end{pmatrix} = \begin{pmatrix} \text{DR1} & \text{SMS} \\ \text{DR2} & \text{OTS} \\ \text{DR3} & \text{ITA} \\ \text{DR4} & \text{QLS} \\ \text{DR5} & \text{PRM} \\ \text{DR6} & \text{RAD} \\ \text{DR7} & \text{KLM} \\ \text{DR8} & \text{SMC} \\ \text{DR9} & \text{EIM} \\ \text{DR10} & \text{AUD} \\ \text{DR11} & \text{ITI} \\ \text{DR12} & \text{DDI} \\ \text{DR13} & \text{IVN} \\ \text{DR14} & \text{ICS} \\ \text{DR15} & \text{DBA} \\ \text{DR16} & \text{DFM} \end{pmatrix}$$

The results from the ANP indicates that the most significant DR is simplification and standardization with a relative importance value of 0.2149 followed by quality standards and IT automation with a relative importance of 0.1483 and 0.1441, respectively. The HOQ thus obtained from the steps outlined above is illustrated in Figure 4.

5. Results and discussions

In this research, we have tried to identify CRs and DRs and its prioritization for integrating SC in an electronic industry. The ICT tools help in effective SCI resulting in cost optimization and effective communication among the SC partners. For the case electronics company, simplification and standardization (DR1 SMS) has the strongest relationship with a relative importance value of 0.2149 compared to other DRs. Hence the company should give prime importance to simplification and standardization while integrating SC using ICT tools. While simplifying and standardizing the processes, role and processes of each SC partner is to be



	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9	DR10	DR11	DR12	DR13	DR14	DR15	DR 16	Relative weight of CRs
CR1	0.4697	0.2414	0.0000	0.0000	0.0000	0.1211	0.0000	0.0761	0.0000	0.0000	0.0000	0.0000	0.0000	0.0588	0.0000	0.0330	**0.2913**
CR2	0.3162	0.0000	0.1985	0.1150	0.1022	0.0781	0.0000	0.0512	0.0000	0.0465	0.0000	0.0000	0.0000	0.0338	0.0429	0.0156	**0.1994**
CR3	0.2687	0.0000	0.2030	0.0000	0.1524	0.1207	0.0000	0.0718	0.0693	0.0000	0.0474	0.0284	0.0236	0.0000	0.0000	0.0146	**0.1478**
CR4	0.2858	0.1386	0.1903	0.1169	0.0848	0.0000	0.0000	0.0673	0.0000	0.0431	0.0357	0.0000	0.0214	0.0162	0.0000	0.0000	**0.1216**
CR5	0.3429	0.1496	0.1429	0.1145	0.0822	0.0000	0.0000	0.0589	0.0440	0.0000	0.0248	0.0000	0.0231	0.0000	0.0000	0.0171	**0.0776**
CR6	0.2733	0.1675	0.1418	0.0000	0.1045	0.0753	0.0498	0.0000	0.0354	0.0000	0.0274	0.0189	0.0163	0.0000	0.0000	0.0134	**0.0663**
CR7	0.0000	0.3327	0.0000	0.2412	0.0000	0.1726	0.0000	0.1207	0.0000	0.0720	0.0000	0.0390	0.0000	0.0217	0.0000	0.0000	**0.0337**
CR8	0.3777	0.1721	0.1598	0.1120	0.0578	0.0000	0.0000	0.0719	0.0000	0.0000	0.0000	0.0000	0.0000	0.0260	0.0227	0.0000	**0.0304**
CR 9	0.3041	0.1463	0.1282	0.1074	0.0804	0.0526	0.0349	0.0000	0.0223	0.0000	0.0000	0.0203	0.0140	0.0000	0.0000	0.0134	**0.0319**
Overall priorities of DR	**0.2149**	**0.1055**	**0.1441**	**0.1483**	**0.1027**	**0.0312**	**0.0354**	**0.0185**	**0.0306**	**0.0021**	**0.0398**	**0.0161**	**0.0242**	**0.0070**	**0.0122**	**0.0188**	

Figure 4.
House of Quality for case electronics company

assessed logically and planning should be done accordingly. Imparting simplification and standardization of process in the entire process of SC will bring in revolutionary changes (Sanchez-Rodrıguez *et al.*, 2006; Stajniak and Kolinski, 2016). It helps in constant improvement of SC process through effective integration that can lead to higher efficiency.

Quality standards (DR4 QLS) are having a relative importance of 0.1483. Electronics industry is highly competitive and following quality standards is a major order qualifier attribute. Adhering to stringent quality standards could lead to production of better products and services satisfying customer needs and value. Literature reveals that providing quality products which meet the standards is one of the most important DRs to be considered for maintaining proper supplier–customer relationship (Sharma *et al.*, 2012). Likewise, quality standards in the area of after sales services should also be given due significance by the case company.

IT automation (DR3 ITA) is the next prominent DR with a relative importance of 0.1441. A centralized, distributed or agent-based methodology automating the processes should be deployed by the case company on priority basis. Internet can be used as a medium for automation and collaboration among partners in SC (Kothari *et al.*, 2018). IT automation could result in robustness and efficiency by exchange of information across SC for its effective planning and integration.

Outsourcing (DR2 OTS) of the internal activities of the firm is also of prime importance to the case company with a relative score of 0.1055. In order to concentrate on their core business areas, many companies in the recent years have adopted to outsourcing practices and electronics industry is no exception. The case company should take a decision on outsourcing based on the cost involved and available in-house facilities for manufacturing. Outsourcing can be opted to reduce the need for internal flexibility (Tsay *et al.*, 2018; Pankowska, 2019).

Process Management (DR5 PRM) has come out with relative significance of 0.1027. It indicates that the case company should ideally streamline the entire processes. Efforts in this direction would enhance customer value in all fronts including cost (Lockamy *et al.*, 2004). Effective tools for process management should be used for measuring performance and controlling the activities. IT integration (DR11 ITI) is another DR with a relative significance of 0.0398 which is to be considered to enhance SC performance. The necessity of access to real-time information in an electronics industry is evident and IT integration will enhance the agility and flexibility of the organization and SC partners (Samadi and Kassou, 2016; Pachayappan, 2018). Knowledge Management (DR7 KLM) with a score of 0.0354 includes acquisition of knowledge, integration, protection, innovation and dissemination (Perez-Salazar *et al.*, 2013). The SC can be designed based on the knowledge gathered resulting in better performance. Research and Development (DR6 RAD) is a competitive tool for development of innovative products and services (Jordan, 2014), which is having a score of 0.0312. Effective R&D across the SC activities of electronics industry helps in gaining competitive advantage. E-intermediation (DR9 EIM) is having a relative significance of 0.0306, involves the integration of communication, computing and control in the electronics industry (Mostafa *et al.*, 2019). This strategy could help the case company in connecting to the outer world.

Intelligent Value Chain Networks (DR13 IVN), helps in sharing of information among the partners in the industry and SC (Hanifan *et al.*, 2014), has got score of 0.0242 in the study. Electronic SC being very robust and dynamic, intelligent value chain networks can support in meeting customer expectations which is one of the top priorities of SC. Design for Manufacturing (DR16 DFM) is having relative significance score of 0.0188. Great significance need to be given for consideration of design aspects while proceeding with digitalization of SC (Roscoe *et al.*, 2019). Smart Contracts (DR8 SMC), 0.0185 helps in communicating among the partners on real-time basis (Hu *et al.*, 2019). The smart contracts methodology adopted in the electronics industry helps in assessing the situations on time and executing actions on the basis of the information gathered to plan manufacturing and other related activities in SC process. Gunasekaran *et al.* (2018) have found that blockchain technologies help in capturing data in real time thereby enhancing SC agility.

Data-Driven Innovation (DR12 DDI); 0.0161 can allow case company to focus on data-driven decision-making based on the real-time data availability (Spanaki *et al.*, 2018). Innovation through effective data management helps in creating better value by providing products and services that matches the customer expectation. Data and Business Analytics (DR15 DBA); 0.0122 assists in obtaining real-time information quickly for proper decision-making. Data and business analytics has the potential to outperform and transform traditional SCM practices by providing better insights for improving processes, operational efficiency, cost reduction and quick decision-making in the electronics SC (Roy, 2018). Proper data and business analytics helps in enhancing the business process by analyzing the information related to various processes obtained from the SC partners.

Gunasekaran *et al.* (2018) highlighted the role of big data and business analytics in agile manufacturing. They have found out that big data and business analytics plays a crucial role in the agility of an organization. They have also highlighted the relevance of big data and business analytics and its application along with IoTs, Industry 4.0 and blockchain technologies.

ICT Security (DR14 ICS) having a relative significance value of 0.0070 reveals the need for securing information which are transmitted by the company across the SC. ICT security helps in reducing the risk of loss of data, misuse, fraud and tampering of data (Ulhaq *et al.*, 2016). The company has to concentrate more on providing enough security while transmitting and receiving the information to receive the trust of their partners. Auditability (DR10 AUD) has come out with the least relative significant value of 0.0021 in this study. It reveals limitations of the company with respect to getting the processes audited. Auditing is helpful in checking whether the set standards and procedures are followed and any deviation is involved (Daghfous and Zoubi, 2017). The case company should make efforts for auditing as it would enable them to take corrective actions through well planned and systematic approach in achieving their targeted objectives.

The methodology adopted can be considered by the practicing managers for integration of SC through digitalization. It helps the managers in effective decision-making for integration process. The CRs and DRs specific to the concerned industry can be identified and applied for effective integration. Further, for effective management of the process, the DRs could also be classified into strategic, tactical and operational factors based on the requirements of the company and the industry.

6. Conclusion

Digitalization of SC has gained immense relevance due to the advancement in digital technologies. This study has proposed an integrated ANP–QFD model for prioritization CRs and DRs for integration of SC through digitalization. The finding of this study provides insights on various attributes that contributes to the process of SCD. The firms should give due significance to the CRs and DRs as per the prioritization in order to enhance SCP. It is also expected that the model will serve as an important tool in digitalization of SC enabling the organization to become more dynamic and competitive. The model developed can also be adjusted suitably to add more requirements specific to the industry for effective decision-making.

In order to prioritize CRs and DRs for SCD, a case evaluation in an electronic manufacturing firm is conducted. The CRs and DRs relevant to digitalization process were identified and shortlisted based on literature review and in consultation with experts from industry and academia. The interdependencies among CRs and DRs were also analyzed. The overall prioritization of the CRs and DRs were identified in a phased manner using ANP–QFD methodology. The proposed model has aimed at bridging the existing gap in literature in digitalization process by identifying the major CRs and DRs which are to be considered in the process of SCD. The study also analyzed and prioritized the extent of interrelationship among the requirements. A HOQ is also constructed for effective decision-making in the process of digitalization.

The study has shown how a systematic analysis can be done for identifying the interdependencies among various CRs and DRs. The model developed in the study provides a rational and reliable solution which can be applied in any organization which is proceeding with the process of digitalization, by suitably modifying the CRs and DRs specific to the industry.

6.1 Managerial and theoretical implications

In order to gain competitive advantage and to survive in the market, digitalization of SC has become a necessity. The adoption of advanced digital technologies will revolutionize the SC process and its management. The companies should consider the changed scenarios and have a strong vision to adopt digitalization for better performance. This study attempts to bring better insights to the process of SCI through digitalization that has both managerial and theoretical implications. It provides insight to theoretical relationships among CRs and DRs that are to be considered for SCD.

The CRs and DRs identified in the study helps in proper planning of digitalization process and identifying solutions for successful integration. The managers can infer which DR is to be given due importance and how the process of SCD can be achieved effectively. The model helps to understand the relationship among CRs and DRs. It also helps managers to understand the extent of dependence and influence among each CRs and DRs. By using the framework given in this study, SC managers can finalize policies and procedures to be adopted for SCD process. The digitalization policy and procedure to be followed can be initiated by giving due significance for the CRs and DRs identified. The attributes identified in this research are quite generic and with suitable modifications could be applied to other industries as well.

6.2 Limitations of the study

The study involving pair-wise comparison among the attributes is a time-consuming task. The results obtained in this study are based on opinion of experts for case company and thus depends upon expert's familiarity with the company and its industry. Also, the bias of experts to some of the criteria might have influenced the results. We have tried to minimize this limitation by verifying the consistency ratio as suggested by Saaty (2004). The attributes identified in this research are quite generic and with suitable modifications could be applied to other industries as well.

6.3 Future scope of the study

Future research could be done by conducting a similar study in a different industry using same CRs and DRs or with suitable modifications and results could be compared. Combinations of MCDM methodologies can also be used and results could be verified. A different ranking method such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) can be used to prioritizing the CRs and DRs. The priority weights obtained from different methods can also be compared. The tool can also be used by researchers for conducting a broader level of analysis of the CRs and DRs in another firm or industry.

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Appendix

AHP	Analytic hierarchy process
ANP	Analytical network process
BDPA	Business data and predictive analysis
CR	Customer requirement
DR	Design requirement
DSC	Digital supply chain
e-SCM	Electronic supply chain management
HOQ	House of Quality
ICT	Information and communication technology
IT	Information technology
OP	Organizational performance
QFD	Quality function deployment
SC	Supply chain
SCD	Supply chain digitalization
SCI	Supply chain integration
SCM	Supply chain management
SCP	Supply chain performance
VoC	Voice of the customer

Table A1. List of acronyms used in the study

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