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Abstract - Technological advancement is re-defining supply chains (SCs) processes and soon traditional ways of managing SCs will no more be feasible and effective. Due to recent advancement in technology, digitalization has become an emerging topic among decision-makers and researchers. To cope-up with this emerging trend in customer behavior and remain competitive, organizations must move from their traditional ways of managing their SCs to digital supply chains (DSCs) for improved organizational performance. Therefore, the purpose of this paper is in two folds: First, to identify critical factors of DSCs that are essential for transitioning traditional SCs to DSCs to improve organizational performance. Second, interpretive structural modeling (ISM) is used to establish the relationship among critical factors and MICMAC (Matriced' Impacts Croise's Multiplication Applique'e a'un Classement) used to identify the driving and dependency power of the critical factors. Thus, this study identified fifteen DSC critical factors and established their direct and indirect effect on DSCs. The results show that "*SC resilience*", and "*proactive prevention*" have the highest dependency power factors whilst "*integration*" and "*advanced operational models*" have the highest driving power factors. This study can help SC managers and decision-makers to understand the critical factors essential in adopting DSCs for improving organizational performance.

Keywords: Digital supply chain; ISM; MICMAC; critical factors; driving power; inter-dependencies, improve organization performance.

1.0 Introduction

Due to the rapid advancement in technology such as artificial intelligence, machine learning etc., it is unpredictable for many SC professionals to know how SCs will be transforming moving forward [1, 2]. Organizations must think out of the box and digitalize their SCs to remain highly competitive and improve organizational performance. Technological advancement allows and makes it easier for decision

makers to collect, analyze, store, and utilize data in a more efficiently [3, 4] for enhancing organizational performance. Digitalizing SCs processes, upgrading of information systems at foundation level etc. [1] must be considered during SCs design and at each level of SC decision. Digitalization and advancement in technology can be seen in every aspect of our lives [5]. In addition to that, several organizations have already incorporated advanced technology in their business operations such as artificial intelligence (AI), internet of things (IoT), robots, virtual reality (VR) and augmented reality (AR), and drones (see: [6, 7, 8, 9, 10, 11]).

Organizations have now realized that in addition to their core business operations, digitalizing their processes can help in fulfilling customer expectations. Incorporating digitalization in the SC helps in adding value to the business operations. Advancement in technology has now totally changed the way of customer thinking and organizations are forced to change their way of doing business especially within supply chain operations [12]. According to [13], more than 70% of the world's population is now using the internet and around half of them have access to social media. Customers are now more familiar than ever with the technology and its usage and they need real-time information about their product or service. This shows that adopting digitalization in business processes has the potential to increase market share and offer benefits [14].

Several studies have shown the importance of supply chain digitization for various organizations, a study by Accenture for pharmaceutical manufacturing organization showed that supply chain digitization would help save \$387 million for them. Another study by McKinsey showed that organizations that go ahead with implementing and adopting supply chain digitization technologies can expect at least 2.3% of their annual revenue growth. Other estimated benefits for supply chain digitization reported are 70% reduction in lost sales, 30% reduction in transportation and warehousing costs, 70-80% reduction in supply chain admin costs and 70% reduction in inventories [15, 16]. These studies show the importance of supply chain digitization for enhancing organizational performance. Other recent studies also signified the importance of

supply chain digitization, [17] researched and found out the importance of digitization for enhancing organizational performance. The study identified big data analytics and Industry 4.0 technologies as the most important enablers of supply chain digitization for enhancing organizational performance. [18] through a case study of pallet renting vendor showed that digitization technologies like IoT and blockchain help digitizing the supply chain and in turn enhancing the organizational performance. [19] Illustrated benefits of digitization on supply chain performance in their research. They found that digitization technologies help in optimizing supply chain management. The major benefits were found in logistics and production areas. [20] in their study found big data analytics as an emergent digitization technology for enhancing the performance of sustainable supply chain, thus not only signifying the importance of digitization for supply chain but also for sustainability within the supply chains.

The term digitization of the SCs is not new and has become an interesting topic among many researchers and practitioners over the last few years [21]. The main goal of DSCs is to deliver the product or service to the customer with improved quality, improved service, and with increased efficiency. This helps in savings in terms of cost, resources, and time. DSC is defined as *"intelligent, customer-centric, system integrated, globally-connected and data-driven mechanism that leverages new technologies to deliver valuable products and services that are more accessible and affordable"* [22, 23]. This shows that digitalization must be incorporated in every process and function of SC to improve organizational performance. It will also help organizations in achieving SC strategic fit and minimize implied demand uncertainty. Additionally, adopting digitalization in SC will help organizations to predict and offer opportunities to fulfil customer needs, helping in managing SC agility, reliability and efficiency to gain a competitive edge.

So far, not many organizations utilize digitalization in their businesses up to its potential and DSCs are in rapid change and on novel innovation path [24]. Many innovative technologies have been incorporated in different SC functions such as the utilization of big data in planning and execution of activities, sensor technology and

automated vehicles in manufacturing, warehousing and logistics. Transparency in SC functions is also an important aspect of digital SC, for example, customers need real time information about their orders. In recent times, customers want to see the online movement of their order, information such as where their order is currently is? How much more time is required for delivery, what is the exact time and date of their order delivery? etc.

Due to increasing customer demand and shorter product life cycle, modern SCs are increasingly becoming more complex [25, 26, 27]. Technological advancement is changing and re-defining SC processes and traditional ways of managing SCs are no more feasible and effective. Customer awareness, global competition, and technological advancement make today's SCs more complex. Complexity in SCs can be managed by efficient coordination among SC partners, on-time information sharing, and real time decision making. Therefore, organizations can manage their SCs digitally by adopting and incorporating digitalization for efficient, flexible, and responsive SC design. In order to do this, organizations need to be aware of the factors that are essential for aiding the transitioning of the traditional SCs towards digital SCs. Moreover, the relationship among those factors must be known for the appropriate SC design. Thus, the objective of this paper is to:

- Identify the critical factors (CFs) that are essential for transforming traditional SCs to DSCs.
- Categorize and analyze the CFs based on their dependencies and driving power.
- Develop structural relationship hierarchy for CFs.

This study will contribute to the literature in several dimensions. First, it will highlight the positive impact of digitalization on organization performance by exploring the relationship between critical factors. Second, it unveils the drivers of digitalization by identifying critical factors affecting successful implementation and transformation of traditional SC to DSC. Lastly, the findings of this study will provide

managers and decision-makers a road map on how organizational performance can be improved by adopting and digitalization in their way of doing business.

The remainder of this study is as follows: first, we review the existing literature to highlight the importance of DSCs and ISM and MICMAC applications in different sectors in section 2, and then we identify and validate the CSFs of DSC through literature survey and panel of experts in section 3. The proposed methodology is discussed, and the steps of the methods are briefly explained in Section 4. In Section 5, a case study of XYZ industry is then used to examine the CFs of DSC. Discussion and analyses of the results, practical implications of the study are presented in Section 6. Finally, section 7 presents the conclusion and highlights future research direction.

2.0 Literature Review

This section will provide an overview and importance of DSC in the context of the study. Some application of the ISM and MICMAC method in the literature are then discussed. Finally, the research gap and contributions are discussed.

2.1 Digital Supply Chain and its Importance

The dynamism of the digital supply chain is increasingly taking a center stage in the business world. The process of satisfying customers' demands through the effective tracking and delivery of products and services have created visibility in supply chains [28]. Adoption of digital technology and electronic commerce as a business operation model and the use of digital supply chain have yielded positive results in organizational performance [29]. Data availability and data exchange offered by the internet has made it possible for organizations to have effective and efficient coordination and collaboration between their SCs. Technology and digital supply chain have made it possible for the exchange of goods, services and information among suppliers, consumers and other stakeholders. Digital supply chain is crucial because it has contributed to the advancement of business operations. It is important to note that DSC is one of the strategic elements that help in the performance improvements of SCs in this competitive global environment. It must suffice to say that DSC not only concerns technological change, but rather crucial in the performance metrics of

organizations, structure, policies, and the operational processes within the supply chain [29].

2.2 Overview of the application of ISM and MICMAC

Prof. Warfield in 1974 introduced ISM since then many researchers in several contexts have applied it effectively. For instance, [30] applied ISM to identify and analyze barriers to green lean implementation. In another study, [31] applied ISM to identify the driving power of different sources of risk in medical device improvement. Similarly, [32] applied ISM to aid in identifying the dominant barriers that hinder sustainability adoption in the food industry of an emerging economy, India. [33] applied ISM to identify the relationship between barriers to LSS product development. [34] in their study, applied ISM to evaluate the barriers to healthcare waste management system in the Indian context. [35] used ISM to aid in identifying the barriers to third part logistic strategy implementation. This literature overview shows that, over the last few years, ISM has seen considerable application in several sectors ranging from product development to sustainability, healthcare waste management and perishable industry.

However, the integration of ISM with that of fuzzy MICMAC analysis has also seen heavy presence in several areas of research. [36] used an integrated ISM and fuzzy MICMAC analysis in determining the enablers of a manufacturing company for building trust. Similarly, [37] studied variables of Indian manufacturing sectors flexible manufacturing system dimensions and competitiveness [38] using the ISM – fuzzy MICMAC technique. In another study, [39] identified and analyzed barriers to solar energy implementation in an emerging economy context, Indian by applying joint ISM and fuzzy MICMAC. [40] studied different variables of just in time and lean technique using ISM –fuzzy MICMAC. [41] studied ports project risk management using ISM – fuzzy MICMAC whereas [42] investigated enablers of manufacturing system which is agile by applying ISM –fuzzy MICMAC.

2.3 Research Roundup and Contribution

New technologies have started influencing the way companies manage their SC [24]. However, DSC is still at its development stage. Organizations have started incorporating digitalization into some of their SC functions. However, the adoption of digital technologies into SC is still at an early stage. To transform traditional SCs into DSCs, there must be a clear road map for managers and decision-makers, and they should be aware of the essential factors to DSCs transformation. Literature is lacking in this aspect and not many studies can be found that study the relationship of DSC CFs that are essential. Moreover, the cluster of critical DSC factors depends on their dependency power and interrelationship is not studied in detailed. Therefore, this study will fill this gap and be a stepping-stone in DSC literature.

3.0 Identification and Validation of Critical Factors of Digital Supply Chain

3.1 Research Design and Experts Selection

For developing a hierarchal structural model of DSC CFs, an extensive literature review was conducted. The keywords used for search are "digital supply chain", "critical factors", "real time supply chain", "digitalization", "and technology advancement", "digital supply chain characteristics", and their different combination. There was no time period specified for the search. Through the literature search, eighteen DSC CFs were identified. Experts' team from academics and industry were formed. Seventeen experts participated in the validation process. Four professors (assistant, associate, and full) from operations and supply chain department, five supply chain managers, one procurement director, two supply and distribution executive, two information technology manager, and three assistant manager warehousing. Experts were selected using the expert sampling technique; a non-probability sampling technique. This technique is a sub-case of purposive sampling in which the researcher relies on his expertise to select the sampling unit. It involves the consolidation of a sample of individuals with some definitive experience and expertise in a particular field. The first step in expert sampling is defined by the criteria of the expert. For the purpose of this study, we define experts as the individual working in the supply chain and familiar with

the digitalization and new technology, involved in performance evaluation and improvement or related departments. Various studies (e.g. [43, 44] followed this approach.

3.2 Validation Process

At the start of the validation process, the purpose and objective of the research were explained to all the experts and all responses were recorded during the one-to-one interview. All of the selected experts are competent based on their knowledge in operations and SC management, operations planning, SC design, technology management, ISM, and directly or indirectly involved in strategic, tactical, and operational level decision-making. All participating experts (professional and academics) have minimum of seven years of experience in the same or different organizations or academic institutions. All the professional experts were from different automotive manufacturing sector such as seat manufacturers, sheet metal component manufacturer, injection moulding parts manufacturer, radiator and muffler manufacturer, and two-wheeler automotive original equipment manufacturer (OEM's) from an emerging economy, Pakistan.

We selected these experts based on a combination of purposive and self-selection. In the purposive sampling, we focused on experts who are knowledgeable and have some experience in our subject of investigation. Since we needed managers who will show much commitment and trustworthiness in the study, we contacted these knowledgeable group of decision makers and decided to allow them to make their own decision to either participate or otherwise (self-selection) in the study as a way of reaffirming their commitment to the study and of course such commitment leads to trustworthiness. We also thought of generalizing our study's findings to the case country (and by extension to emerging and developing economies), hence we decided to cover managers across the two-wheeler sectors who had high interest in going global and committed to adopting digitalization in their supply chain, specifically to improve their overall organizational performance and connect to the global supply chain network. Due to the combination of purposive and self-selection approaches

and the coverage of these managers, we are confident that their reviews and other evaluation are reliable.

The shortlisted DSC CFs and its description are summarized in Table I below.

Table I: Critical Factors of Digital Supply Chain Management
Compiled from [24]

DSC Critical Factor	Description	Reference
On Time Visibility (CF1)	Secure, real time, and accurate information about order, process, system across the entire SC	[13, 45, 46, 47, 48]
Collaboration (CF2)	Capabilities are resources are utilized within and beyond physical boundaries of all SC functions	[46, 47, 48]
Suppliers Configuration (CF3)	Aligning the interest of all SC functions to improve performance and trust development	[46, 49, 50, 51]
Integration (CF4)	Integration of SC functions to improve visibility across the entire functions	[49, 50, 51]
Information Sharing (CF5)	Ease of information sharing related to demand forecast etc.	[13, 46, 47, 49, 50, 51]
Advanced Operational Models (CF6)	Flexibility in product and service functions to meet customers' changing demands	[48, 50, 52]
Adoption of innovative analytics tools (CF7)	Advanced data analytic tools such as big data, IoT, gives better demand forecast and solve unknown problem across SC	[48, 49, 50]
Automation in operation execution (CF8)	Human-machine interactions increase all SC functions operational efficiency	[46, 48, 50, 51, 53, 54, 55]
Innovation in SC Operations (CF9)	Digital SCs stimulate and assist innovations across all SC functions	[13, 48, 49, 50, 51]
Efficiency Maximization (CF10)	Efficiently utilization of people, processes and technology across all SC functions	[50, 54]
Flexibility in SC Operations (CF11)	Capabilities related to digitalization, information, and data driven decision making to re-configure SC operations	[13, 50, 53]
Customization (CF12)	Customized products and services delivery through Channel-centric supply networks support	[48, 49, 50, 51, 52, 56]

Responsiveness in SC Operations (CF13)	Effective and efficient information sharing among all SC functions improves overall SC responsiveness	[13, 46, 48, 49, 50, 51, 52]
Proactive prevention (CF14)	Data driven decision support systems can strengthen adaptability and reliability and predict disruptions	[48, 49, 50, 52]
SC Resilience (CF15)	SC is able to ensure that the supplies are aligned with evolving demands	[48, 49, 50, 52]

4.0 Research Methodology

In order to achieve the objectives, set out in section 1, and to identify and categorize the relationship among DSC CFs, we used a systematic research approach illustrated in figure 1 below.

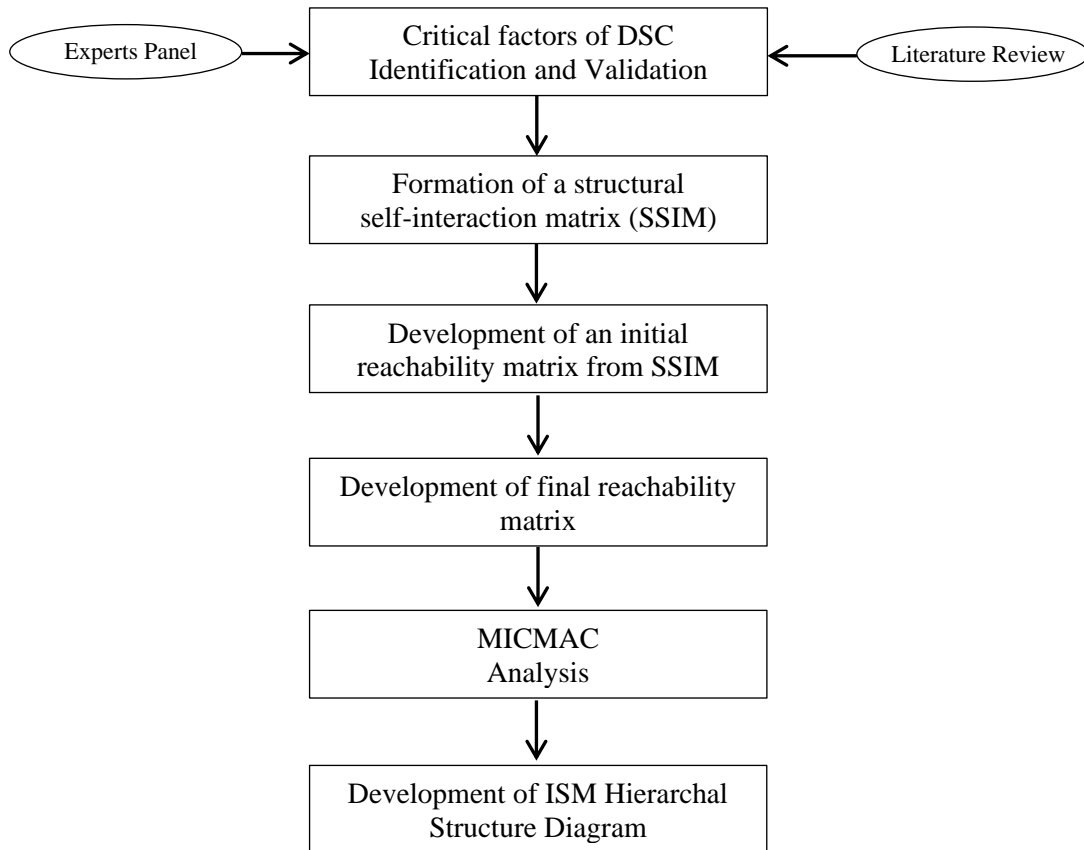


Figure 1: Research Methodology

4.1 Interpretive Structural Modeling (ISM)

Our research methodology is based on ISM, which was developed and introduced by Prof. Warfield in 1974 [57] and MICMAC technique. He studied the relationship

between different factors of socio-economic systems [57]. ISM is a well-known methodology to identify the interactions among factors and their influence on the overall goal [58]. ISM uses expert's opinion in establishing the interrelationship among unstructured variables [59]. ISM is helping in finding the relationship of different factors in an entire process [60] and based on their relationships (mutual) and structures complicated factors [61]. ISM is known for decomposing complex problem into a much simpler form by building different sub-level structural models [62]. It helps in establishing relationship among the factors and by utilizing factors based on its dependency and driving power [60, 63, 64, 65].

The reason behind using ISM is motivated by the fact that ISM is a well-established technique to solve complex decision-making problems and helps in identifying relationships among factors [57, 66]. It is also evident that ISM helps in transforming an un-defined and un-clear problem into a well-defined and well-structured model by establishing the interrelationships among variables [67, 68]. The reason for adopting the ISM-MICMAC method is that the ISM and fuzzy MICMAC method is used in identifying the interrelationships of numerous SCKFEs and their driving power and dependences. ISM also provides the appropriate explanation to problems by creating a systematic hierarchical structure of variables from the top to the lowest level [69]. Several techniques such as DEMATEL, VIKOR, AHP, and ANP are available to rank and prioritize the parameter but in most cases, these techniques fail to deliver systematic hierarchical structure needed for the parameter. This is because several quality initiatives in the industries require systematic structuring of the parameter to achieve unique quality strategy [70].

ISM is a well-recognized method for classifying relationships among specific items which outline problems or issues [57]. As a well-established methodology, the ISM-MICMAC has been used by many researchers including [71] in their article assessing contributory factors in potential systemic accidents using AcciMap and integrated fuzzy ISM - MICMAC approach.[72] used this method in his work titled "A framework for Crosby's quality principles using ISM and MICMAC approaches".

Another research that adopted this method was [73] in the study entitled, "Impediments to Social Sustainability Adoption in the Supply Chain: An ISM and MICMAC Analysis in Indian Manufacturing Industries". The ISM has some standard steps [57] which are as follows [74]:

- a) **Development of a structural self-interaction matrix (SSIM):** This step will help in analyzing contextual relationships between identified CFs that are essential for transforming from traditional SCs to DSC.
- b) **Formation of the initial reachability matrix from SSIM:** In this step, transitivity is checked, and final reachability matrix has been formed.
- c) **Development of the final reachability matrix:** In this step, construction of partition of various levels of identified CFs that are essential for transforming from traditional SCs to DSC.
- d) **Diagraph formation:** This step will remove all the transitivity links and develop the diagraph.
- e) **ISM model development:** This step will develop an ISM model from the developed digraph in step "d".
- f) **Conceptual consistency assessment:** In this step, assessment of conceptual consistency of the formed ISM model, will be checked and modification / adjustment will be made if required.

4.2 MICMAC

Michel Godet and François Bourse developed the MICMAC method [75] which is widely used to study the indirect relationship for classification in a structural perspective [76]. For example, consider three factors and their impact: factor A affects B, factor B affects C, A and C have no direct effect, but their relationship with B is a cross-correlation, where any change in A will affect C. This kind of relationship identification is also known as gray area exploration [37]. This is useful and widely used in combination of ISM because it explores the relationship of non-explored relationship during ISM which is the so-called gray area between 0 and 1 [75]. It also

helps in developing graph that arranges and classify criteria or variables based on their dependency and driving power [77].

5.0 Case Illustration

A case of two-wheeler sectors in an emerging economy, Pakistan has been selected for this study. The reason for selecting this sector is that Pakistan is among the top five largest motorcycle markets' in the world and only China, India, Indonesia and Vietnam are ahead. This sector is one of the largest manufacturing sectors with a total production of approximately one million a year. Pakistan motorcycle market manufactures 70cc & 125cc models. Currently, there are more than 40 motorcycle assemblers in the country assembling Japanese and Chinese motorcycle. The topmost brands are Honda, Suzuki, and Yamaha. Around 200 small, medium, and large vendors are supplying sub-assemblies to the assemblers. This sector is providing employment to more than 200,000 people directly and indirectly [78 719. Figure 2 below shows the growth of this sector over the last 10 fiscal year (FY).

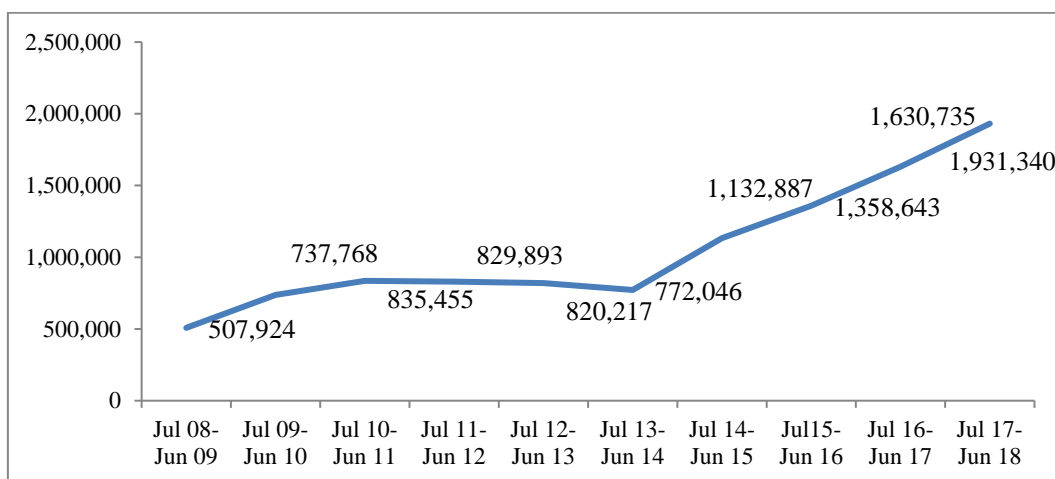


Figure 2: Sales volume of 2/3 wheelers in Pakistan 2008-2018

Source: [78, 79]

In order to increase sales volume and remain competitive globally, this sector needs to transform their traditional SC into DSC.

5.1 Developing the structural self- interaction matrix (SSIM)

In order to analyze the DSC CFs, the symbols below were used to identify and explore the relationship between selected DSC CFs (i and j) and develop the SSIM.

V = Criteria i will help achieve criteria j;

A = Criteria j will be achieved by criteria i;

X = Criteria i and j will help accomplish each other; and

O = Criteria i and j are unrelated.

The same experts who validated the identified DSC CFs were used to give the relationship'. All of the experts in most of the cases were agreed on the type of relationship that existing between the any two DSC CFs based after discussions. However, in five DSC CFs, they did not come to an agreement on choose one relationship. In order to solve this concern, final decision was made based on the highest occurrence assigned to V, A, X and of individual responses from the all seventeen experts. The responses in the form of SSIM are shown in table II below.

Table II: Structural Self- Interaction Matrix (SSIM)

DSC CFs (i,j)	CF 15	CF 14	CF 13	CF 12	CF 11	CF 10	CF 9	CF 8	CF 7	CF 6	CF 5	CF 4	CF 3	CF 2	CF 1
CF1	V	V	V	V	O	V	V	O	O	O	V	V	O	O	
CF2	V	V	V	V	V	O	O	O	O	A	V	V	O		
CF3	O	O	V	V	V	V	O	O	X	O	A	V			
CF4	V	V	V	O	V	V	V	V	A	V	V				
CF5	V	V	V	V	V	V	O	V	A	A					
CF6	V	V	V	V	V	V	O	O	V						
CF7	V	V	V	O	V	V	V	O							
CF8	V	O	V	V	V	V	O								
CF9	V	O	V	V	V	V									
CF10	O	V	O	O	V										
CF11	V	O	V	V											
CF12	O	O	O												
CF13	V	V													
CF14	V														
CF15															

5.2 Initial reachability matrix

Based on the pairwise relationship of the CFs in SSIM (see table II) is converted into initial reachability matrix by substituting "1" and "0". The transformation of SSIM table to reachability matrix is done by the following rules explained in table III below.

Table III: Transformational rule

If the (i,j)th element of SSIM is	Corresponding substitution in the initial matrix	
	(i,j)	(j,i)
V	1	0
A	0	1
X	1	1
O	0	0

Source: [80]

The initial reachability matrix after incorporating the rules mentioned above is shown in table IV.

Table IV: Initial Reachability Matrix

DSC CFs (i,j)	CF 1	CF 2	CF 3	CF 4	CF 5	CF 6	CF 7	CF 8	CF 9	CF 10	CF 11	CF 12	CF 13	CF 14	CF 15
CF1	1	0	0	1	1	0	0	0	1	1	0	1	1	1	1
CF2	0	1	0	1	1	0	0	0	0	0	1	1	1	1	1
CF3	0	0	1	1	0	0	1	0	0	1	1	1	1	0	0
CF4	0	0	0	1	1	1	0	1	1	1	1	0	1	1	1
CF5	0	0	1	0	1	0	0	1	0	1	1	1	1	1	1
CF6	0	1	0	0	1	1	1	0	0	1	1	1	1	1	1
CF7	0	0	1	1	1	0	1	0	1	1	1	0	1	1	1
CF8	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1
CF9	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1
CF10	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
CF11	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
CF12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CF13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
CF14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
CF15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

5.3 Final Reachability Matrix after Incorporating Transitivity

One of the essential assumptions of ISM technique is transitivity check. It can be explained that if critical factor "a" is related to critical factor "b" and critical factor "b" is related to critical factor "c", then critical factor "a" will necessarily be related to critical factor "c". Once transitivity check has been done, new entries in final reachability matrix is marked with "1*" and shown in table V below.

Table V: Final Reachability Matrix (After Incorporating Transitivity)

DSC CFs (i,j)	CF 1	CF 2	CF 3	CF 4	CF 5	CF 6	CF 7	CF 8	CF 9	CF 10	CF 11	CF 12	CF 13	CF 14	CF 15	Driving Power	Rank
CF1	1	0	1*	1	1	1*	0	1*	1	1	1*	1	1	1	1	13	II
CF2	0	1	1*	1	1	1*	0	1*	1*	1*	1	1	1	1	1	13	II
CF3	0	0	1	1	1	1*	1	1*	1*	1	1	1	1	1*	1*	13	II
CF4	0	1*	1*	1	1	1	1*	1	1	1	1	1*	1	1	1	14	I
CF5	0	0	1	1*	1	0	1*	1	0	1	1	1	1	1	1	11	III
CF6	0	1	1*	1*	1	1	1	1*	1*	1	1	1	1	1	1	14	I
CF7	0	0	1	1	1	1*	1	1*	1	1	1	1*	1	1	1	13	II
CF8	0	0	0	0	0	0	0	1	0	1	1	1	1	1*	1	7	IV
CF9	0	0	0	0	0	0	0	0	1	1	1	1	1	1*	1	7	IV
CF10	0	0	0	0	0	0	0	0	0	1	1	1*	1*	1	1*	6	V
CF11	0	0	0	0	0	0	0	0	0	0	1	1	1	1*	1	5	VI
CF12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	IX
CF13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	VII
CF14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	VIII
CF15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	IX
Dependence Power	1	3	7	7	7	6	5	8	7	10	11	12	12	13	14	123/123	
Rank	XI	X	VII	VII	VII	VIII	IX	VI	VII	V	IV	III	III	II	I		

1*: Entries are included to incorporate transitivity

5.4 Level Partition and Development of ISM Based Hierarchical Structure

Once we get the final reachability matrix (table IV), we will find the antecedent and reachability set of identified CFs will be deduced. The antecedent set consists of the DSC CFs itself and the other DSC CFs, which can help in achieving it. Similarly, the reachability set consists of the DSC CFs itself and other CFs that can help in achieving digitalization in SC. We have derived the intersections of all critical DSC factors. The top level of ISM hierarchy, which is shown in figure 3, compiled and mentioned all the DSC CFs with the same reachability and intersection sets. Here it is important to mention that not all the DSC CFs in ISM hierarchy at the top level would help any other

critical DSC factors above its level. These DSC CFs are identified at top level, it is separated out from the remaining DSC CFs. We will repeat the same process at the next level and level after to find out the other critical DSC factors. This process of level partitions is continued until we will find out the level of each critical DSC factors [81]. Result of level partitioning (after eight iterations) is showing in table VI below. The identified levels (see table VI) help in building the ISM based hierarchal model.

Table VI: Level Partitions Results (Iteration 1 to Iteration 9)

Codes	Reachability set	Antecedent set	Intersection set	Rank
CF1	(1,3,4,5,6,8,9,10,11,12,13,14,15)	1	1	IX
CF2	(2,3,4,5,6,8,9,10,11,12,13,14,15)	(2,4,6)	(2,4,6)	VIII
CF3	(3,4,5,6,7,8,9,10,11,12,13,14,15)	(1,2,3,4,5,6,7)	(3,4,5,6,7)	VII
CF4	(2,3,4,5,6,7,8,9,10,11,12,13,14,15)	(1,2,3,4,5,6,7)	(2,3,4,5,6,7)	VII
CF5	(2,3,4,7,8,10,11,12,13,14,15)	(1,2,3,4,5,6,7)	(2,3,4,7)	VII
CF6	(2,3,4,5,6,7,8,9,10,11,12,13,14,15)	(1,2,3,4,6,7)	(2,3,4,6,7)	VIII
CF7	(3,4,5,6,7,8,9,10,11,12,13,14,15)	(3,4,5,6,7)	(3,4,5,6,7)	VII
CF8	(8,10,11,12,13,14,15)	(1,2,3,4,5,6,7,8)	8	VI
CF9	(9, 10,11,12,13,14,15)	(1,2,3,4,6,7,9)	9	VI
CF10	(10,11,12,13,14,15)	(1,2,3,4,5,6,7,8,9,10)	10	V
CF11	(11,12,13,14,15)	(1,2,3,4,5,6,7,8,9,10,11)	11	IV
CF12	12	(1,2,3,4,5,6,7,8,9,10,11,12)	12	I
CF13	(13,14,15)	(1,2,3,4,5,6,7,8,9,10,11,13)	13	III
CF14	(14,15)	(1,2,3,4,5,6,7,8,9,10,11,13,14)	14	II
CF15	15	(1,2,3,4,5,6,7,8,9,10,11,13,14,15)	15	I

Based on the above level partition, figure 3 shows the ISM hierarchal structure below.

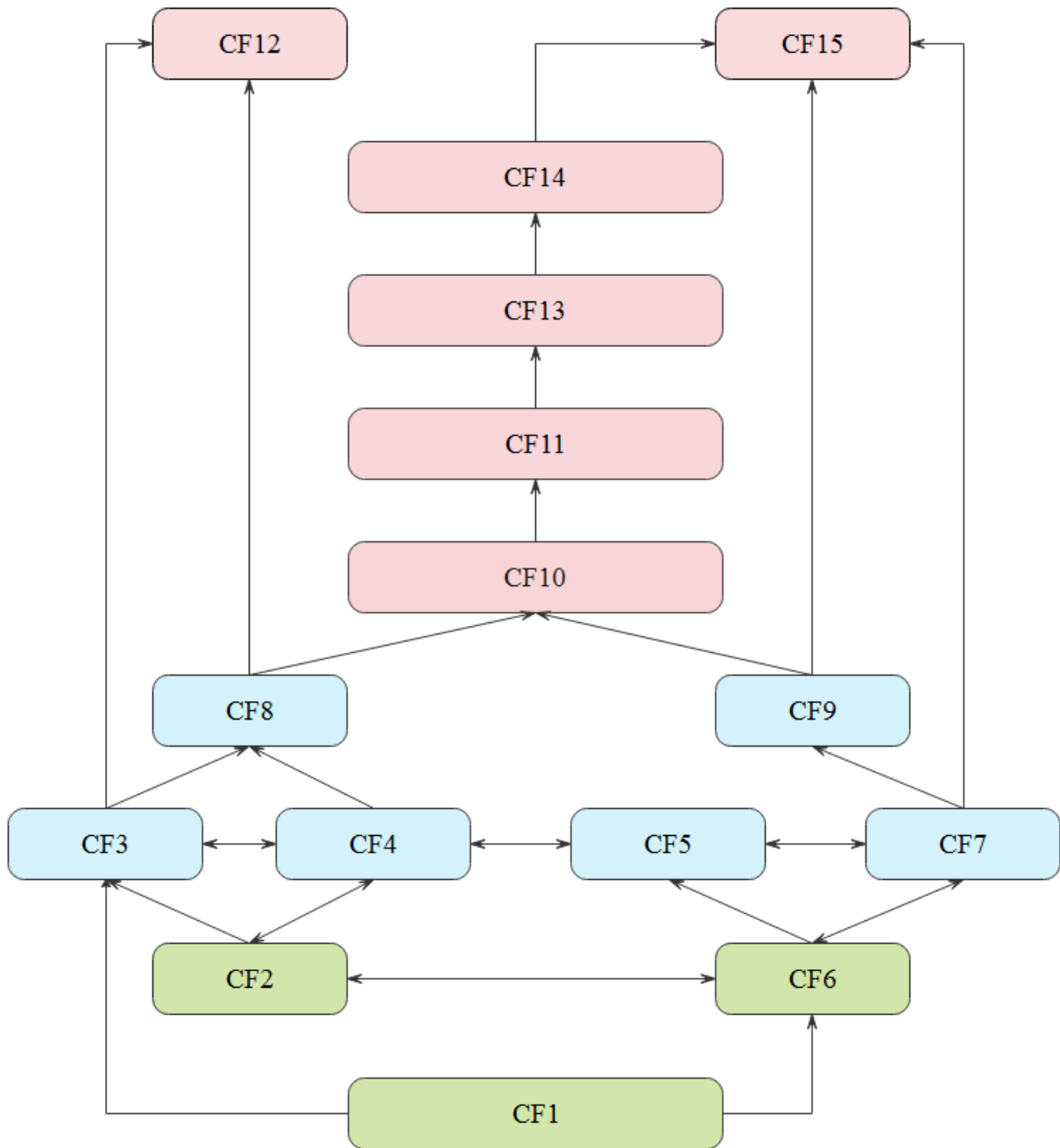


Figure 3: ISM Based Hierarchical Structure for DSC CFs

5.5 MICMAC Analysis: CSFs Classification based upon Driving and Dependence power

The Matrice d'Impacts Croisés Multiplication Appliqués à un Classement (MICMAC) approach is widely used to analyze and explain factors based on their influential power and dependency and depends on driving and dependency power [82]. In order to do the validation of ISM of identified critical DSC factors, MICMAC analysis has also been performed. To categorize identified critical DSC factors, driving and dependence

power of each critical DSC factors helps us in doing it. The influential power and their dependency power and their ranks are calculated and can be found in table V. Based on these ranks, four clusters will be formed which are "autonomous", "dependent", "linkage", and "driving" cluster. The factors with "weak influential power" and "weak dependency" will be placed in "autonomous" cluster. The factors that have "low influential power" and "high dependency" will be placed in "dependent" cluster. Similarly, factors having "significant driving power" with many dependencies will be placed in "linkage" cluster, and in the "independent" cluster, factors possessing "high driving power" and "low dependency" will be placed. Figure 4 below shows the MICMAC matrix categorizing CFs.

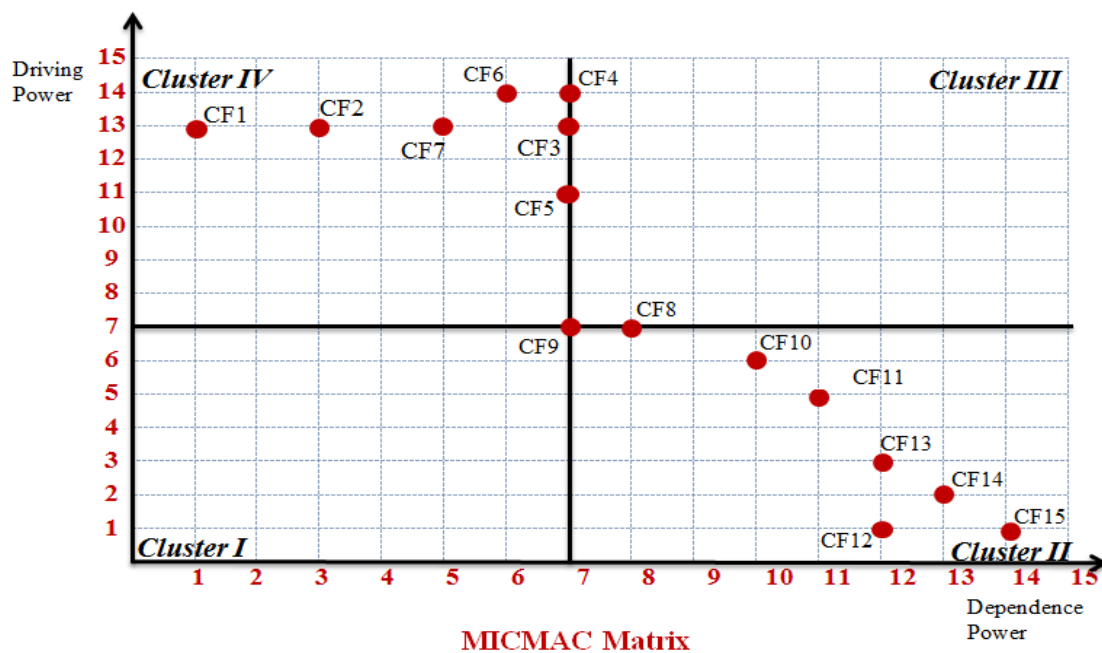


Figure 4: MICMAC Analysis

6.0 Discussion of Results

The major advantage of developing ISM digraph and categorizing DSC factors in terms of different levels is to represent the CSFs and their interdependencies in terms of edges and nodes or to visually represent the CSFs and their interdependence [83]. The results of the study can be found in Figures 3 and 4. The top-level factors in this study are On Time Visibility (C1), Collaboration (C2), Supplier Configuration (CF3),

Information Sharing (CF5), Advanced Operational Models (C6), and Adoption of Innovative Analytics Tools (CF7). These factors are those factors that do not lead to the other factors and have the highest driving power and lowest dependency power. Similarly, CFs, Efficiency Maximization (CF10), Flexibility in SC Operations (CF11), Responsiveness in SC Operations (CF13), and Proactive Prevention (CF14) are highest dependent factors and not driving many other factors. This finding confirms that flexibility in SC operation, responsiveness, and proactive maintenance are significantly dependent on other aspects such as top management commitment, training etc.

In this study, the objective of MICMAC analysis is to cluster all the fifteen DSC CFs into different groups based on their driving power and dependence power. Based on this analysis, the present study classifies the DSC CFs into four clusters as shown in figure 4. MICMAC analysis suggests that CFs, Innovation in SC Operations (CF9) is classified as autonomous factors in cluster I. This CFs is disconnected from other CFs; however, they have few links, which may be strong. The reason these factors are autonomous may be that automation in operation execution and innovation in SC operations have already started in several organizations and that they just must build on it to gain the maximum benefit [84, 85]. Cluster II consists of dependent CFs, which have strong dependency power and weak driving power. CFs that are in this cluster are, Efficiency Maximization (CF10), Flexibility in SC Operations (CF11), Customization (CF12), Responsiveness in SC Operations (CF13), Proactive prevention (CF14), and SC Resilience (CF15). These CFs must be considered important because these factors are strongly depending on other CFs and these factors are needed to achieve digitalization in SC. The reason for these factors being dependent on others is that these factors need input from other factors to contribute to the overall goal effectively. For example, flexibility in SC operations requires integrated efforts from other operational functions to achieve overall flexibility [85, 86]. Similarly, to have resilient SC, all functions of SC must be aligned and coordinated effectively and efficiently [87]. The findings of this study confirm that, by having SC resilience factor as one of the dependent factors, plays a vital role in achieving overall resilience in SCs.

Cluster III is linkage cluster, which clusters CFs that have strong driving and dependency power. In this study, Integration (C4) and Automation in operation execution (CF8) CFs are classified as linkage factors. This result may be that to transform traditional SC to DSC completely, integration and automation in operations critical factor must contribute individually by either being dependent, independent or provide a link to other factors [88, 89]. The last cluster, cluster IV consists of factors that have strong driving power and weak dependency power and classified as an independent cluster. In this study, CFs such as On Time Visibility (CF1), Collaboration (CF2), Suppliers Configuration, (CF3), Information Sharing (CF5), Advanced Operational Models (CF6), and Adoption of innovative analytics tools (CF7) are classified as independent factors. These factors are independent and influence all other factors significantly. These factors are considered as significant inhibitors in transforming traditional SC to DSC. These factors have strong potential to drive other factors in transforming traditional SC to DSC. For example, factors such as information sharing, collaboration, and advanced operational models have the potential to influence other factors as they are independent and have strong driving power. If organizations and decision- makers make appropriate strategy for these factors, they will be able to achieve digital transformation effectively and efficiently. If a considered sector wanted to transform traditional SC into DSC, they must consider these CFs on a priority basis.

The findings from our study show that Integration (CF4) has the strongest driving power and it is essential for organizations to adopt an integrated approach when seeking to transform their traditional SC into DSC. This is because Integration of SC functions is essential to improve visibility across the entire functions [23]. Similarly, SC Resilience (CF15) has the highest dependency power, as it can ensure that the supplies are aligned with evolving demands and capture uncertainty. The finding of our study is in line with [49, 50, 51] who argued that organization must pay more attention to SC integration and SC resilience to efficiently transform their traditional SC into DSC. These factors may be strengthened by enhancing visibility across SC functions,

increasing collaboration among different SC functions, and developing trust among SC partners [17, 90].

6.1 Theoretical/Literature, Managerial / Practical and Country/Industry Implications

In this study, ISM and MICMAC analysis has been carried out to suggest how the identified DSC CFs can be implemented in transforming traditional SC into DSC. This study contributes to the theory and practices on the transformation of traditional supply chains into digital supply chains by identifying CSFs of DSC adoption and their inter-relationships.

From a theoretical point of view, the DSC CSFs identified, and their relationships established, are limited in literature and are not comprehensively explored. This paper pursued this goal and contributes to the DSC CSFs literature/theory in this direction and emphasizes the idea that organizations must use these factors to help them in transforming their tradition SC into DSC. The conceptualization of the DSC framework further enhances the theoretical foundation necessary for aiding evaluation and monitoring of the automobile digital supply chain performance [91]. This new typological framework and its constructs can serve as a theoretical framework for broader investigations for a more complete evaluation of digitalization within organizational supply chain management literature. ISM analysis identified the relationship among DSC CSFs depicted by the digraph exhibiting the factors at different levels. Similarly, MICMAC analysis shows the categorization of the factors in terms of autonomous, linkage, dependent, and independent clusters. Due to unavoidable pressure from different stakeholders to adopt digitalization in managing SCs, there is a need to categorize the transformation factors (from traditional to digital) to identify which factors organizations must focus initially and which they can delay. This simultaneous consideration of the relationships and categorization of the factors can help organizations effectively and efficiently manage their DSC CSF and make more relevant decisions [92]. Therefore, this study is a stepping-stone and contributes to the DSC theory.

Managerially, it is quite common that mostly management focuses on a few CFs to which they think are essential without considering the effect of other CFs. These ignored relationships might be particularly important and have a significant impact on overall implementation. For example, if factor “x” is positively or negatively connected/related to a set of factors, it is very important for managers to pay much more attention to factor “x’s” connections as changes in factor “x” will cause changes to the other factors. Therefore, this relationship should be considered very important in decision-making. Our proposed ISM – MICMAC based model in this work which takes into consideration this relationship suggests to managers and decision-makers what factors they need to consider initially and those factors they may delay during implementation along with their effect on overall DSC adoption. Moreover, this study will facilitate managers and decision-makers to understand the identified CFs and their interdependencies. This study will also be helpful for SC managers and decision-makers in moving forward the adoption of DSC. To remain competitive organizations must transition from the traditional ways of managing SC into digital SC and that this study will be helpful to them to identify which factors are essential to start with when pursuing this goal and how these factors impact on other factors [24]. Thus, the study’s results provide the SC managers, decision-makers and analysts internal or external to the automobile industry with some useful insights, guidelines and clues for making a more strategic decision towards the DSC adoption [93].

The study also offers some implications to the case country and industry. Pakistan automotive industry needs to adopt digitalization in managing their SC. This research work will assist Pakistan automotive industry to prepare to build the necessary capabilities and competencies for the successful transformation of their traditional SC to DSC. The CFs with high driving power and low dependence power mainly require top management attention as these factors are more at the strategic level. Similarly, CFs with high dependence power and low driving power mostly need operational managers attention as these factors mostly depend on performance and result orientation of operational factors. Managers and decision-makers do have some

insights from this study which can help them achieve digitalization by managing their SC focusing more on independent CFs.

Overall, it is essential to note that digitization enables SCs and managers to be able to have visibility in their operations as well as making them effective and efficient. The supply chain managers can access critical information remotely. For instance, inventory reports can be run and accessed with logistics and shipment data processed and accessed using ERP systems. One crucial element of DSC is that it enables supply chain managers to interface their system with their suppliers and customers. The system of vendor managed inventory has made it possible for managers and suppliers to monitor, manage and coordinate stock level and subsequent replenishments without necessary having human presence/interferences.

7.0 Conclusion and Future Research Work

Due to globalization and advancement in technology that is rapidly transforming traditional SC into DSC, organizations need to find efficient and effective ways of achieving this transformation. With the advancement in the use of sensors and tracking system, customers' want real-time track of their product or service throughout the entire SC process. Organizations must therefore adopt the end-to-end communication across their SC. The objective of this study was to identify the DSC CFs that are essential for transforming traditional SC into DSC. The ISM – MICMAC methodology has been used in this study. An expert panel constructed the SSIM matrix of identified DSC CFs and established the contextual relationships among the critical using pairwise comparison. This study summarizes the CFs that are essential for adopting DSC in Pakistan automotive industry.

This study identified fifteen CFs from literature and validated them by a panel of experts' consisting of professionals from academics and industry. Further, we calculated their dependency and driving power using ISM and categorized them in five different levels. CFs such as suppliers' configuration (CF3), adoption of innovative analytics tools (CF7), customization (CF12), and SC resilience (CF15) occupied first few levels in ISM based hierarchal structure and on time visibility (CF1) placed at the

bottom of the hierarchy. This is very surprising as a key goal and foundation to digitalization is visibility and of course 'on time visibility'. Therefore, placing 'on time visibility' at the bottom of the hierarchy may mean that, the industry might have already started with this initiative and that, they may need other initiatives to complement and enable its implementation to achieve the full benefits. This view is supported by a recent study conducted by [17] that also found that transparency and visibility are usually matured initiatives even before digitalization agenda are initiated. It may also mean that the industry should focus more on the lower hierarchy and less mature factors such as 'on time visibility', which are yet to be fully implemented, as initiatives such as 'suppliers' configuration' may have been fully developed already, hence, the reason for it been ranked at the top hierarchy.

In addition to that, MICMAC analysis was carried out to categorize identified DSC CFs. Our study shows that CFs such as customization (CF12), proactive prevention (CF14), and SC resilience (CF15) have the highest dependency power and low driving powers. Similarly, CFs such as advanced operational models (CF6) have the highest driving power. This means that managers and decision-makers' need to pay more attention to these set of CFs to enable them to achieve digitalization in their SC. Moreover, these factors if implemented correctly will help them in making their SC strategies more efficient and effective.

The result of this study is subject to few limitations, which provides an opportunity for future research: The limitation of ISM-MICMAC method may have an impact on the result such that the individual's knowledge and skill with the specific industry may impact the relationship among the variables; there is no weight allotted to the variables by ISM; and there is no bias done by the individual judging. It is apparent that the future of the MICMAC method can be overcome through the development of an integrated approach. As a future research direction, a careful adoption of SWOT analysis needs to be done by qualifying the supply chain knowledge flow enablers SCKFEs and their interrelationships. There must be the analytical hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) method among

the various industries. Again, through a questionnaire-based survey that focuses on a specific sector, statistical validation of this model could be utilized. To test the validity of the recommended model, structural equation modelling (SEM) or systems dynamics modelling (SDM) could be used [94].

Notwithstanding the above-mentioned limitations of this study, we do strongly believe that the proposed ISM – MICMAC based DSC CFs classifications and their partition levelling methodology is general and can be implemented in all sectors with no or slight modifications. Also, we do believe that this research is a stepping-stone in DSC specifically, and in the context of the emerging economy as it categorized the identified DSC CFs into four clusters and gives an understanding of the relationship among DSC CFs. This is indeed an advancement to the DSC literature and providing managerial insights for organizational and supply chain processes digital transformation.

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