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Supply chain mapping for improving "visilience": A hybrid multi-criteria decision making based methodology

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Abstract

Supply chain mapping is gaining heightened attention due to its vital role in improving supply chain visibility and resilience. Despite its crucial role in uplifting supply chain resilience, the critical elements of supply chain mapping are yet to be determined. The study adopts a twofold approach to identify and prioritize the dimensions and sub-dimensions of supply chain (SC) mapping. At the first stage, through an extensive review of literature, 43 sub-dimensions of SC mapping were identified. In the second stage, Gray - DEMATEL-based Analytic Network Process (GDANP) was employed by taking the input from 25 experts selected from Oil and Gas industry of an emerging market. The findings reveal three major dimensions of SC mapping followed by 15 sub-dimensions. Among the dimensions, upstream mapping contains the highest priority weights, followed by midstream and downstream mapping. The findings suggest a step-wise strategy to adopt SC mapping where upstream mapping should be given the first priority. The major contribution of this study is to develop a framework for measuring the extent of SC mapping of a firm using GDANP.

KEYWORDS

analytic network process, gray - DEMATEL-based analytic network process, gray-DEMATEL, process mapping, supply chain mapping

1 | INTRODUCTION

While organizations are striving to minimize the supply chain (SC) disruption occurred due to COVID19 (Alzarooni et al., 2022; Mubarik et al., 2021), they are also looking forward to bouncing back with resilient and sustainable supply chain strategies. It implies that businesses are bent to develop supply chain capabilities for minimizing the loss of any such disruption in future (Choi et al., 2020; Imran et al., 2022; Mubarik et al., 2021). Especially the focus of the organizations is on improving SC resilience—*characterized as SC readiness, response and recovery*—and SC visibility. This is the very reason that firms are increasingly looking forward toward any organizational capability(ies) and strategies that can help them improve resilience and visibility simultaneously.

Supply chain mapping appears as an essential organizational capability, which can play an instrumental role in supply chain visibility and resilience, combined termed as '*vislience*'. Primarily, SC mapping is an organization's ability to keep track of its upstream, downstream, and midstream processes through the latest digital technologies. Despite the importance of SC mapping, the scholarly work in this area is minimal. A handful of articles have been published on this topic, and the majority of which vaguely define as to what SC mapping is. Amid COID-19, Choi et al. (2020) strongly emphasized the need to look into SC mapping for fighting against the negative impacts of the pandemic and recommended SC mapping as a remedial action to cope with SC disruptions. Fabbe-Costes, Lechaptois, and Spring (2020, pp. 1–2) opine that, "companies, professors and consulting firms make various supply chain maps [SC mapping], but few studies question the role of these maps, their use or value for supply chain practitioners or how they might relate to the central concepts in SC mapping theory and practice."

Most importantly, studies have not addressed the question of measuring SC mapping. Unless SC mapping is measurable, it is difficult to examine its impacts on any performance indicator (Kusi-Sarpong et al., 2022; Melnyk et al., 2009; Piprani et al., 2022). Hence, it is essential to identify and prioritize the various dimensions and sub-dimensions of SC mapping. This leads us to set out the major objective of this study, that is,, to identify and prioritize dimensions and sub-dimensions of SC mapping and propose a framework for measuring it. The proposed framework could be used for analyzing the levels of SC mapping in a firm. Likewise, it can also be used to develop the construct of SC mapping for operationalizing it in any research framework.

In this case, multi-criteria decision making (MCDM) approaches appear to be the most suitable options to systematically evaluate and select the dimensions and sub-dimensions of SC mapping based upon workable criteria (See: Ayağ & Samanlioglu, 2016; Dweiri & Khan, 2012; Khan et al., 2019; Khan et al., 2020; Khan et al., 2022). Generally, a multi-criteria data management approach is applied to convert the subjective judgment into a quantifiable solution (Ou Yang et al., 2013). Numerous studies (e.g., Lin, 2013; Hsu., et al., 2013; Tsai et al., 2015; Mubarik et al., 2018) have applied MCDM based techniques like AHP, ANP, DEMATEL, and DEMATEL-ANP (D-ANP), and so forth; however, these methods bear certain limitations. Starting from AHP, this method's major limitation is the assumption of independence of criteria and sub-criteria, which may not be practical in many situations (Saaty, 1980). This limitation is well tackled by Analytical Network Process (ANP), which allows interdependence and feedback among criteria and alternatives (Saaty, 1996). However, one serious issue with ANP is consistent pairwise comparisons, particularly for a matrix with higher order. This issue arises due to the limitations in human cognition and cumbersomeness in the traditionally used one-to-nine scale (Hu & Tsai, 2006; Xu & Wei, 1999). Furthermore, both DEMATEL and the DEMATEL-ANP (D-ANP) require producing a direct influence matrix entangled in pairwise comparisons. An additional issue with both of these methodologies is the higher the number of factors, the higher the degree to which a respondent would require to complete an initial direct influence matrix. As a result, the output's reliability and quality could be affected as the respondents could get bored or inattentive while responding the longer questionnaire. Hence, an MCDM technique is required that automatically produce the direct influence matrix for multiple criteria.

Gray relational analysis (GRA), combined with D-ANP, could be a viable option to comprehensively evaluate the extent of association between the criteria and sub-criteria (Deng 1989; Hu, 2016; Liu & Lin, 2006). This study adopts a GRA-DEMATEL-ANP (GDANP) technique by combining the GRA and DANP to solve the aforementioned issue. The key difference between GDANP and D-ANP is that the former deploys GRA for automatically generating the direct influence matrix from a Delphi questionnaire instead of getting it completed from respondents. Some of the gray-based decision-making models have been developed and used by scholars (e.g., Golmohammadi & Mellat-Parast, 2012; Li et al., 2007) using gray numbers. Likewise, some researchers (e.g., Govindan et al., 2015; Liang et al., 2016; Su et al., 2016) have proposed a few gray DEMATEL-based techniques using a particular gray number to define each component in the direct influence matrix. Further, Zhou et al. (2017) proposed D-DEMATEL by combining the theory of D numbers and DEMATEL. The proposed GDANP is unique from these methods in two ways. First, it applies the Gray relational analysis (GRA) to produce the direct influence matrix, then it syndicates ANP and DEMATEL to offer the final decision structure.

TABLE 1 List of keywords

S#	Keywords
1	Supply chain mapping
2	Value chain mapping
3	Upstream mapping
4	Downstream mapping
5	Midstream mapping
6	SC mapping
7	Business process mapping

The reminder of this study is as follows: first, we review the existing literature to discuss the definitions and dimensions of SC mapping in Section 2, then explain the adopted methodology based on the two-fold approach to identify and prioritize the dimensions and sub-dimensions of supply chain mapping in Section 3. In Section 4, the empirical findings will be discussed followed by discussion and analyses of the results in Section 5. Finally, Section 6 presents the conclusion, implications, limitations and highlights future research directions.

2 | LITERATURE REVIEW

Although supply chain maps, demonstrating material flows of the companies, could be found in the firms in early 30s, this concept formally evolved in the early 80s (Stevens, 1989). Hence, we explored the literature from 1980 to 2020 to find out the dimensions and sub-dimensions of the supply chain. Using the following keywords, we explored the articles on supply chain mapping from seven major publishers: Wiley, Elsevier, Sage, Springer, Taylor & Francis, and Emerald. By using the keywords, listed in the Table 1, initially, 298 research papers were found, which were review in two stages. In the first stage, 193 research papers were removed after reading the abstracts of the research papers. In the second stage, 32 research papers were removed after reading the introduction of the research papers, thus retaining a total of 73 documents for the review. Following are the list of keywords used and articles retained for review. Figure 1, developed

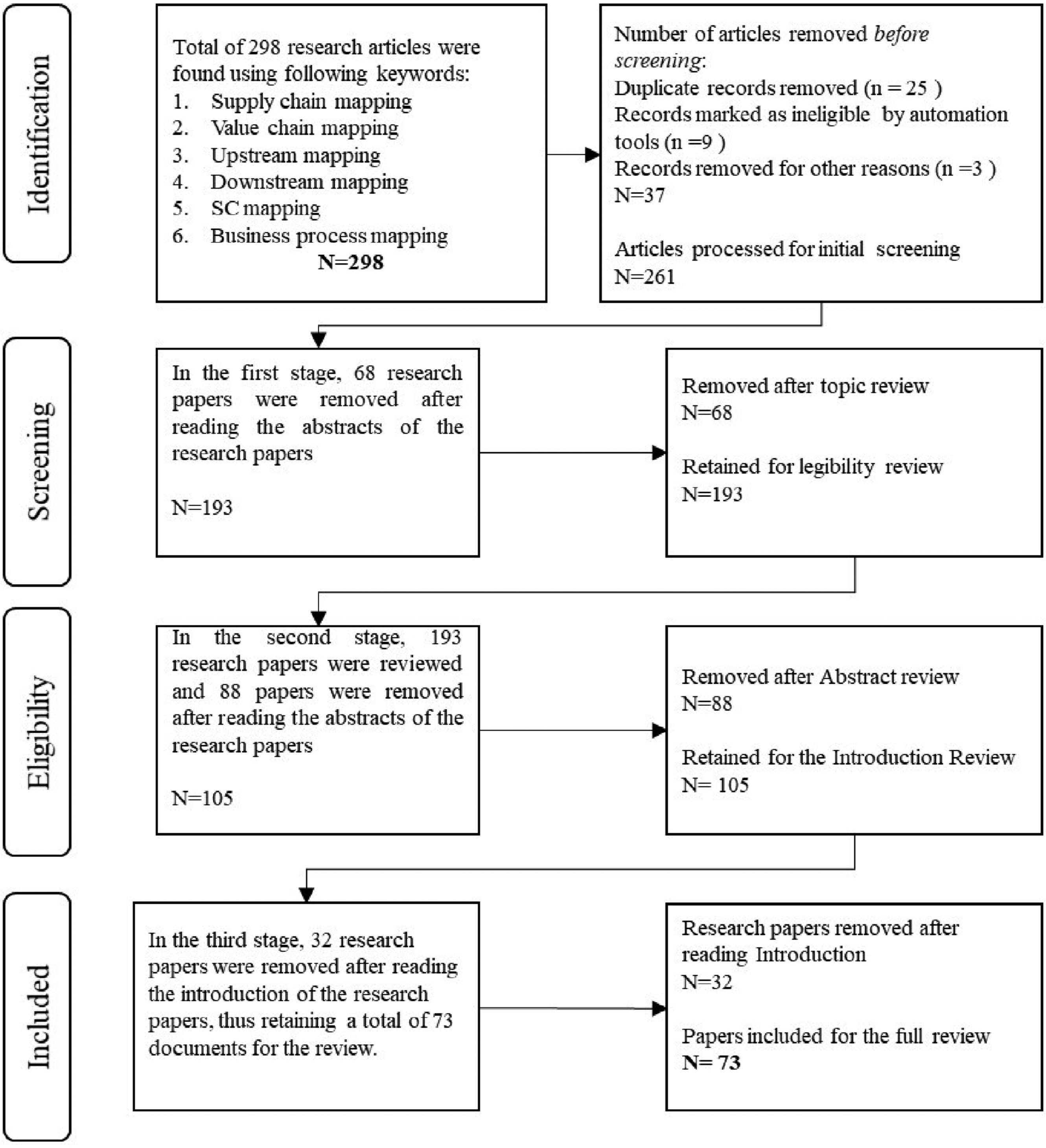

FIGURE 1 Process of literature identification.

using PRISMA template (page et al., 2021), exhibits the process of selecting the literature for review and identification of SC mapping's dimensions and sub-dimensions. Besides above, we kept the three inclusion criteria factors: *focus of the study*, *the population studied and the outcome measures used*. For the papers to be included in the review, it must have focused on supply chain mapping or any of its dimensions (focus of the study). Likewise, the papers must be focused on the for-profit sector, it implies that papers focusing upon humanitarian organizations supply chain would not have qualified for the review. Further, we kept two exclusion criteria factors: paper published before 1980s, and papers only focusing upon qualitative research design.

2.1 | SC mapping: Definitions and dimensions

The majority of the literature perceived SC map as a physical map, which simulates the real supply chain environment by simplifying the complex processes and relationships without losing the essence of the environment. For Fabbe-Costes, Lechaptois, and Spring, (2020, p. 2) "*As such, a supply chain map, like a geographical map, is supposed to represent the supply chain territory*". In other words, SC mapping is a macrographic illustration of the current state of SC.

SC mapping has been defined as linking of activities, actors, resources, and geography to ensure that the flow of products and information is visible across all three streams—*upstream*, *midstream*, and *downstream*—and SC networks are visible as a whole (e.g., Fabbe-Costes et al., 2020; Mubarik et al., 2021). Upstream SC represents the network of a firm's suppliers and supplier's suppliers. Midstream SC refers to all activities and processes which are performed within the company to convert the raw material to a value-added product. Whereas downstream SC refers to the coordination of the flow of information and goods with clients and customers.

This reveals three important views of SC mapping (i) the SCM view (Eriksson, 2003; Gardner & Cooper, 2003; Hines & Rich, 1997; Lambert et al., 2008), (ii) the network view (Geiger & Finch, 2010; Henneberg et al., 2006; Meyer et al., 2013) and (iii) the boundary objects view (Carlile, 2004; Henderson, 1991; Star, 2010; Star & Griesemer, 1989; Zeiss & Groenewegen, 2009). For Fabbe-Costes et al., (2020, p. 4), "*The concept of boundary objects was developed in science and technology studies but was subsequently adopted by organization scholars.*" The boundary object emphasizes on the utilization of objects for example, models, maps, graphical illustrators, or drawings that illustrate both inter-firm and intrafirm process flow, co-ordination and communication. Mubarak et al. (2021) argue that boundary objects could play an instrumental role in developing understating among group members from diverse backgrounds, responsibilities, and tasks. In condensed form, SC mapping from the boundary perspective is illustration of SC on model, map or drawing with the aim to improve the visualization of processes, co-ordination among stakeholders improved communications.

The supply chain view considers supply chain as "chain of various interconnected activities" and takes SC mapping as linear illustration of all activities and functions. According to Mubarak et al. (2021), "in the early 90s, SC mapping was expanded, and linear representation was extended and elaborated by the work of Mentcer et al. (2001)". However, a detailed view of SC mapping from the SC perspective was presented by Lambert et al. (1998). They take encapsulate all three dimensions of the SC, paving the way for value stream mapping (VSM) (Slack et al., 2016). Their overarching focus was on connecting and illustrating the resources, actors and activities through SC mapping. Farris (2010), extending the work of Lambert et al., (1998), included the illustration of geographical dispersions as important objective of SC mapping.

Building upon the object view and SC view, network view of SC mapping combines the literature from the field of supply chain, and industrial marketing. In doing so it represents more pragmatic explanation of SC mapping. According to network view scholars, "the inherent complexities of an actual SC can be best explained in term of an integrated network of firms connected to serve end consumer". According to Fabbe-costes et al. (2020), "acknowledging the great complexity of real SCs, many SC mapping researchers have also adopted the concept of the network rather than chain."

Since the objective of this study is to develop a construct to measure SC mapping, we adopt hybrid approach. In doing so, we define SC mapping as *"a diagrammatic stand-in of the actual SC environment demonstrating the flow of materials from upstream to midstream and downstream supply chains*." In the proceeding lines, we review the literature to identify the various dimensions and sub-dimensions of SC mapping.

2.2 | SC mapping dimensions

The dimensions of SC mapping can be identified by digging into its major objectives. The broader objective of SC mapping is to improve the visualization of interconnected organizations in SC networks (Melnyk et al., 2009; Saberi et al., 2019). Researchers argue that SC mapping helps to understand the upstream, and downstream supply chain dynamics (Wakolbinger & Cruz, 2011; Mubarik, Warsi & Niaz, 2012; Wichmann et al., 2020) and offers a comprehensive basis for analyzing the strengths and weaknesses of a supply chain (Choi et al., 2020). For Gardner and Cooper (2003, p. 39), "a well-constructed supply chain map with the right information, easily displayed and understood, should enhance the environmental scanning process of strategic planning." Extending their assertion, they argue that SC mapping allows a firm to effectively catalogue and distribute the critical information essential for surviving in a disruptive environment (Song et al., 2018). A well-mapped SC enables a firm to visualize all three streams of the SC (upstream, midstream, and downstream) and highlights the inefficiencies in the SC processes. In the upstream supply chain, timely identification of critical information about suppliers' and suppliers' supplier (tier-II suppliers), can significantly help to avoid any SC disruption. A SC map can also play an instrumental role in tracking the flow of material, components, and products in the SC, according to Farris (2010). Further, SC mapping provides a broad based framework enabling firm to look into the business processes beyond first tier suppliers and customers. SC mapping allows firms to zoom in and evaluate the business practices, processes and technologies of tier 2 suppliers and in some cases tier 3 and tier 4 suppliers. This visualization plays an instrumental role in identifying the hiccups, waste, and issues in the SC process. Likewise, it also helps to better prepare for any unforeseen supply chain disruptions.

Putting together, the prime objective of SC mapping is to permit a firm to visualize the flow of products, information, and finance both upstream and downstream. Hence any systematic strategy or action adopted by the firm to improve the visualization of business processes from upstream to downstream, enhance the flow of the product, information, and material across the chain, and help integrate the various entities involved in the SC, would be considered as part of SC mapping. Likewise, all the strategies and action taken to extend the

TABLE 2 Dimensions of SC mapping

S#	Indicators	Code	Source(s)
A. Upstream mapping (USM)			
1	Information about the supplier of critical components	ISC	Stevens (1989); Gardner and Cooper (2003); Bagdia and Pasek (2005); Farris (2010); Fearne et al. (2012); Faisal et al. (2006); Fabbe-Costes et al. (2020); Naghavi and Mubarik (2019); Mubarak and Naghavi (2019)
2	Information about the financial stability of suppliers	IFS	Gardner and Cooper (2003); Taylor (2005); Fearne et al. (2012); Faisal et al. (2006); Wichmann et al. (2018); Wichmann et al. (2020); Fabbe-Costes et al. (2020)
3	Visualization of upstream supply chain processes	VUS	Choi et al. (2001); Gardner and Cooper (2003); Bagdia and Pasek (2005); Farris (2010); Carvalho et al. (2012); Knoll et al. (2017); Wichmann et al. (2018); Fabbe-Costes et al. (2020)
4	Geographical representations of suppliers	GRS	Choi et al. (2001); Gardner and Cooper (2003); Singer and Donoso (2008); Farris (2010); Choi et al. (2020); Fearne et al. (2012); Wichmann et al. (2018); Anastasiadis et al. (2020)
5	Visualization of key information	VKI	Choi et al. (2020); Gardner and Cooper (2003); Bagdia and Pasek (2005); Nevo and Chan (2007); Mason et al. (2008); Farris (2010); Fearne et al. (2012); Omurca (2013); Fabbe-Costes et al. (2020)
7	Real time information sharing with suppliers	RTS	Choi et al. (2001); Gardner and Cooper (2003); Singer and Donoso (2008); Farris (2010); Fearne et al. (2012); Fabbe-Costes et al. (2020)
8	Real time information about the geographical locations of suppliers	RTG	Choi et al. (2020); Gardner and Cooper (2003); Mason et al. (2008); Farris (2010); Fearne et al. (2012); Faisal et al. (2006)
9	Have real time information of Supplier's supplier	RTS	Sarkis (2003); Bagdia and Pasek (2005); Carvalho et al. (2012); Farris (2010); Fearne et al. (2012); Rajesh and Ravi (2015); Rezaei et al., (2016); Roehrich et al., (2017); Choi et al. (2020)
10	Understanding of the tier 2 suppliers technology	USS	Choi et al. (2001); Gardner and Cooper (2003); Busse et al. (2017); Wichmann et al. (2018)
11	Visual documentation of the processes dealing with suppliers	VDP	Gardner and Cooper (2003); Bagdia and Pasek (2005); Barroso et al. (2011); Carvalho et al. (2012); Anastasiadis et al. (2020)
12	Real time visualization of the flow of material from key suppliers	RTM	Choi et al. (2020); Gardner and Cooper (2003); Singer and Donoso (2008); Busse et al. (2017); Anastasiadis et al. (2020)
13	Digitalized processes	DPS	Gardner and Cooper (2003); Mason et al. (2008); Singer and Donoso (2008); Farris (2010); Barroso et al. (2011); Anastasiadis et al. (2020)
14	Sharing of real time information with suppliers	SRT	Harland (1996); Mason et al. (2008); Farris (2010); Fearne et al. (2012); Anastasiadis et al. (2020)
15	Visualization of flow of materials across the value chain	VFC	Harland (1996); Mason et al. (2008); Singer and Donoso (2008); Farris (2010); Busse et al. (2017)
16	Visualization of material coming from tier 2 supplier to tier1 supplier	VMS	Choi et al. (2020); Mason et al. (2008); Farris (2010); Barroso et al. (2011); Busse et al. (2017); Fabbe-Costes et al. (2020)
B. Midstream mapping (MSM)			
1	Value stream mapping	VSM	Bagdia and Pasek (2005); Jones and Womack (2002); Barroso et al. (2011); Carvalho et al. (2012); Wichmann et al. (2018)
2	Tracking of the goods with the company	TGC	Gardner and Cooper (2003); Farris (2010); Barroso et al. (2011); Carvalho et al. (2012)
3	Real time sharing of information across the departments	RTD	Jones and Womack (2002); Gardner and Cooper (2003); Farris (2010); Barroso et al. (2011); Faisal et al. (2006); Anastasiadis et al. (2020)
4	Identification of process inefficiencies	IPI	Gardner and Cooper (2003); Bagdia and Pasek (2005); Carvalho et al. (2012); Faisal et al. (2006); Fabbe-Costes et al. (2020)
5	Visualization of the supply chain processes	VP	Bagdia and Pasek (2005); Singer and Donoso (2008); Farris (2010); Barroso et al. (2011); Busse et al. (2017)
6	Monitoring of supply chain strategy	MSS	Gardner and Cooper (2003); Singer and Donoso (2008); Farris (2010); Faisal et al. (2006); Wichmann et al. (2018)
7	Cataloguing and distribution of key information with the help of mapping	CKI	Gardner and Cooper (2003); Taylor (2005); Taylor (2009); Farris (2010); Carvalho et al. (2012); Fabbe-Costes et al. (2020)
8	SC alertness	SCA	Jones and Womack (2002); Gardner and Cooper (2003); Mason et al. (2008); Carvalho et al. (2012); Faisal et al. (2006)
9	Visualization of end-to-end supply chain	VEE	Gardner and Cooper (2003); Taylor (2005); Mason et al. (2008); Carvalho et al. (2012); Faisal et al. (2006)

(Continues)

TABLE 2 (Continued)

S#	Indicators	Code	Source(s)
10	Identification of areas of improvement through mapping	IAI	Harland (1996); Fine (1998); Jones and Womack (2002); Taylor (2005); Taylor (2009); Vachon (2010); Carvalho et al. (2012); Fabbe-Costes et al. (2020)
11	Mapping guides about quantum changes	MQC	Jones and Womack (2002); Gardner and Cooper (2003); Taylor (2009); Farris (2010); Fabbe-Costes et al. (2020)
12	Simplified representation of supply chain	SRS	Gardner and Cooper (2003); Taylor (2005); Singer and Donoso (2008); Farris (2010); Barroso et al. (2011); Hsuan and Parisi (2020)
13	Visualization of information, products and finances	VIP	Gardner and Cooper (2003); Bagdia and Pasek (2005); Mason et al. (2008); Taylor (2009); Barroso et al. (2011); Carvalho et al. (2012); Faisal et al. (2006); Anastasiadis et al. (2020)
C. Downstream Mapping (DSM)			
1	Real-time information about the customers network	RTI	Choi et al. (2001); Gardner and Cooper (2003); Farris (2010); Knoll et al. (2017)
2	System of obtaining real-time information from customers	SRT	Choi et al. (2020); Gardner and Cooper (2003); Barroso et al. (2011); Knoll et al. (2017)
3	Mapping flow of information from tier 1 supplier	FIS	Choi et al. (2020); Mason et al. (2008); Farris (2010); Wichmann et al. (2018)
4	Mapping flow of product from tier 1 supplier	FPS	Choi et al. (2020); Gardner and Cooper (2003); Barroso et al. (2011); Faisal et al. (2006)
5	Linkage with tier 2 customers	LSS	Choi et al. (2020); Gardner and Cooper (2003); Faisal et al. (2006)
6	Information sharing with tier 2 customers	ISC	Gardner and Cooper (2003); Taylor (2009); Farris (2010); Barroso et al. (2011); Faisal et al. (2006)
7	Can track the geographical dispersed tier 2 customers	TGD	Choi et al. (2020); Gardner and Cooper (2003); Fearne et al. (2012); Wichmann et al. (2018)
8	System of getting real-time information from customers	RTC	Choi et al. (2020); Gardner and Cooper (2003); Farris (2010); Barroso et al. (2011); Busse et al. (2017)
9	Sharing of information to customers	SIC	Gardner and Cooper (2003); Singer and Donoso (2008); Farris (2010); Barroso et al. (2011); Fearne et al. (2012); Knoll et al. (2017)
10	Visualization of flow of goods going out from company	VFG	Harland (1996); Gardner and Cooper (2003); Taylor (2009); Fearne et al. (2012); Busse et al. (2017); Fabbe-Costes et al. (2020)
11	Visualization of outbound logistics	VOL	Harland (1996); Gardner and Cooper (2003); Singer and Donoso (2008); Barroso et al. (2011); Knoll et al. (2017); Anastasiadis et al. (2020)

spatial supply chain visualization beyond first tier supplier and customers, enabling channel integration would also be considered as an essential part of SC mapping process. Such spatial visualization should offer real-time information of the products and services, their costs, lead time, and real-time flows, and so forth. Majority of scholars argue that SC mapping should be a simplified illustration of upstream, midstream, and downstream SC processes, relationships, and technologies and it must capture the essence of the environment in which the SC operates.

Based on the review of literature, proceeding Table 2 illustrates the three dimensions and sub-dimensions of SC mapping. These aspects can serve as the basis for developing a measure of SC mapping. However, it is important to identify the most relevant dimensions to keep the construct focuses and effective.

3 | METHODOLOGY

We have adopted a two-fold approach to identify and prioritize the dimensions and sub-dimensions supply chain mapping.

3.1 | Identification of the dimensions and sub-dimensions of SC mapping

This step consisted of two phases. In the first phase, we reviewed the literature from 1980 to 2020 for identifying the dimensions of a SC that denote the abstract construct of SC mapping. In this process, we identified 40 dimensions of SC mapping—16 upstream, 13 midstream, and 11 downstream as exhibited in Table 2. Since the nomenclatures are too long, each of the dimension and sub-dimension has been abbreviated as shown in column 2 of the Table 2. These acronyms have been used to represent the actual dimensions & sub-dimensions. After identifying the dimensions and sub-dimensions, we have employed Gray-DEMATEL-ANP for prioritizing the dimensions and sub-dimensions of SC mapping. Proceedings sections have been dedicated to explain the application of GDANP.

3.2 | Prioritization: GDANP

This study adopts a Gray-DEMATEL-ANP (GDANP) technique by combining the GRA and DANP for solving the abovementioned issue.

The Gray-DEMATEL-ANP (G-D-ANP) approach combines gray relational number, DEMATEL and ANP. In the conventional approach, direct influence matrix is generated directly from respondents whereas in GDANP, GRA is used to generate the direct influence matrix from a Delphi questionnaire. The key difference between GDANP and D-ANP is that the former deploys GRA for automatically generating the direct influence matrix from a Delphi questionnaire, instead of getting it completed from respondents. Some of the gray-based models of decision making have been developed and used by scholars (e.g., Golmohammadi & Mellat-Parast, 2012; Li et al., 2007) using gray numbers. Likewise, some researchers (e.g., Govindan et al., 2015; Liang et al., 2016; Su et al., 2016) have proposed a few gray DEMATEL-based techniques using particular gray number to define each component in the direct influence matrix. Further, Zhou et al. (2017) proposed D-DEMATEL by combining the theory of D numbers and DEMATEL. The proposed GDANP is unique from these methods in two ways. First, it applies the Gray relational analysis (GRA) to produce the direct influence matrix then it syndicates ANP and DEMATEL to offer the final decision structure.

3.2.1 | Delphi method

To determine outcome, this method primary depends upon the experience, perception, and judgment of the experts (Khan et al., 2021). The premise of this approach is consensus without confrontation (Mubarak et al., 2021).

For the model proposed in this study, we suppose that there are *v* (*v* ≥ 2) facets and every criterion factor is classified into a single facet. Further, factor *m* in facet *k* is characterized as $X_{km}(1 \le m \le d_k)$, and factor *j* in facet *r* is characterized as $X_{rj}(1 \le j \le d_r)$, here d_k and d_r symbolize the number of factors in facet *k* and *r*. *Further,* $d_1 + d_2 + d_3 + d_4 + \ldots + d_v = n$, and a_{kmx} characterize the need for factor X_{km} for inclusion in the research model as suggested by expert *e*. Table 3 exhibits the Delphi methods' decision matrix.

3.3 | DEMATEL based analytical network process

In order to deal with the issue of consistency, which traditional ANP faces, we integrated the DEMATEL with ANP as DEMATEL does not require any consistency test. According to Mubarak et al. (2021), "in DANP, DEMATEL's *total influence matrix* substitutes the ANP's *unweighted super matrix which* does not require pairwise comparison".

TABLE 3 Delphi outcomes (the general decision matrix)

		Expert				
Facet	**Criteria**	**Ex1**	**Ex2**	**Ex3**	**.....**	**Ex_e**
X_k	X_{k1}	a_{k11}	a_{k11}	a_{k13}	.....	X_{k1e}
	X_{k2}	a_{k21}	a_{k22}	a_{k23}	.....	X_{k2e}
	X_{k3}	a_{k31}	a_{k33}	a_{k33}	.....	X_{k3e}

3.4 | Generation of the GRA-DIM direct influence matrix

Depending upon the nature, any data sequence can have certain relationships. According to Mubarak et al. (2021), "multiple reference sequences and comparative sequences may exist simultaneously. In such a case, 'the *grey relational matrix*' appears to be the most suitable method for examining the associations among multiple reference sequences and comparative sequences". In such case GRA has the ability to evaluate the relationship between a specfic reference sequence and various comparative sequences (Agyemang et al., 2020). While doing so, it considers the reference sequence as the desired objective. The capability of GRA, allow us to examine the relationship among formed criteria for automatically generating the DIM (direct influence matrix).

To mathematically illustrate it, assume $B_{jl}=(B_{jl1}, B_{jl2}, \ldots . B_{jls})$ $(1 \le m \le d_k)$, as a reference sequence, and $B_{qk}=(B_{qk1}, B_{qk2}, \ldots, B)$ $(1 \le k \le d_q)$ a comparative sequence. For computing gray relational matrix (GRM), following procedure would be adopted:

Step 1: Computing gray relational coefficients (GRC).

Let $\partial_j(B_{jl}, B_{qk})$ illustrates a gray relational coefficient (GRC) representing the relationship between B_{jl} and B_{qk} on attribute j $(1 \le j \le s)$. Then,

$$\partial_j(B_{jl}, B_{qk}) = \frac{\partial_{min} + \mu \partial_{max}}{\partial_{lsj} + \mu \partial_{max}} \tag{1}$$

where μ illustrates the discriminative co-efficient (0 ≤ μ ≤ 1), which normally has value equal to 0.5 (μ = 0.5):

$$\partial_{min} = min\,|B_{qks} - B_{jls}|\,; l = 1 \ldots d_q \tag{2}$$

$$\partial_{max} = max\,|B_{qks} - B_{jls}|\,; l = 1 \ldots d_q \tag{3}$$

and

$$\partial_{knx} = |B_{jlx} - B_{qkx}| \tag{4}$$

Step 2: Calculating gray-relational-grade.

The extent of relationship between $B_{qks}\, and\, B_{jls}$ is illustrated by GRG (gray relational grade). Equation 5 below exhibits it:

$$V(B_{qk}, B_{jl}) = \sum\nolimits_{n=1}^{h} X_z \partial_z(B_{qk}, B_{jl}) \tag{5}$$

Where X_z represents the comparative significance of attribute is n, $v_j(B_{qk}, B_{jl})$ ranges from 0 to 1. The sum of X_1, $X_2 \ldots\ldots X_n$ is equal to one.

Step 3: Attaining the gray relational matrix (GRM).

The V matric is exhibited in equation below, which comprises of V^2 segments. Whereas each segment represents a relationship between two facets *q* and *j* as illustrated *below:*

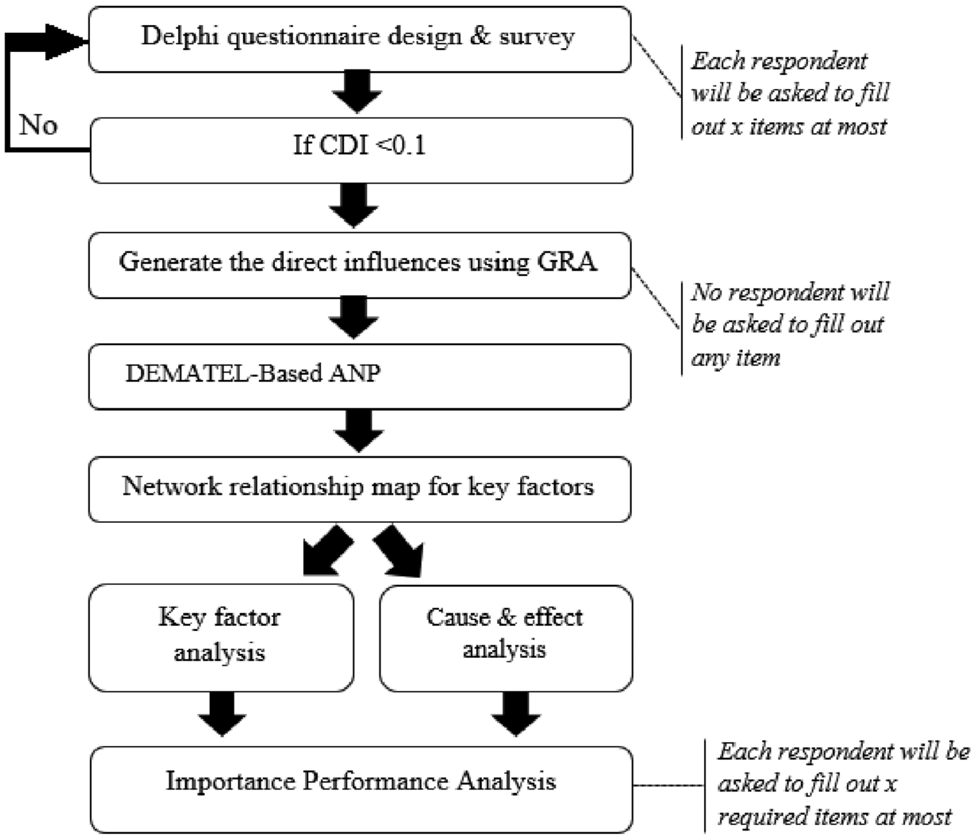

FIGURE 2 Step-by-step methodological flow (Source: Mubarik et al., 2021).

$$V_{qj} = \begin{vmatrix} V(x_{q1}x_{j1}) & V(x_{q1}x_{j2})\ldots & V(x_{q1}x_{jn}) \\ V(x_{q2}x_{j1}) & V(x_{q2}x_{j2})\ldots & V(x_{q2}x_{jn}) \\ \vdots & \vdots & \vdots \\ \vdots & \vdots \quad \ldots & \vdots \\ V(x_{qd_q}x_{j1}) & V(x_{qd_q}x_{j2}) & V(x_{qd_q}x_{jn}) \end{vmatrix}, \text{for } 1 \leq j; q < \qquad (6)$$

When q = j, the resulting matrix is gray self-relational matrix (GRM). In this context, $V(B_{qk}, B_{jl})$ in V_{qq} *can be equalized to* zero for conforming the requirements of DEMATEL. Here, instead of asking experts to provide their opinion, the responses are directly taken from Delphi questionnaire are used by gray relational matrix (GRA) for generating the *direct influence matrix* (DIM) as shown in Figure 2 below, adopted from Mubarak et al. (2021). Figure 2 demonstrates the process adopted in the present study to identify, select and prioritize the dimensions and sub-dimensions of S mapping. It provides a stand-in of the actual process.

It is important to note that conventional approaches like normalization and weighted average approach (WAA) are incapable to investigate the relationships among facets. Hence, we employed GRA to undertake this task. Further, looking into the robustness of CDI (Consensus Deviation Index) consistency test, we have employed it to test the consistency (Okoli & Pawlowski, 2004).

3.4.1 | Delphi survey

According to Mubarak et al. (2021), for Delphi Survey *"If m numbers of survey-rounds are to be conducted, each expert (respondent) in each round could assess n number of items. At the end of the m rounds, all the experts would have given their assessment on nm items. In this case, the minimum condition for the Delphi survey is m = 3."* The same has also been elaborated by Jiang et al., (2018, p. 5), *"assume m rounds are required for the survey. Then, each expert can be asked to rate n items in each round. After m rounds are finished, each expert has provided input on mn items. In the worst case, m = 3 is sufficient to complete a whole Delphi survey*. We follow the same approach to conduct Delphi survey.

Further, for Initial direct influence matrix (IDIM), each respondent (expert) is asked to respond $n^2 - n$ *items.*

Pairwise Comparisons: Every expert is supposed to respond nC_2^n pairwise comparison for each dimensions. Hence, equation $mn + (n^2 - n) + nC_2^n$ denotes items to be responded by the experts while participating in all three surveys.

3.5 | Case industry description

The considerable sources of energy of Pakistan are from the oil and gas sector which are considered as spine of the country. It has enormous share in the nation's economy. At the moment, there are six major oil refineries in Pakistan (Salehg, 2015). Pakistan produces 2,000,000 tons of molasses each year as ethanol fuels for transport side. Pakistan production capacity of oil is 0.31 billion barrels, gas is 30 Trillion cubic feet and shale gas is 51 Trillion cubic feet per year. With an entire stock of 0.31 billion barrels of oil, Pakistan is incapable of fulfilling the demand of their oil because the production of oil in the nation is just 59.08 thousand billion barrels/day and the utilization is 426.72 thousands billion barrel/day, rest of the demand is satisfied by oil imports (Salehg, 2015). With SWOT analysis conducted on the oil and Gas industry of Pakistan, it is identified that, the strength of the industry is on the stock of naturel resources, weakness is the political influence, opportunity is to invest in research and provide skill/training of employees and upgrade the government policies and the threat is off shores companies.

3.6 | Experts sampling

We selected 25 experts working in the Oil and Gas sector of Pakistan using an expert sampling approach. A comprehensive criterion based upon experience, managerial position and job relevance was developed. A person must have 07 years of relevant experience in the capacity of manager or above. The demographic profile of experts has been exhibited in Table 4. After detailed review of literature, we identified 43 dimensions of SC mapping—17 upstream, 15 midstream, and 10 downstream as exhibited in Table 2. First round of Delphi survey was conducted to identify the overlapping, redundant and irrelevant dimensions of SC mapping. It reduced the number of dimensions to 20—*08 upstream, 06 midstream, and 06 downstream*. In the second phase of Delphi survey, experts were asked to provide their rating to the 20 dimensions, grouped into three categories.

TABLE 4 Experts demography

Designation	Number	Total
Vic President SCM	01	
Director supply chain	02	
GM logistics and planning	01	
GM SCM	02	
Dy GM SCM	04	
Senior manager	04	
Procurement manager	05	
Material engineer	02	
Planning manager	02	
Quality manager	02	25
Experience		
24 years and above	05	
Between 19 and 24 years	09	
Between 13 and 18 years	06	
Between 07 and 12 years	05	25
Qualification (Highest degree only)		
BE	07	
MBA	09	
BS (industrial management)	02	
BS (economics)	01	25
ME	03	
BBA	02	

4 | RESULTS

The score of experts for each dimension are exhibited in Table 5. The results show that values of CDI are well below the 0.10, thus confirming the consistency in the rating of experts. Based on consensus, 85 was kept as threshold value. It implies that any dimension with the score of less than 85 would be excluded from further analysis. It resulted in exclusion of 05 dimensions—03 USM, 01 MSM, 01 DSM. Consequently, total of 15 dimensions—05 UMS, 05 MSM, 05DSM—were proceeded in the third round of Delphi, as shown in Table 6. The DIM was obtained from experts using questionnaires for DANP. Further, to integrate the importance of criteria scores GRA was employed to produce the DIM.

4.1 | Producing initial direct influence matrix using GRA

As the measurement scales are homogenous in present study, there is no need for normalization. Employing Equations 1–5, we calculated the gray relational grades. We have three major criteria ($C = 5$) with 05 dimensions each. We put $V(B_{qk}, B_{jl})$ to "0" to conform to DEMATEL requirements. Further, we used Equation 6, to obtain the association between criteria. The computation is shown in Table 7.

4.2 | Total influence matrix and identification of critical dimensions

We computed the NDIM using DEMATEL approach, resulting TIM (total influence matrix) which is illustrated in Table 8. Further the importance of each dimension is illustrated in Table 9. In order to acquire the weights of WSM (The weighted super matrix), the TIM was normalized. Further, by normalizing the WSM, the Limiting Super Matrix (LSM) was obtained as shown in Table 10. The priority weightage of all dimension has been illustrated in Table 11. Among the top 05 dimensions of SC mapping, 03 dimensions belong to upstream mapping (×15, ×1, ×14). It shows the significance of the upstream mapping while initiating the process of supply chain mapping. The proceeding section briefly discusses the possible inferences, that can be drawn from the results and as to how it can be proceeded for developing a measure of SC mapping. Researchers (e.g., Mubarik et al., 2021) mention that mapping upstream supply chains can be as, namely organizations preparedness, flexibility and responsiveness.

TABLE 5 Scores of criteria

Dim	Sub	Experts 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Avg. value	SD	CDI
USM	GRS	85	80	85	85	90	80	80	85	80	85	85	80	80	75	80	80	80	80	85	75	80	80	80	85	70	81	4.15	0.042
	RTS	85	90	90	95	80	90	85	85	85	85	85	90	80	85	80	80	90	90	90	90	80	85	90	90	90	87	4.26	0.043
	IFS	80	85	80	85	80	90	80	85	80	85	85	80	85	90	85	85	85	90	85	85	80	85	90	85	85	84	3.33	0.033
	ISC	95	90	85	90	95	90	90	85	90	95	85	85	95	95	95	80	90	90	80	95	85	90	95	95	90	90	4.79	0.048
	RTG	80	80	90	85	85	85	80	85	80	80	85	80	85	80	90	80	90	90	80	90	80	90	80	85	85	84	4.08	0.041
	RTM	90	85	85	85	90	90	90	80	80	85	85	90	90	95	95	90	85	90	90	90	80	80	90	80	80	87	4.76	0.048
	SRT	80	90	80	90	85	90	90	90	90	90	85	80	80	86	80	95	90	85	85	90	90	90	95	85	85	87	4.55	0.046
	VUS	95	95	85	85	90	90	95	85	85	85	85	95	95	90	95	90	90	90	90	85	90	90	90	85	90	90	3.80	0.038
MSM	CKI	90	90	85	95	90	95	85	90	90	85	90	80	80	80	85	80	90	90	90	80	80	90	90	85	90	87	4.79	0.048
	IAI	80	90	90	95	90	90	95	85	90	85	85	90	85	95	85	80	90	95	90	80	95	90	95	90	90	89	4.79	0.048
	IPI	75	75	80	75	75	80	80	80	80	85	85	80	85	90	90	85	85	90	85	80	85	80	85	90	80	82	4.81	0.048
	RTD	90	90	85	90	95	95	90	95	90	90	85	80	95	90	95	95	90	85	80	95	85	90	95	95	90	90	4.67	0.047
	VSM	85	80	90	80	85	95	80	85	85	80	85	80	80	95	90	85	90	90	90	90	80	90	80	85	85	86	4.86	0.049
	VP	90	85	90	85	90	95	90	80	85	80	85	90	90	90	90	85	90	95	95	95	85	80	90	80	85	88	4.80	0.048
DSM	RTI	85	80	85	85	90	85	90	80	80	85	85	90	90	95	80	90	90	85	85	90	85	90	90	85	85	86	3.96	0.040
	ISC	90	85	90	95	80	90	80	95	95	80	95	90	90	95	90	90	90	90	95	95	90	95	90	90	85	90	4.79	0.048
	TGD	95	90	85	90	80	80	90	90	90	90	85	90	85	85	80	80	90	90	85	90	90	95	85	90	90	88	4.36	0.044
	RTC	90	95	85	95	90	85	95	85	85	90	85	85	95	85	85	95	90	95	90	85	80	80	85	90	90	88	4.73	0.047
	SIC	90	95	85	85	85	85	90	85	90	90	80	90	80	85	80	85	80	80	90	95	80	95	85	90	90	**87**	4.94	0.049
	VFG	90	95	85	95	85	95	85	90	95	95	80	95	85	90	90	90	95	90	95	80	95	90	85	85	90	90	4.89	0.049

TABLE 6 Scores of formal criteria

Dim	Sub	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
USM	RTS	85	90	90	95	80	90	85	85	85	85	85	90	80	85	80	80	90	90	90	90	80	85	90	90	90
	ISC	95	90	85	90	95	90	90	85	90	95	85	85	95	95	95	80	90	90	80	95	85	90	95	95	90
	RTM	90	85	85	85	90	90	90	80	80	85	85	90	90	95	95	90	85	90	90	90	80	80	85	80	80
	SRT	80	90	80	90	85	90	90	90	90	90	85	80	80	86	80	95	90	85	85	90	90	90	95	85	85
	VKI	95	95	85	85	90	90	95	85	85	85	85	95	95	90	95	90	90	90	90	85	90	90	90	85	90
MSM	CKI	90	90	85	95	90	95	85	90	90	85	90	80	80	80	85	80	90	90	90	80	80	90	90	85	90
	IAI	80	90	90	95	90	90	95	85	90	85	85	90	85	95	85	80	90	95	90	80	95	90	95	90	90
	RTD	90	90	85	90	95	95	90	95	90	90	85	80	95	90	95	95	90	85	80	95	85	90	95	95	90
	VSM	85	80	90	80	85	95	80	85	85	80	85	80	80	95	90	85	90	90	90	90	80	90	80	85	85
	VP	90	85	90	85	90	95	90	80	85	80	85	90	90	90	90	85	90	95	95	95	85	80	90	80	85
DSM	RTI	85	80	85	85	90	85	90	80	80	85	85	90	90	95	80	90	90	85	85	90	85	90	90	85	85
	ISC	90	85	90	95	80	90	80	95	95	80	95	90	90	95	90	90	90	90	95	95	90	95	90	90	85
	TGD	95	90	85	90	80	80	90	90	90	90	85	90	85	85	80	80	90	90	85	90	90	95	85	90	90
	RTC	90	95	85	95	90	85	95	85	85	90	85	85	95	85	85	95	90	95	90	85	80	80	85	90	90
	VFG	90	95	85	95	85	95	85	90	95	95	80	95	85	90	90	90	95	90	95	80	95	90	85	85	90

TABLE 7 The initial direct influence matrix

	X11	X12	X13	X14	X15	X21	X22	X23	X24	X25	X31	X32	X33	X34	X35
X11	0.000	0.890	0.950	0.850	0.708	0.970	0.613	0.563	0.735	0.835	0.670	0.867	0.645	0.800	0.833
X12	0.410	0.000	0.440	0.560	0.680	0.633	0.613	0.530	0.690	0.802	0.590	0.560	0.583	0.580	0.490
X13	0.800	0.829	0.000	0.740	0.670	0.717	0.671	0.813	0.695	0.766	0.645	0.583	0.470	0.510	0.900
X14	0.735	0.735	0.835	0.000	0.867	0.645	0.767	0.735	0.688	0.735	0.688	0.788	0.767	0.833	0.708
X15	0.910	0.890	0.930	0.950	0.000	0.890	0.880	0.870	0.940	0.890	0.930	0.890	0.880	0.880	0.950
X21	0.520	0.560	0.870	0.470	0.583	0.000	0.480	0.450	0.530	0.690	0.497	0.370	0.587	0.320	0.470
X22	0.688	0.688	0.788	0.767	0.833	0.750	0.000	0.854	0.829	0.854	0.829	0.000	0.833	0.833	0.583
X23	0.450	0.490	0.712	0.590	0.670	0.423	0.514	0.000	0.431	0.750	0.672	0.500	0.550	0.561	0.532
X24	0.900	0.670	0.829	0.735	0.708	0.633	0.613	0.833	0.000	0.670	0.854	0.833	0.771	0.688	0.688
X25	0.800	0.829	0.780	0.833	0.833	0.717	0.738	0.708	0.592	0.000	0.708	0.750	0.771	0.900	0.788
X31	0.735	0.735	0.835	0.670	0.867	0.645	0.767	0.708	0.633	0.767	0.000	0.000	0.854	0.766	0.767
X32	0.769	0.769	0.869	0.867	0.000	0.583	0.833	0.833	0.717	0.738	0.813	0.000	0.583	0.645	0.833
X33	0.650	0.695	0.766	0.645	0.583	0.660	0.750	0.540	0.490	0.610	0.735	0.613	0.000	0.583	0.660
X34	0.688	0.540	0.890	0.671	0.800	0.750	0.456	0.624	0.583	0.833	0.771	0.738	0.708	0.000	0.650
X35	0.970	0.890	0.930	0.880	0.790	0.850	0.810	0.860	0.910	0.920	0.950	0.833	0.769	0.880	0.000

TABLE 8 Total influence matrix

	X11	X12	X13	X14	X15	X21	X22	X23	X24	X25	X31	X32	X33	X34	X35
X11	3.221	3.280	3.627	3.273	3.125	3.174	3.059	3.184	3.044	3.470	3.304	2.703	3.139	3.144	3.173
X12	2.521	2.572	2.843	2.565	2.447	2.487	2.395	2.493	2.383	2.716	2.587	2.117	2.458	2.463	2.486
X13	2.839	2.896	3.207	2.890	2.759	2.804	2.700	2.808	2.688	3.063	2.917	2.388	2.773	2.778	2.799
X14	3.189	3.252	3.596	3.249	3.096	3.149	3.030	3.154	3.018	3.440	3.275	2.679	3.110	3.116	3.147
X15	3.735	3.810	4.213	3.801	3.633	3.688	3.550	3.695	3.534	4.029	3.835	3.139	3.644	3.652	3.684
X21	2.282	2.327	2.570	2.323	2.216	2.254	2.169	2.257	2.159	2.459	2.342	1.919	2.225	2.232	2.252
X22	3.119	3.181	3.518	3.174	3.032	3.080	2.968	3.084	2.950	3.363	3.202	2.627	3.043	3.049	3.079
X23	2.420	2.468	2.727	2.462	2.349	2.389	2.299	2.395	2.289	2.607	2.482	2.033	2.360	2.365	2.387
X24	3.142	3.207	3.545	3.199	3.053	3.104	2.988	3.108	2.977	3.391	3.226	2.640	3.066	3.073	3.102
X25	3.230	3.294	3.644	3.287	3.137	3.190	3.070	3.195	3.058	3.489	3.317	2.715	3.151	3.157	3.187
X31	2.979	3.038	3.359	3.032	2.895	2.942	2.831	2.946	2.819	3.213	3.062	2.510	2.905	2.912	2.938
X32	2.862	2.919	3.227	2.912	2.788	2.827	2.719	2.831	2.708	3.088	2.938	2.408	2.794	2.799	2.822
X33	2.555	2.605	2.881	2.600	2.482	2.522	2.427	2.528	2.419	2.756	2.622	2.146	2.495	2.498	2.520
X34	2.891	2.950	3.259	2.943	2.806	2.854	2.750	2.860	2.736	3.117	2.967	2.429	2.820	2.830	2.853
X35	3.879	3.958	4.376	3.949	3.770	3.831	3.688	3.838	3.671	4.185	3.983	3.261	3.786	3.793	3.834

5 | DISCUSSION

After various iterative processes, the supply chain mapping dimensions were reduced from 40 to 15. The results of relative importance of 15 dimensions provide two important insights. First, the 3 among 5 dimensions of upstream mapping falls among the top 5 dimensions, lighting the importance of upstream mapping in the overall process of supply Chain mapping. Secondly, looking into the difference in the priority rankings, we may not find very huge difference. It implies that all the selected dimensions of SC mapping are essential for the overall process of mapping. Being the present study pioneering in the application of GDANP and SC mapping dimensions, apple to apple comparisons of the results of this study with any other is not possible. However, a crude comparison can be done. So, looking into the most of literature on the SC mapping, it becomes apparent that upstream mapping is the starting point to map a supply chain and in a lot of cases mapping only upstream supply chain has resulted in greater visibility. For example, according to Mubarak et al. (2021), "visualization of materials across the value chain (VFC)" is an essential objective of SC mapping.

Likewise, they also mention "availability and sharing of real time information with tier1 and tier 2 suppliers (RTS & SRT) reflects the upstream mapping of an organization. It implies that the effective SC mapping should result in agile and effective sharing of real-time information between the company and its upstream stakeholders. The study of Fabbe-Costes et al. (2020) also support real time effective exchange of information with tier 1 and tier 2 suppliers as an essential outcome of upstream mapping. They argue that upstream mapping, through linking tier 1 and tier 2 suppliers, permits a firm to preempt any change or disruption in the upstream supply chain and develop a proactive response to respond disruptions. Further, VFC can play an instrumental role in identifying the bottlenecks in upstream value chain causing slowdown in production or service delivery. Putting together, the literature supports the VFC, RTS and SRT as the key dimensions of upstream mapping. Despite of the fact that, some of the dimensions possess higher importance as compare to others, their relative difference is very minimal. If we compare the highest dimensions in the list that is, VKI($x15 = 0.0793$) with the lowest RTD ($x23 = 0.0534$), the appears a very minimal difference. It highlights the fact that all of the selected 15 dimensions are important for mapping a supply chain. Nonetheless, upstream mapping could be a starting point to map the supply chain.

Further findings on the identification of midstream mapping highlight the visualization and integration of internal processes as the essential part of midstream mapping. Likewise, the value stream mapping VSM ($x24 = 0.0695$) also appears as an important aspect of supply chain mapping. It reiterates the important of conventional VSM,

TABLE 9 Prominence and relation of each factor

d	r	d − r	d + r
7.186	8.713	−1.527	15.899
5.615	8.858	−3.243	14.473
6.330	9.346	−3.016	15.677
7.119	8.816	−1.698	15.935
8.352	8.825	−0.472	17.177
5.081	7.736	−2.655	12.817
6.966	8.454	−1.488	15.420
5.384	8.068	−2.684	13.452
7.019	7.742	−0.723	14.762
7.213	9.088	−1.875	16.301
6.643	8.322	−1.678	14.965
6.395	7.592	−1.198	13.987
5.695	8.328	−2.633	14.022
6.448	8.683	−2.235	15.131
8.683	9.055	−0.372	17.738

TABLE 11 The overall ranking for the factors.

X15	VKI	0.0793
X35	VFG	0.0791
X11	RTS	0.0715
X25	VP	0.0715
X14	SRT	0.0704
X24	VSM	0.0695
X22	IAI	0.0690
X31	RTI	0.0659
X34	RTC	0.0644
X32	ISC	0.0636
X13	RTM	0.0631
X12	ISC	0.0619
X21	CKI	0.0604
X33	TGD	0.0569
X23	RTD	0.0534

TABLE 10 The limit super matrix for factors

	x11	x12	x13	x14	x15	x21	x22	x23	x24	x25	x31	x32	x33	x34	x35
x11	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
x12	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
x13	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
x14	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
x15	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
x21	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
x22	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
x23	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
x24	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
x25	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
x31	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
x32	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
x33	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
x34	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
x35	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086

adopted to align, integrate and visualize the internal processes of a company. Results on the identification and importance of downstream mapping, underscores the significance of Real-time information about the customers network (RTI, $x31 = 0.0695$) and information sharing with tier 1 and tier 2 customers (ISC, $x32 = 0.636$). The literature on the forward integration with customers supports our findings. Studies of Taylor (2005), Fabbe-Costes et al. (2020), and Faisal et al. (2006) mention aligning and integrating with tier 1 and tier 2 customers as important facets of downstream mapping.

In condensed form, our findings highlight the significance of all identified dimensions while measuring SC mapping.

6 | CONCLUSION

The overarching objective of this study was to identify and prioritize the dimensions of SC mapping using Gray-DEMATEL-ANP. A comprehensive review of literature revealed 43 dimensions of SC mapping—17 upstream, 15 midstream, 11 downstream. Three rounds of Delphi survey were conducted in order to identify and prioritize the selected dimensions of SC mapping. Total of 15 dimensions were selected after first Delphi survey. Through GDANP, the identified 15 dimensions were prioritized. The results showed that 03 major dimensions of upstream mapping, 01 dimension of midstream mapping and 01 of downstream mapping appear among top 5 dimensions. Nevertheless, the difference in the importance was marginal as the highest value of dimensions was 0.0793 and lowest is 0.534. The results broadly concur with the literature on SC mapping.

The findings of the study provide valuable input for developing SC mapping construct. As this study only highlights the important facets, which can be instrumental in measuring the extent of SC mapping of a firm, there is a need to convert these identified dimensions into a construct. It can be done by adopting a conventional construct development approach. The developed construct could be used for modeling and examining the antecedents and precedents of SC mapping. The findings have some key implications for the managers. The results of the study could also be instrumental in embarking on SC mapping journey. The higher relative importance of upstream mapping dimensions demonstrate the need to develop a proper sourcing criteria and supplier relationship management framework. This is essential as the mapping can never be done without involvement of upstream entities that is, suppliers in the process. A proper sourcing criteria and appropriate relationship management strategy will play a key role in understating and involving suppliers in the process of SC mapping. Further, the higher relative importance of visualization of materials across the value chain (VFC) reveal the need to deploy a proper data and information tracking system across the supply chain, first starting from upstream chain. Such system would track the data and flow of information throughout the supply chain.

From a research perspective, this study advances the literature on SC mapping by further investigating the effects of SC mapping on SC resilience in the Oil and Gas organizations supply chain. Its extends previous studies that only focus on introducing supply chain visibility to proposing dimensions and sub-dimensions of SC mapping to propose a framework for measuring SC resilience. The study introduces SC mapping measures as an important aspect of supply chain resilience. The conceptualization of the SC mapping measurement framework strengthens the theoretical foundation for evaluating, controlling and monitoring SC resilience in the Oil and Gas sectors. These SC mapping dimensions and sub-dimensions may prove valuable for broader theoretical investigations for a more complete assessment of SC mapping within the Oil and Gas SC resilience literature.

From a practical perspective, managers and policymakers may encourage broader adoption of the SC mapping measurement initiatives by focusing on the sub-dimensions that are highly ranked as an initial step. Another option is that, if the Oil and Gas organizations wishes to build a strong SC resilience, they can invest in the lower ranked SC mapping measurement sub-dimensions, which seems immature or less reinforced initiatives. The results can provide an initial implementation insights and pathways. These insights and pathways do inform and provide options to industrial managers and decision-makers on which sub-dimensions to focus during implementation and which sub-dimensions they may delay as a way to systematically introduce the SC mapping measurement initiatives. The results although specific to a given industry in an emerging economy nation, the outcome may be extended to other emerging economies and contexts, affirming its worth.

There exist some implications for Pakistan and its oil and gas sector. The Pakistan oil and gas sector may face more upstream and midstream pressures in terms of SC resilience when compared to downstream pressures. Thus, their foundational initiatives for SC resilience implementation programs are still in the early stages, overall for the upstream, buyer–supplier relationship. Also, organizations may be resource-constrained to adopt and implement SC mapping sub-dimensions simultaneously and may choose among them. Maximizing performance outcomes in such situations is a goal for most industries. Therefore, this modeling efforts and results can be helpful in setting the stage for prioritization.

Some limitations to the study exist. One principal limitation is the snap-shot in time of the study. A more longitudinal study to determine if and how the SC mapping measurement requirements and importance will change with time is required. Methodologically, the study used GRA and DEMATEL approaches to help develop the network relationship and interdependencies to deal with the issue of consistency which the traditional ANP faces. This is only one approach to do so. Other methods such as fuzzy set theory and other mental modeling causal analysis tools may be used to determine if the independent relationships would change. As can be seen, there is still significant amount of work to be done with respect to integrating ANP with other tools and further study on SC mapping for resilience in the Oil and Gas sector in emerging economies. However, this present work sets the stage for additional and important methodological and SC mapping for resilience investigations.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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