Identifying Construction Managers' Challenges: A Novel Approach Based on Social Network Analysis

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Abstract: Due to the complex and dynamic atmosphere in the construction sector, different types of challenges are faced by project managers (PMs). These challenges potentially have negative impacts on the PM's managerial performance, which mostly leads to budget and schedule contingencies. In this vein, scrutinizing the main challenges in a construction project and identifying the cause-and-effect relationships among these challenges is a crucially important process. In the literature, a considerable number of papers have tried to determine construction PM challenges, mainly using statistical methods. These methods do not consider the cause-and-effect relationship among variables. To enhance the existing methods, this paper applies social network analysis (SNA) principles in order to rank a group of variables based on cause-and-effect relationships. To demonstrate the proposed idea, a data set is constructed that includes different types of challenges acquired from the literature comprehended with the forward-chaining approach. In total, 49 critical challenges were identified and subsequently categorized into 12 groups. Two questionnaires were designed to assist in ranking the challenges. 108 construction experts and 20 panelists participated in this study, and the acquired data were used to evaluate the proposed SNA-based method. By applying the proposed method to the obtained data, a complex weighted and directed network is constructed and examined by three metrics: weighted in-degree centrality, betweenness centrality, and closeness centrality. The results revealed that poor planning, contractors'/subcontractors' financial difficulties, and poor decision making are the main challenges that occur in the construction environment. Moreover, it was figured out that considering the cause-and-effect relationship among variables resulted in a highly different ranking of challenges, much closer to the real situation. This model could be used in quantitative-analytical research conducted in the construction project knowledge area in order to obtain more interpretable answers. **DOI: 10.1061/JCEMD4.COENG-13771.** © *2023 American Society of Civil Engineers.*

Practical Applications: Due to the complex and dynamic atmosphere in the construction sector, different types of challenges are faced by project managers (PMs). These challenges potentially have negative impacts on the PM's managerial performance, which mostly lead to time and cost overruns. In this vein, scrutinizing the main challenges in a construction project and identifying the cause-and-effect relationships among these challenges is a crucially important process. In this research, comprehensive scientific efforts were made in order to rank the main PMs' challenges in the construction sector, especially in developing countries. For this purpose, cause-and-effect relationships among variables were considered. By using different questionnaires as well as forming different focus groups and interviewing different experts, we found that the main top 10 challenges in the construction sector are: poor planning, contractors'/subcontractors' financial difficulties, poor decision making, time pressure, rework, stressful atmosphere, design alteration (even after execution), workforce turnover, fluctuation rate and economic instability, and inappropriate and unrealistic scheduling.

Author keywords: Construction industry; Project manager (PM); Social network analysis (SNA); Delphi technique; Quantitative research.

Introduction

A project manager (PM) has the most important role in handling the majority of financial, technical, and managerial challenges that occur in the construction environment. One of the momentous challenges that PMs usually face relates to their skills and capabilities in managing and handling construction site issues. A skilled and knowledgeable PM could overcome challenges encountered during the design or implementation phases. A PM with insufficient skills or knowledge could direct the project to failure (Yadollahi et al. 2014).

Surprisingly, in a study conducted by Hewage et al. (2008), it was found that nearly 50% of construction employees are faced with communication issues with PM. In addition, Campbell (2006) reported that nearly 70% of construction employees suffer from stress, anxiety, or depression. As a result, facing serious construction challenges that are engendered by stressful environments is unavoidable for PMs (Leung et al. 2008).

Other issues such as increases in the scope and complexity of the project, low productivity, incorrect design, and poor planning could lead to cost and time overruns (Tatum 2012), as well as unrealistic time scheduling and a deterioration of the project team's reputation (Yap et al. 2019).

Although, among all issues in construction projects, financial issues have a vital role in the progress of projects (Ofori 2012;

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Suprun and Stewart 2015), so the continuity of this sector hinges directly on governmental budget and private sector investment. Kog and Loh (2012) ranked economic risks as one of the most important terms in civil and structural work. As well, Young (2008) highlighted that "population and migration growth, economic fluctuations, and growing pressure from universe economic instability" are the main characteristics of the construction industry.

There is no doubt that the success of a project not only depends on the PM's role but also heavily relies on other important factors such as project economics, clients, owners, supervision, and labor forces. However, it is clear that the PM usually stays at the center of the project and plays an influential role in overcoming the project's issues by using different strategies.

By considering multiple time, executive, and managerial limitations in construction projects, it cannot be denied that a PM is not capable of handling all the challenges occurring in a project. In this vein, detecting the most important challenges is necessary for a PM in order to set a strategic plan to deal with these challenges.

By reviewing multiple articles in this field, it becomes clear that in order to rank the challenges, all variables were almost considered independent. For this purpose, a quantitative scale is used to rank the variables, and usually, statistical parameters such as mean and standard deviation are used as well (Yadollahi et al. 2014). However, there is criticism that the interaction (or cause-and-effect relationship) between variables has not been considered in detail, whereas applying the relationship or interaction between variables in general ranking could practically change the outcomes. However, due to the complexity of modeling and calculation, the cause-and-effect relationship among variables has not been covered in previous papers as a feature in ranking a group of variables. To tackle this issue, in this paper, a semiautomatic platform based on social network analysis (SNA) concepts has been introduced to rank the variables by considering the cause-and-effect relationship among variables. This model identifies the most important challenges in three phases by covering the following questions:

- *What challenges occur in construction projects for the PMs?*
- *What relationships exist between these challenges?*
- *Which challenges are the most important in a construction project from the PM's perspective?*

It is expected that, first, the outcome of this study could help PMs build a big picture of the project and its challenges in their minds in order to develop their own strategy effectively. Second, the proposed platform could provide a new path in the quantitative-analytical research domain with the aim of ranking a group of variables. Developing this novel approach could be applied to other research areas in construction-related studies such as identifying the critical success or failure factors, critical risks, the main causes of delays or reworks, essential competencies, and any other type of research in which scholars wish to rank and identify the most important variables in a set of variables.

Literature Review

Challenges in the Construction Sector

In the literature, a considerable number of efforts were devoted to identifying PMs' challenges in the construction sector. In a study done by Yadollahi et al. (2014), they categorized the main challenges that a PM would encounter in the construction environment into six main groups: (1) technical, (2) personal, (3) managerial skills, (4) contractual, (5) psychological, and (6) financial. They believed that awareness of the main challenges in residential projects is one of the main requirements for electing the most eligible PMs. Yap et al. (2019), in their research, extracted the 23 most common challenges plaguing the global construction industry and identified (1) poor site coordination and management; and (2) the incompetency of construction stakeholders as the two major challenges.

Notwithstanding, it is worth noting that the effects of all construction challenges can manifest in time-scheduling delays and cost overruns (Abbasi et al. 2020; Zidane and Andersen 2018). According to Sambasivan and Soon (2007), time and cost overruns are the most important effects of construction sector delays. Several issues, such as (1) inadequate planning by the contractors, (2) improper site management by the contractors, and (3) delay in the payments for the work completed, are detected as the main challenges in construction projects (Sambasivan and Soon 2007).

Khoshgoftar et al. (2010) reported that (1) the finance and payments of completed work; and (2) improper planning and site management are the main challenges in the construction sector that cause schedule delays. As well, they insinuated the role of management in problems pertaining to construction.

In another study, by reviewing several articles that were conducted in developing countries, Alsehaimi et al. (2013) figured out that managerial issues play the most important role in downgrading construction management performance. This finding is in great part in line with that of Yap et al. (2019), who compared several developing countries and expressed that human and managerial issues are the main causes of different construction challenges.

Recently, Abbasi et al. (2020) reported several contractor managerial challenges in the Iranian construction industry. (1) Unrealistic scheduling, (2) reworks, (3) poor management of subcontractors, (4) poor site management, and (5) delay in decision making in critical situations were some of the challenges detected.

In several studies, management-related issues were mentioned as the main obstacles to improving labor productivity in the construction sector (Jarkas 2015; Mahamid 2013; Ghoddousi and Hosseini 2012).

In summary, it could be concluded that managerial problems are expressed as one of the most important predicaments in the construction industry. In an overall view, (1) poor planning and controlling (Koushki et al. 2005; Odeh and Battaineh 2002; Sweis et al. 2008; Abdul-Rahman et al. 2006; Alaghbari et al. 2007; Mezher and Tawil 1998; Long et al. 2004), (2) poor site management (Sweis et al. 2008; Abdul-Rahman et al. 2006; Alaghbari et al. 2007; Lo et al. 2006; Mezher and Tawil 1998; Long et al. 2004; Le-Hoai et al. 2008; Makulsawatudom and Emsley 2003), and (3) incompetency of construction stakeholders (Makulsawatudom and Emsley 2003; Le-Hoai et al. 2008; Toor and Ogunlana 2008; Niazi and Painting 2017) are detected as some of these management-related issues that were argued in papers as fundamental challenges in construction environment.

SNA Applications in Construction Projects

The SNA approach has been used as a useful instrumental tool for discovering the interdependencies between a group of elements since the relevant concepts were introduced by Moreno in 1934 (Moreno 1934). According to a definition by Otte and Rousseau (2002), SNA is a process of studying social structures by using its networks through graph theory.

The SNA approach lets researchers interpret qualitative data via mathematical and graphical analysis in different domains of science, especially in business, management, decision science, engineering, and social sciences. Nonetheless, since 1980, SNA concepts have been implemented in the project management research domain (Zheng et al. 2016). Surprisingly, publications in construction project management have witnessed a huge number of articles concerning the application of SNA in the last few years (Zheng et al. 2016). Project management scholars get help from social science disciplines in order to understand the main issues and problems occurring in project management (Bresnen et al. 2005). Loosemore (1998) classified SNA as a capable quantitative tool that could be applied within an interpretative context in research on construction projects.

In SNA theory, different variables, such as things, people, or individual actors, are referred to as nodes, and the relationships or interactions among variables are defined as links. This fundamental definition could effectively help in understanding the complexity of the relationships among variables. In this vein, studies in construction project management can be broadly divided into two categories (Pryke 2017). In the first category, human actors are defined as nodes, and the purpose of SNA is to determine the interpersonal and intera- or inter-organizational links in the project context (Mok et al. 2017). Modeling different types of communication in construction projects in order to enhance the performance of projects (Chinowsky et al. 2008, 2010; Priven and Sacks 2015; Liu et al. 2015; Pollack and Matous 2019) and stakeholder management (Mok et al. 2017; Dadpour et al. 2019) are examples of applying SNA to social problems.

In the second category, nonhuman objects are considered nodes in construction and engineering fields (Mok et al. 2017). In this approach, nodes could be connected to each other, and the interaction of which will be analyzed by SNA. Identifying construction risk interactions or risk networks in engineering projects (Fang et al. 2012; Yu et al. 2017; Aljassmi et al. 2014), strategic management (Abdul-Aziz and Wong 2011), knowledge management (Brookes et al. 2006), and site and resource management (Lin 2015; Pryke et al. 2011) are examples of applying SNA to nonsocial problems.

Different parameters are defined in a network analysis in order to mathematically measure the performance. In the current study, the following parameters will be used for developing the model:

- Node: Separate and distinct social or nonsocial entities.
- Link (Arrow): A directed tie that is drawn between two nodes. Links could be weighted or unweighted.
- Weighted In-degree Centrality: The number of links directed to a node by considering their weights. This parameter is an indication of the influence and authority of each node.
- Weighted Out-degree Centrality: The number of ties that the node directs to others by considering the weight of each tie. This parameter is an indication of dependency.
- Betweenness Centrality: This concept shows how many times a particular node is located on the shortest path connecting other actors.
- Closeness Centrality: This parameter is preferred in SNA to mean shortest path and gives higher values to more central nodes.

Construction in Developing Countries (the Case of Iran)

Generally, the classification of a country as "developed" or "developing" is based on certain measures such as (1) economic development, (2) education and training provision, (3) political stability, technological development, infrastructure, and production rate, (4) healthcare, life expectancy, and growth rate of the population, and (5) society, demography, and culture issues (Othman and Ahmed 2013). Developing countries [where approximately 85.4% of the world's population lives (IMF 2023)] are countries whose standard of living, income, economic, and industrial development remain more or less below average. According to the IMF's (2023) definition, there are 152 developing countries with a current population of around 6.77 billion. Corruption and political instability, lack of capital and technology, dualistic economy, low levels of productivity, inadequate infrastructure, underutilized natural resources, poor health care, and low standard of education and vocational training are several characteristics of developing countries (Kumar 2012; Othman and Ahmed 2013).

For many developing economies worldwide, the construction sector is expected to play a critical role in the economy and can be comprehensively leveraged by the government as a platform to encourage the national economic transformation toward developed country status (Isa et al. 2015).

Many developing countries are currently spending on construction projects due to the high demand resulting from rapid urbanization. However, the results of these projects in terms of time, cost, and quality do not tend to meet the expectations of the stakeholders (Amoah et al. 2021).

In developing countries, the reputation of the construction industry is frequently tarnished by poor performance (Islam and Trigunarsyah 2017; Yap and Skitmore 2018). As well, many project failures are attributed to a poor and inefficient management system (Hui et al. 2017).

In last years, a valuable efforts were devoted to understanding the construction issues in developing countries, namely, Egypt (Aziz and Abdel-Hakam 2016), Benin (Akogbe et al. 2013), Botswana (Adeyemi and Masalila 2016), Burkina Faso (Bagaya and Song 2016), Ghana (Fugar and Agyakwah-Baah 2010; Frimpong et al. 2003), Vietnam (Long et al. 2004; Le-Hoai et al. 2008; Kim and Tuan 2016), Thailand (Makulsawatudom and Emsley 2003; Toor and Ogunlana 2008), Zimbabwe (Nyoni and Bonga 2017), South Africa (Oshungade 2016), India (Parikh et al. 2019; Ismail and Varghese 2019; Doloi et al. 2012), Ethiopia (Zewdu 2016), North Cyprus (Yitmen 2007), Malaysia (Yap and Skitmore 2018; Yadollahi et al. 2014; Taofeeq and Adeleke 2019; Sambasivan and Soon 2007; Jatarona et al. 2016; Abdul-Rahman et al. 2006; Alaghbari et al. 2007), Nigeria (Tunji-Olayeni et al. 2019; Kasimu and Isah 2012), Cambodia (Santoso and Soeng 2016; Durdyev et al. 2017; Kang et al. 2018), Jordan (Sweis et al. 2008), Bahrain (Jarkas 2015), Kuwait (Koushki et al. 2005), Saudi Arabia (Elawi et al. 2015), Pakistan (Gardezi et al. 2014), Qatar (Gunduz and AbuHassan 2016), United Arab Emirates (Mpofu et al. 2017), Afghanistan (Niazi and Painting 2017), and Iran (Parchami Jalal et al. 2019; Khoshgoftar et al. 2010; Heravi and Mohammadian 2021; Ghoddousi and Hosseini 2012; Fallahnejad 2013; Banihashemi et al. 2017; Abbasi et al. 2020; Abbasnejad and Izadi Moud 2013; Asnaashari et al. 2009; Pourrostam and Ismail 2012).

Recent studies have opined that although the construction industries worldwide share some common characteristics, some conditions can be specific to developing countries (Olawale and Sun 2010; Yap et al. 2019). In this vein, an Iranian-based study will help identify the salient issues most relevant to developing countries spatially in the Middle East region. On the other side, by choosing the case of Iran, due to the familiarity and sufficient experience of the authors in Iranian construction projects and easy accessibility to pure and reliable data, several data quality criteria such as accessibility, relevancy of outcome, timeliness, and ease of understanding will meet the relevant criteria introduced by Strong et al. (1997).

The construction industry plays an undeniable role in the Iranian economy and employment sections (Pournader et al. 2015; Banihashemi et al. 2017). Likewise, it has created a strong correlation between economic growth and economic stability, resulting in social development. Pournader et al. (2015) stated that the annual turnover of the construction sector in Iran accounted for about US$38.4 billion, with a 4.4% estimated growth rate between 2008 and 2012.

Based on previous research, it is understood that the PMs in the Iranian construction sector face several challenges that could and have resulted in project failure in several cases (Khoshgoftar et al. 2010; Abbasnejad and Izadi Moud 2013; Abbasi et al. 2020). It seems that due to the devaluation of the national currency and subsequently high inflation rate in Iran (Iranmanesh et al. 2019), as well as the lack of managerial competencies in governmental agencies in the last years and consequently the lack of proper planning in the construction sector, several disincentive challenges have emerged in the construction industry. As a consequence, the sizable reduction in the annual construction budget is one of the most important aftereffects of these issues. By referring to national documents, it is discernible that the approved annual civil and construction budget by the Iranian parliament decreased from US$29.91 billion in 2010–2011 to US$4.8 billion in 2019–2020 (PBOI 2020).

By considering the causes of construction delays, it is understood that some financial, managerial, and environmental issues are the most common challenges in the Iranian construction sector (Asnaashari et al. 2009; Pourrostam and Ismail 2012).

Methodology

The purpose of this research is to implement a quantitative approach in order to rank a group of construction PM challenges by considering both experts' viewpoints on the importance of each challenge in project performance and the cause-and-effect relationship among challenges. SNA, due to its' capability of considering nonhuman objects as nodes, could be appropriately used for figuring out the cause-and-effect relationship among variables. For this aim, the concepts of SNA are considered as central approaches. The research program is schematically presented in Fig. 1, which consists of five *phases*. In *phases* 1 and 2, the most important challenges are identified, and in phases 3 to 5, all detected challenges are ranked. In the following, each *phase* is described separately.

Phase One (Identifying PMs' Challenges)

In *Phase One*, a total of 64 relevant papers were reviewed by applying a forward-chaining approach. In order to classify the chosen papers, it is interesting to note that 50% of the papers were published between 2016 and 2022, 23% of which were published between 2010 and 2015, and the others were published between 2002 and 2009. In this *phase*, a total of 67 challenges were identified during a comprehensive literature review.

Phase Two (Selecting the Main PMs Challenges)

In *Phase Two*, the unique challenges were designated from the identified challenges based on their considerable effects on project objectives (time, cost, quality, and HSSE). For this purpose, a *focus group method* was adopted. A *focus group* refers to a controlled group discussion that intends to obtain perceptions on specific topics in a defined environment (Krueger 2014; Leung et al. 2014).

Although the number of participants in a focus group should be between 2 and 20 (Breakwell et al. 2006; Liang et al. 2018), 5–10 participants are optimal to create a balance between depth and breadth of data collection (Beyea and Nicoll 2000; Breakwell et al. 2006; Leung and Chan 2012; Liang et al. 2018). In addition, a small group size allows each participant more time to express their opinions and ideas (Liang et al. 2018). Hence, the current study recruited a focus group consisting of the authors and three educated

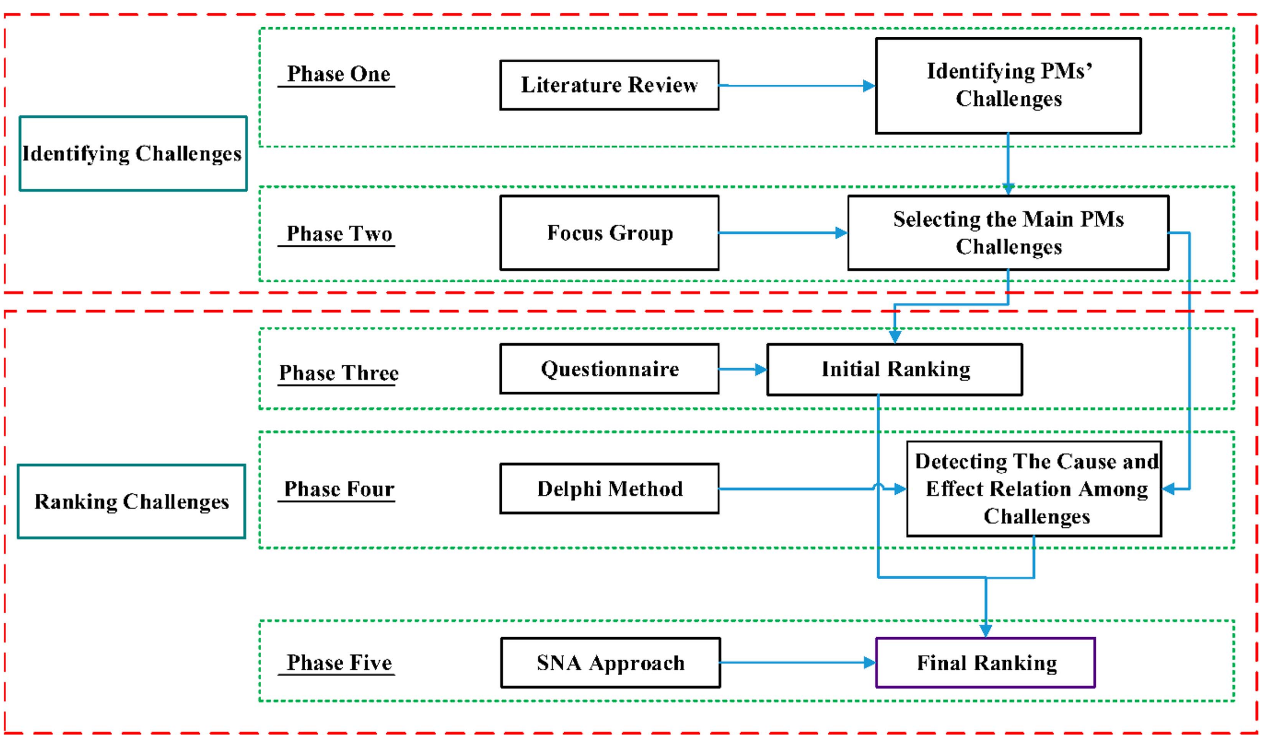

Fig. 1. Research program.

PMs with more than 10 years of experience (overall, 6 participants plus 1 coordinator). The output of *Phase Two* is a set of 49 challenges (Table 1).

Next, these challenges were categorized into 12 groups: (1) Managerial, (2) Procurement, (3) Personal skill, (4) Financial, (5) HSSE, (6) Technical, (7) Workforce, (8) Organizational, (9) Design, (10) Consultant, (11) Psychological, and (12) External. Notably, the detected challenges were revised and some items were merged wherever possible. Table 1 summarizes the selected PMs' challenges in the implementation phase in the construction industry. Also, the frequency of each challenge in the literature is presented in Fig. 2.

Phase Three (Determining the Importance of Each Challenge Independently)

The main objective of this phase was to determine the level of importance of each challenge, assuming that all identified challenges are independent. For this purpose, a Likert-based questionnaire was designed. The three most common Likert scales are: 1–5, 1–7, and 1–10 (Dawes 2008), but it has to be mentioned that most scholars agree that, at a minimum, a 5-point Likert scale survey is sufficient for accurate data gathering, although studies are proving that the more choices there are, the less often respondents use the middle or neutral category (Jebb et al. 2021). Dawes (2008) stated that if a

Table 1. Summary of literature review regarding the detection of PM challenges

Code	Category	Challenges	Reference
CH-1	Managerial	Delay in project deliveries	Shehu and Akintoye (2010), Milosevic et al. (2009), Cicmil et al. (2006), Yadollahi et al. (2014), and Abbasi et al. (2020)
CH-2	Managerial	Lack of coordination between tasks	Shehu and Akintoye (2010), Milosevic et al. (2009), Cicmil et al. (2006), and Yadollahi et al. (2014)
CH-3	Managerial	Improper training method for personnel	Shehu and Akintoye (2010) and Yadollahi et al. (2014)
CH-4	Managerial	Conflict in project objectives	Shehu and Akintoye (2010), Hewage et al. (2008), and Yadollahi et al. (2014)
CH-5	Managerial	Inappropriate constructionSequence	Chua et al. (2003), Yitmen (2007), Sexton and Barrett (2004), and Yadollahi et al. (2014)
CH-6	Procurement	Poor selection of subcontractor	Chua et al. (2003) and Yadollahi et al. (2014)
CH-7	Managerial	Inappropriate and unrealistic scheduling	Hwang et al. (2009), Yadollahi et al. (2014), Abbasi et al. (2020), Odeh and Battaineh (2002), Assaf and Al-Hejji (2006), Sambasivan and Soon (2007), Fallahnejad (2013), and Gardezi et al. (2014)
CH-8	Managerial	Lack of coordination between machinery equipment and the type of executive operation	Abbasi et al. (2020), Frimpong et al. (2003), Odeh and Battaineh (2002), Sambasivan and Soon (2007), Doloi et al. (2012), Kasimu and Isah (2012), and Gardezi et al. (2014)
CH-9	Managerial	Concurrent design and implementation	Abbasi et al. (2020), Orangi et al. (2011), Odeh and Battaineh (2002), Sambasivan and Soon (2007), Doloi et al. (2012), and Assaf and Al-Hejji (2006)
CH-10	Managerial	Lack of coordination and relationships between subcontractors	Abbasi et al. (2020) and Assaf and Al-Hejji (2006)
CH-11	Managerial	Unrealistic estimation of cost	Gardezi et al. (2014), Fallahnejad (2013), Abbasnejad and Izadi Moud (2013), Wong and Vimonsatit (2012), Zewdu (2016), Fugar and Agyakwah-Baah (2010), Nyoni and Bonga (2017), and Abbasi et al. (2020)
CH-12	Managerial	Ethical issues among project managers and stakeholders	Abbasi et al. (2020) and Sambasivan and Soon (2007)
CH-13	Managerial	Poor planning	Leung et al. (2008), Shehu and Akintoye (2010), Milosevic et al. (2009), Cicmil et al. (2006), Yadollahi et al. (2014), Zidane and Andersen (2018), Durdyev et al. (2017), Adeyemi and Masalila (2016), Oshungade (2016), Bagaya and Song (2016), Gunduz et al. (2016), and Sanni-Anibire et al. (2022)
CH-14	Personal skill	Poor communication in project	Liao (2007), Chua et al. (2003), Yitmen (2007), Sexton and Barrett (2004), Hewage et al. (2008), Hellmund et al. (2008), Gorse and Emmitt (2007), Yadollahi et al. (2014), Abbasnejad and Izadi Moud (2013), Kim and Tuan (2016), and Oshungade (2016)
CH-15	Personal skill	Poor decision making	Liao (2007), Chua et al. (2003), Yadollahi et al. (2014), Abbasi et al. (2020), Frimpong et al. (2003), Odeh and Battaineh (2002), Assaf and Al-Hejji (2006), Sambasivan and Soon (2007), Zidane and Andersen (2018), Wong and Vimonsatit (2012), Doloi et al. (2012), Elawi et al. (2015), and Gunduz et al. (2016)
CH-16	Personal skill	Lack of commitment	Shehu and Akintoye (2010), Yadollahi et al. (2014), and Zidane and Andersen (2018)
CH-17	Personal skill	Lack of trust	Yitmen (2007), Sexton and Barrett (2004), and Yadollahi et al. (2014)
CH-18	Financial	Inadequate payment	Hwang et al. (2009) and Yadollahi et al. (2014)
CH-19	Financial	Problems in payment of subcontractor/personnel salaries	Abbasi et al. (2020), Fallahnejad (2013), Frimpong et al. (2003), Odeh and Battaineh (2002), Sambasivan and Soon (2007), and Gardezi et al. (2014)

Table 1. (*Continued*.)

Code	Category	Challenges	Reference
CH-20	Financial	Contractors'/subcontractors' financial difficulties	Wong and Vimonsatit (2012), Nyoni and Bonga (2017), Fallahnejad (2013), Doloi et al. (2012), Frimpong et al. (2003), Koushki et al. (2005), Bagaya and Song (2016), and Gunduz et al. (2016)
CH-21	Financial	Fluctuation rate and economic instability	Shehu and Akintoye (2010), Yadollahi et al. (2014), Abbasi et al. (2020), Orangi et al. (2011), Frimpong et al. (2003), and Sambasivan and Soon (2007)
CH-22	HSSE	Safety issues and unsafe conditions	Haupt and Harinarain (2016), Jatarona et al. (2016), Yap and Skitmore (2018), Liao (2007), and Yadollahi et al. (2014)
CH-23	HSSE	Prevalence of infectious and contagious diseases (i.e., COVID-19)	Alicandro et al. (2020) and Wang et al. (2020)
CH-24	HSSE	Bad weather condition	Bagaya and Song (2016), Durdyev et al. (2017), Santoso and Soeng (2016), Koushki et al. (2005), and Zewdu (2016)
CH-25	HSSE	Environmental pollution	Liang et al. (2019) and Ning et al. (2019)
CH-26	Technical	Complexities in the construction process	Shehu and Akintoye (2010), Chua et al. (2003), Tatum (2012), and Yadollahi et al. (2014)
CH-27	Technical	Unfamiliar technology	Zhang et al. (2011), Hewage et al. (2008), Tatum (2012), and Yadollahi et al. (2014)
CH-28	Managerial	Defects in controlling the project schedule	Abbasi et al. (2020), Frimpong et al. (2003), Sambasivan and Soon (2007), Orangi et al. (2011), and Doloi et al. (2012)
CH-29	Technical	Rework	Abbasi et al. (2020), Gardezi et al. (2014), Frimpong et al. (2003), and Heravi and Mohammadian (2021)
CH-30	Workforce	Poor labor productivity due to a shortage of skills	Abbasi et al. (2020), Gunduz et al. (2016), Wong and Vimonsatit (2012), Doloi et al. (2012), Abbasnejad and Izadi Moud (2013), Durdyev et al. (2017), Adeyemi and Masalila (2016), Oshungade (2016), Santoso and Soeng (2016), Hwang et al. (2009), Yadollahi et al. (2014), Frimpong et al. (2003), Sambasivan and Soon (2007), and Sanni-Anibire et al. (2022)
CH-31	Workforce	Workforce turnover	Ayodele et al. (2020) and Ismail and Varghese (2019)
CH-32	Workforce	Workforce protest and strike in site environment	Taofeeq and Adeleke (2019)
CH-33	Workforce	Diversity issues in construction site	Al-Bayati (2019) and Wu et al. (2019)
CH-34	Organizational	Workforce occupational insurance	Tunji-Olayeni et al. (2019)
CH-35	Organizational	Changes at various levels of management and supervision	Abbasi et al. (2020), Assaf and Al-Hejji (2006), Orangi et al. (2011), and Kasimu and Isah (2012)
CH-36	Organizational	Bureaucracy	Haupt and Harinarain (2016) and Mpofu et al. (2017)
CH-37	Procurement	Unclear contract	Yitmen (2007), Sexton and Barrett (2004), Gorse and Emmitt (2007), Yadollahi et al. (2014), Abbasi et al. (2020), and Assaf and Al-Hejji (2006)
CH-38	Procurement	Contractual claims	Parikh et al. (2019), Parchami Jalal et al. (2019), Zhang et al. (2019), and Heravi and Mohammadian (2021)
CH-39	Procurement	Shortage of resources and materials	Milosevic et al. (2009), Cicmil et al. (2006), Bartlett (2002), Yadollahi et al. (2014), Abbasi et al. (2020), and Zidane and Andersen (2018)
CH-40	Procurement	Failure or poor productivity of equipment	Aziz and Abdel-Hakam (2016), Khoshgoftar et al. (2010), Sambasivan and Soon (2007), Kim and Tuan (2016), and Nyoni and Bonga (2017)
CH-41	Procurement	Poor quality of materials	Abbasi et al. (2020)
CH-42	Design	Design alteration (even after the execution)	Chua et al. (2003), Yadollahi et al. (2014), Abbasi et al. (2020), Frimpong et al. (2003), Sambasivan and Soon (2007), Gardezi et al. (2014), Zidane and Andersen (2018), Akogbe et al. (2013), Doloi et al. (2012), Durdyev et al. (2017), Adeyemi and Masalila (2016), Oshungade (2016), Mpofu et al. (2017), Jatarona et al. (2016), and Yap and Skitmore (2018)
CH-43	Design	Drawings with inadequate details	Abbasi et al. (2020), Frimpong et al. (2003), and Fallahnejad (2013)
CH-44	Consultant	Delay in the approval of the completed project sections	Abbasi et al. (2020) and Odeh and Battaineh (2002)
CH-45	Consultant	Poor inspection and supervision	Leung et al. (2008), Yadollahi et al. (2014), Abbasi et al. (2020), and Doloi et al. (2012)
CH-46	Psychological	Stressful atmosphere	Leung et al. (2008) and Yadollahi et al. (2014)
CH-47	Psychological	Time pressure	Yitmen (2007), Sexton and Barrett (2004), Tatum (2012), Hellmund et al. (2008), and Yadollahi et al. (2014)
CH-48	External	Governance policy and issues (i.e., political instability)	Chua et al. (2003), Yadollahi et al. (2014), Oshungade (2016), and Gardezi et al. (2014)
CH-49	External	External stakeholder's issues (i.e., local resident problems)	Fallahnejad (2013) and Frimpong et al. (2003)

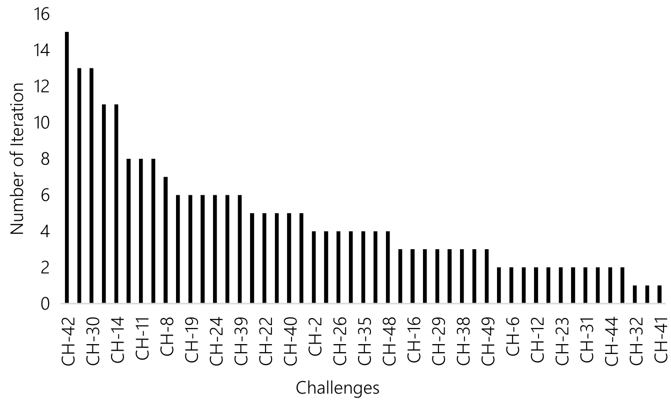

Fig. 2. Number of iterations of each challenge in literature.

multiitem scale with more response options was administered, respondents did use more response options. So, in order to increase the accuracy of the data-gathering process, a 10-point Likert scale was used. In this survey, PMs are asked to determine the level of importance of each challenge. For this aim, a 10-point Likert scale was used, in which a level of "10" referred to the most important, and "1" referred to the least important.

In a common Likert-based questionnaire, respondents are asked to answer all questions. Although several missed data items exist in each questionnaire, they are substituted by median or mode values. In this research, for each challenge, a two-part question is asked of each respondent:

> Have you ever experienced the challenge x? If yes, please determine its relative importance in terms of negatively affecting the project's performance. If not, please move on to the next question.

For sampling, a nonprobability approach based on the snowball technique with stratification was used (Bagaya and Song 2016; Ling and Khoo 2016; Yap et al. 2019). Overall, 136 construction PMs were approached, 108 of whom (79% ratio) accepted to participate in this survey. In Table 2, the demographic characteristics of respondents are reported.

Then, in order to obtain accurate and honest augmented questionnaires, unlike e-surveys or postal ones, each questionnaire was physically delivered to the experts. Also, a short open-ended interview (around 10 to 15 min) was done with each of the experts (a qualitative interview) in order to increase the respondents' interest in fulfilling the questionnaire as well as find the point where little new information is obtained (Weller et al. 2018).

It is worth mentioning that establishing a friendly atmosphere as well as conducting reliability checks in each conversation led to the rise of several useful points that were used in checking the validity and reliability of the questionnaire (Cohen et al. 2017). Conducting these interviews helped the authors better understand the challenges of managing construction projects. In the following, several frequent questions for interviews with participants are shown:

- *"How do you feel about this questionnaire?"*
- *Do you think the challenges were chosen correctly? If this questionnaire does not satisfy you, based on your opinion, which of them can be omitted or which challenges have to be added?*
- *"Based on your experience in construction projects (residential, building, or infrastructure), what are the main challenges in this industry?"*
- *"What are the main reasons for occurring challenge x, y, ... (the most important challenges based on the participant's opinion) in the construction projects?"*

Table 2. Demographic characteristics of respondents

Demographic characteristic	Frequency	Percentage
Gender		
Male	103	95
Female	5	5
	108	100
Education		
Preuniversity	2	2
University	59	55
Postgraduate	47	43
	108	100
Level of experience in the construction industry		
2–5 years	18	17
6–10 years	29	27
11–15 years	22	20
16–20 years	18	17
More than 20 years	21	19
	108	100
Level of experience as a project manager		
Less than 2 years	9	8
2–5 years	54	50
6–10 years	27	25
11–15 years	11	10
16–20 years	3	3
More than 20 years	4	4
	108	100
Fields of specializations		
Residential	32	30
Building	37	34
Infrastructure	39	36
	108	100
Level of project management position		
Junior supervisor	28	26
Senior supervisor	24	22
Project manager	42	39
Project/program director	14	13
	108	100

Also, in order to apply a quantitative method for measuring the reliability and accuracy of the questionnaire, the retest method was applied. This method involves presenting a test more than once to a portion of a statistical population tested under the same conditions and requirements. For this purpose, to calculate the reliability coefficient, the questionnaire was delivered twice to a group of 25 experts over a 14-day period. Then, the results of the two tests were compared with each other and reported as the reliability coefficient. The *Pearson* correlation coefficient [Eq. (1)] is used to calculate the numerical reliability coefficient of the questionnaire where x and y are random variables, $\mathrm{cov}(x, y)$ is the *covariance*, and "δ" is the *standard deviation*

$$\mathrm{r}_{xy} = \frac{\mathrm{cov}(x, y)}{\delta_x \delta_y} = \frac{\sum(x\text{-}\bar{x})\sum(y\text{-}\bar{y})}{\sqrt{(x\text{-}\bar{x})^2}(y\text{-}\bar{y})^2} \tag{1}$$

A r_{xy} closer to one reflects higher reliability. In this research, the *Pearson* correlation coefficient was determined to be 0.83, meaning that the mentioned questionnaire had sufficient and acceptable reliability.

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Table 3. Profile of panelists in the Delphi method

ID	Experience as a PM (year)	Education level	Role	Organization experiences	Fields of experience
Panelist 1	11	Ph.D.	Academic/project manager	University/consultant	Residential/buildings
Panelist 2	6	M.S	Site manager	Construction contractor	Residential
Panelist 3	7	B.S	Site manager	Construction contractor	Residential/buildings
Panelist 4	15	B.S	Site manager	Construction contractor	Residential/buildings
Panelist 5	10	B.S	Site manager	Construction contractor	Residential/buildings
Panelist 6	10	Ph.D.	Academic/project manager	University/consultant	Residential/buildings
Panelist 7	12	M.S	Site manager	Construction contractor	Buildings
Panelist 8	8	M.S	Site manager	Construction contractor	Buildings
Panelist 9	10	M.S	Project manager	Construction contractor	Buildings
Panelist 10	7	Ph.D.	Academic/project manager	University/consultant	Residential
Panelist 11	35	Preuniversity	Project manager	Construction contractor	Infrastructure
Panelist 12	8	Ph.D.	Academic/project manager	University/consultant	Infrastructure
Panelist 13	6	M.S	Site manager	Consultant	Residential/buildings
Panelist 14	6	M.S	Project manager	Construction contractor	Buildings
Panelist 15	20	B.S	Project manager	Consultant	Buildings/infrastructure
Panelist 16	11	B.S	Project manager	Construction contractor	Residential/buildings
Panelist 17	13	B.S	Project manager	Construction contractor	Residential/buildings
Panelist 18	12	B.S	Project manager	Consultant	Buildings/infrastructure
Panelist 19	19	B.S	Project manager	Construction contractor	Infrastructure
Panelist 20	23	B.S	Project manager	Construction contractor	Infrastructure

Phase Four (Determining the Cause-and-Effect Relationship among Challenges)

In this *phase* (Fig. 1), the interaction and relationship between challenges were determined using a structured *Delphi* method. Originally, this method was used in order to gain consensus opinions from the subject matter experts in two or three rounds (Murray 1979; Simmons et al. 2020). In this study, 20 panelists who had an average of 12.5 years of experience as PM in the construction sector, participated. The description of the panelists is reported in Table 3.

In order to detect the interaction among the 49 identified challenges, the participants were asked to answer the survey question:

> Based on your experience, to what extent could the occurrence of challenge 'A' result in the occurrence of challenge 'B'?

For this purpose, 2401 binary relationships (a 49 × 49 matrix of challenges) among challenges had to be determined. It is worth noting that a quantitative approach based on massive data gathering probably resulted in less accuracy. Therefore, to downsize the number of relationships, the authors took a primary evaluation in order to omit the irrelevant relationships and improve the respondents' concentration and the quality of their answers. In this effort, 2071 binary relations were distinguished as irrelevant (based on engineering judgment and focus group), so only 330 binary relationships are qualified, which are formatted in 15 tables, and a Likert-based scale, similar to that explained in the section "Phase Three," was used. It is noteworthy that the reliability of the *Delphi* questionnaire was calculated based on Eq. (1) and the contributions of six panelists at 14-day intervals. The *Pearson* correlation coefficient for this *phase* was 0.73. Considering the huge number of questions (330) as well as the extensive range for the *Likert scale* (1, 10), the calculated amount for the *Pearson* correlation coefficient can be acceptable for this questionnaire.

Phase Five (Developing the Ranking Model)

In this study, a quantitative model based on the SNA approach is implemented to provide a chance for semi-automatically detecting chains of cause-and-effect in the constructed data set. For this purpose, three different networks are built from the available data. In the following, the mentioned networks are described comprehensively.

Network A (Determining the Importance of Each Challenge Independently): This network is a weighted graph where nodes are respondents (X_i) and challenges (Y_i) that are directed (Fig. 3). It is expected to retrieve the initial ranking for a set of challenges (Y).

The value of weighted in-degree centrality for challenge x is calculated according to Eq. (2)

$$C_{\mathrm{WID}}(x) = \sum_{i=1}^{n} W_{ix} \tag{2}$$

where W_{ix} = weight for a link between respondent i and challenge x.

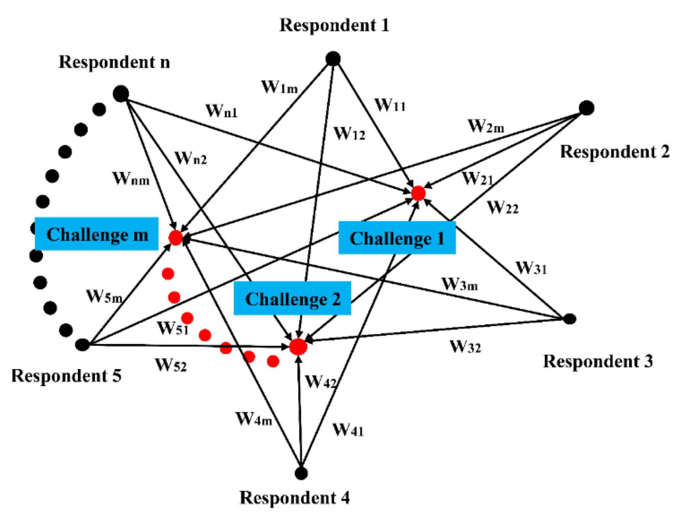

Fig. 3. The graphical form of Network **A**.

Also, to normalize the obtained values, a new term is defined for calculating the relative weighted in-degree centrality in percentage, as shown in Eq. (3):

$$C_{\mathrm{RWID}}(x) = \frac{\sum_{i=1}^{n} W_{ix}}{\sum_{j=1}^{m}\sum_{i=1}^{n} W_{ij}} \times 100 \tag{3}$$

where W_{ij} = weight for a link between respondent i and challenge j.

Network B (Determining the Cause-and-Effect Relationship among Challenges): In a similar approach, the interaction among challenges is calculated based on the network's values. In this network, all links are considered directed and weighted. In graph concepts, there is no necessity for equality of W_{ij} with W_{ji} due to different levels of node impactability from others. In the present case, relative weighted in-degree centrality (C_{RWID}) indicates the authority in the network which helps in detecting the most powerful variables among a group. As well, by defining relative weighted out-degree centrality (C_{RWOD}) in the same effort as defining C_{RWID}, the most dependent challenges could be detected. In other words, calculating C_{RWID} and C_{RWOD} reveals the main causes and effects, respectively. The values of both weighted in- and out-degree centralities as well as relative weighted in- and out-degree centralities for challenge x are calculated by Eqs. (4)–(7), respectively

$$C_{\mathrm{WID}}(x) = \sum_{i=1}^{n} W_{ix} \tag{4}$$

where W_{ix} = weight for a link between challenge i and challenge x

$$C_{\mathrm{WOD}}(x) = \sum_{j=1}^{m} W_{xj} \tag{5}$$

where W_{xj} is weight for a link between respondent x and challenge j

$$C_{\mathrm{RWID}}(x) = \frac{\sum_{i=1}^{n} W_{ix}}{\sum_{j=1}^{m}\sum_{i=1}^{m} W_{ij}} \times 100 \tag{6}$$

$$C_{\mathrm{RWOD}}(x) = \frac{\sum_{j=1}^{m} W_{xj}}{\sum_{i=1}^{m}\sum_{j=1}^{m} W_{ij}} \times 100 \tag{7}$$

where W_{ij} = weight for a link between respondent i and challenge j; and m = total number of challenges.

Also, based on the definition of both betweenness and closeness centralities and adjusting these definitions to challenges, it is deduced that both terms refer to the middle role of challenges, which could be interpreted as the "most likely to happen" challenges with respect to detecting the cause-effect interaction among challenges network. The graphical form of Network **B** is presented in Fig. 4.

Network C (Developing the Ranking Model): To calculate the final ranking of challenges, the graphical model shown in Fig. 5 is used. As can be seen, in this network, both Network **A** and Network **B** were considered. It should be pointed out that by considering the weight of each network (**A** and **B**), when increasing the number of respondents, the impact of Network **A** on the final outcome would increase as well. Hence, it seems that before the final ranking of a group of variables, the weight of each network has to be defined. For this aim, a correction factor CF was proposed, which is throughout calculated according to Eq. (8) and multiplied in all weights in Network **B**:

$$CF = \frac{TN_R \times M_{\mathrm{WRVQ}} \times W_R}{(TN_v - 1) \times M_{\mathrm{WINV}} \times (1 - W_R)} \tag{8}$$

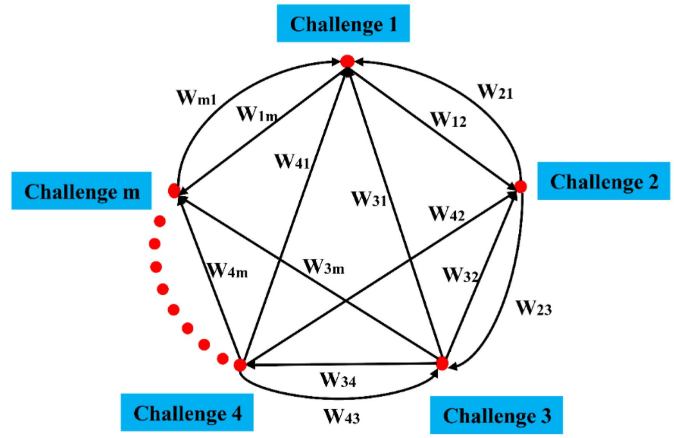

Fig. 4. The graphical form of Network **B**.

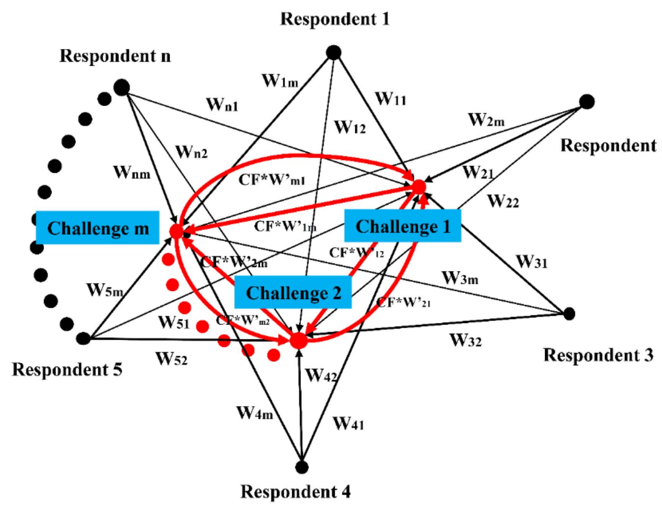

Fig. 5. The graphical form of Network **C**.

where TN_R = total number of respondents; TN_v = total number of variables; M_{WRVQ} = maximum possible weight in the respondent's viewpoint questionnaire; M_{WINV} = maximum possible weight in the interaction network of variables; and W_R = total weight of the interaction network of variables in the final ranking.

In the present study, the same weight is considered for Network A and Network B ($W_R = 0.5$). Therefore, by considering 108 respondents and 49 challenges as well as considering both M_{WRVQ} and $M_{\mathrm{WINV}} = 10$, the CF was calculated to be 2.25.

After the formation of Network **C**, in order to overcome the complexity of interpreting a large volume of data as well as increase the level of applicability of the model, a unique criterion needs to be defined to rank all variables. For this aim, three main network parameters, weighted in-degree centrality, betweenness centrality, and closeness centrality, are considered criteria for ranking. The ranking criterion (RC) could be formulated as shown in Eq. (9):

$$RC = \alpha C_{\mathrm{RWID}}(\%) + \beta C_{RB}(\%) + \gamma C_{CC}(\%) \tag{9}$$

where RC = ranking criterion; $C_{\mathrm{RWID}}(\%)$ = relative weighted in-degree centrality; $C_{RB}(\%)$ = relative betweenness centrality; $C_{CC}(\%)$ = relative closeness centrality; and α, β, and γ = coefficient for which $\alpha + \beta + \gamma = 1.0$.

To determine these coefficients, an *AHP approach* was employed in this research, and a *Delphi technique* was applied for data collection. For this purpose, 14 academic experts specializing in SNA and familiar with the concepts and parameters of social networks were asked to participate as panelists in this research. The *Delphi technique* was run in two rounds, and after all requirements were satisfied, the amount of each coefficient was calculated. In Eq. (10), the RC with all the mentioned coefficients is shown

$$RC = 0.713C_{\text{RWID}}(\%) + 0.196C_{RB}(\%) + 0.091C_{CC}(\%) \quad (10)$$

As it can be seen, among all coefficients, C_{RWID} (%) has the highest amount and $C_{\text{CC}}(\%)$ has the lowest one. This means that although both betweenness and closeness centralities show the level of importance of each node in the network, weighted in-degree centrality has a noticeably higher weight in Eq. (10) based on the panelists' opinions.

In order to interpret the data set, *Gephi* (Bastian et al. 2009) is employed for the graphic representation and visualization of the networks. It is noteworthy that *Gephi* is not capable of calculating a weighted and directed network. For this reason, the *Python programming language* is employed to analyze and evaluate different SNA terms.

Results

In this section, the interpretation of data is discussed for each network.

Network A

The obtained amount of relative weighted in-degree centrality ($C_{\text{RWID}}(\%)$) and both the mean and standard deviation (*SD*) for each challenge in Network A are presented in Table 4. Based on the obtained results, the participants chose challenges CH-21 (fluctuation rate and economic instability), CH-20 (contractors'/subcontractors' financial difficulties), CH-19 (problems in payment of subcontractor/personnel salaries), CH-1 (delay in project deliveries), Ch-39 [shortage of resources and materials), CH-47 (time pressure), CH-42 (design alteration (even after the execution)], CH-2 (lack of coordination between tasks), CH-6 (poor selection of subcontractor), and CH-13 (poor planning) as the top 10 challenges construction PMs usually face. It is noteworthy that all variables in Network **A** were considered independent, in line with the previous studies. These results revealed that the financial challenges (CH-21, CH-20, and CH-19) are the major concerns of PMs who work in the Iranian construction sector (based on Network **A**).

Network B

In Table 5, the ranking of all challenges based on *RC* as well as $C_{\text{RWOD}}(\%)$ (Relative weighted out-degree centrality) for Network **B** is shown. Moreover, in Fig. 6, the formation of Network **B** based on weighted in-degree centrality is presented.

The results suggest that based on the cause-effect relationship among challenges, CH-13 (poor planning), CH-20 (contractors'/subcontractors' financial difficulties), CH-15 (poor decision making), CH-21 (fluctuation rate and economic instability), and CH-14 (poor communication in projects) are the top five challenges. In other words, the aforementioned five challenges play an undeniable role in the occurrence of other challenges, such that 33 challenges have a direct relationship with poor planning (CH-13). On the other hand, based on $C_{\text{RWOD}}(\%)$, CH-1 (delay in project deliveries), CH-38 (contractual claims), CH-29 (rework), CH-46 (stressful atmosphere), and CH-47 (time pressure), were the top five challenges that were highly responsible for the occurrence of other challenges. In simple words, it is concluded that the mentioned challenges occur in construction projects with a high probability. It is interesting to note that delays in project deliveries are related to 23 of the other challenges.

Table 4. Analysis of Network **A**

No.	Challenge	C_{WID}	$C_{\text{RWID}}(\%)$	Mean	SD	No.	Challenge	C_{WID}	$C_{\text{RWID}}(\%)$	Mean	SD
1	CH-21	928	2.77	8.67	1.26	26	CH-23	681	2.03	6.55	1.28
2	CH-20	815	2.43	7.55	1.34	27	CH-48	681	2.03	6.95	2.79
3	CH-19	791	2.36	7.46	1.74	28	CH-5	676	2.02	6.83	1.83
4	CH-1	790	2.36	7.45	1.33	29	CH-4	675	2.02	6.8	1.63
5	CH-39	778	2.32	7.27	1.39	30	CH-36	673	2.01	6.66	1.70
6	CH-47	776	2.32	7.25	1.67	31	CH-41	672	2.01	6.72	1.72
7	CH-42	768	2.29	7.24	1.79	32	CH-31	671	2	6.39	1.34
8	CH-2	763	2.28	7.27	1.96	33	CH-40	670	2	6.57	1.63
9	CH-6	762	2.28	7.2	2.17	34	CH-12	666	1.99	6.87	1.89
10	CH-13	762	2.28	7.26	1.71	35	CH-35	662	1.98	6.62	1.74
11	CH-16	761	2.27	7.18	1.65	36	CH-9	648	1.94	6.48	1.24
12	CH-43	759	2.27	7.16	0.98	37	CH-14	642	1.92	6.29	1.53
13	CH-11	753	2.25	7.17	1.79	38	CH-28	642	1.92	6.17	1.92
14	CH-18	753	2.25	7.1	1.45	39	CH-10	629	1.88	5.99	1.39
15	CH-44	742	2.22	7	2.06	40	CH-37	625	1.87	6.44	1.24
16	CH-7	741	2.21	6.93	1.67	41	CH-24	624	1.86	5.83	1.37
17	CH-3	740	2.2	6.9	1.86	42	CH-8	597	1.78	5.97	1.36
18	CH-30	732	2.19	6.91	1.73	43	CH-34	588	1.76	5.94	1.24
19	CH-15	716	2.14	6.69	1.83	44	CH-32	540	1.61	5.75	1.13
20	CH-29	710	2.12	6.7	1.65	45	CH-26	527	1.57	5.38	1.14
21	CH-46	698	2.08	6.78	1.49	46	CH-49	523	1.56	5.56	1.52
22	CH-22	693	2.07	6.48	1.50	47	CH-25	471	1.41	5.12	1.17
23	CH-45	688	2.06	6.75	1.88	48	CH-27	463	1.38	5.38	1.23
24	CH-17	684	2.04	6.45	1.63	49	CH-33	448	1.34	4.62	1.23
25	CH-38	684	2.04	6.77	1.90						

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Table 5. Final ranking of variables based on Network **C**

No.	Code	Challenges	*RC* (Network C)	Ranking based on $C_{\mathrm{RWID}}(\%)$ in Network A	Ranking based on RC in Network B	Ranking based on $C_{\mathrm{RWOD}}(\%)$ in Network B
1	CH-13	Poor planning	5.856	10	1	8
2	CH-20	Contractors'/subcontractors' financial difficulties	4.077	2	2	15
3	CH-15	Poor decision making	3.581	19	3	7
4	CH-47	Time pressure	2.981	6	6	5
5	CH-29	Rework	2.904	20	15	3
6	CH-46	Stressful atmosphere	2.659	21	13	4
7	CH-42	Design alteration (even after the execution)	2.579	7	7	19
8	CH-31	Workforce turnover	2.571	32	18	6
9	CH-21	Fluctuation rate and economic instability	2.544	1	4	39
10	CH-7	Inappropriate and unrealistic scheduling	2.464	16	10	18
11	CH-14	Poor communication in project	2.423	37	5	32
12	CH-19	Problems in payment of subcontractor/personnel salaries	2.392	3	14	17
13	CH-16	Lack of commitment	2.35	11	8	12
14	CH-38	Contractual claims	2.318	25	22	2
15	CH-35	Changes at various levels of management and supervision	2.296	35	16	10
16	CH-18	Inadequate payment	2.288	14	9	24
17	CH-1	Delay in project deliveries	2.137	4	29	1
18	CH-11	Unrealistic estimation of cost	2.062	13	19	14
19	CH-12	Ethical issues among project managers and stakeholders	2.043	34	20	11
20	CH-2	Lack of coordination between tasks	1.93	8	26	31
21	CH-30	Poor labor productivity due to a shortage of skills	1.919	18	28	9
22	CH-45	Poor inspection and supervision	1.864	23	11	—
23	CH-37	Unclear contract	1.81	40	17	28
24	CH-40	Failure or poor productivity of equipment	1.735	33	32	23
25	CH-22	Safety issues and unsafe conditions	1.721	22	39	22
26	CH-6	Poor selection of subcontractor	1.72	9	30	13
27	CH-39	Shortage of resources and materials	1.719	5	31	—
28	CH-44	Delay in the approval of the completed project sections	1.718	15	41	27
29	CH-43	Drawings with inadequate details	1.697	12	36	42
30	CH-5	Inappropriate construction sequence	1.688	28	24	30
31	CH-10	Lack of coordination and relationships between subcontractors	1.679	39	43	35
32	CH-34	Workforce occupational insurance	1.666	43	27	36
33	CH-48	Governance policy and issues (i.e., political instability)	1.628	27	23	—
34	CH-41	Poor quality of materials	1.623	31	33	16
35	CH-3	Improper training method for personnel	1.622	17	34	41
36	CH-17	Lack of trust	1.614	24	35	20
3	CH-36	Bureaucracy	1.599	30	25	—
38	CH-26	Complexities in the construction process	1.575	45	12	40
39	CH-4	Conflict in project objectives	1.544	29	37	21
40	CH-8	Lack of coordination between machinery equipment and the type of executive operation	1.526	42	42	26
41	CH-23	Prevalence of infectious and contagious diseases (i.e., COVID-19)	1.515	26	38	38
42	CH-49	External stakeholder issues (i.e., local resident problems)	1.411	46	44	33
43	CH-28	Defects in controlling the project schedule	1.405	38	46	37
44	CH-9	Concurrent design and implementation	1.401	36		29
45	CH-24	Bad weather condition	1.381	41	40	43
46	CH-32	Workforce protest and strike in the site environment	1.28	44	47	25
47	CH-27	Unfamiliar technology	1.267	48	21	—
48	CH-25	Environmental pollution	1.199	47	45	34
49	CH-33	Diversity issues in construction site	0.971	49	49	—

Network C (Final Ranking)

In Table 5, the ranking of all challenges based on *RC* (Network **C**) is presented. In addition, in Fig. 7, the Network **C** based on weighted in-degree centrality is shown. It has to be noted that due to the large number of respondents (*R* nodes), all respondents were categorized into five nodes based on their level of experience as a PM.

Based on the obtained results, CH-13 (poor planning), CH-20 (contractors'/subcontractors' financial difficulties), CH-15 (poor decision making), CH-47 (time pressure), CH-29 (rework), CH-46 (stressful atmosphere), CH-42 (design alteration), CH-31 (workforce turnover), CH-21 (Fluctuation rate and economic instability), and CH-7 (Inappropriate and unrealistic scheduling) are the top 10 challenges that occur in the construction sector for PMs. In the following, each of these challenges is discussed in more detail.

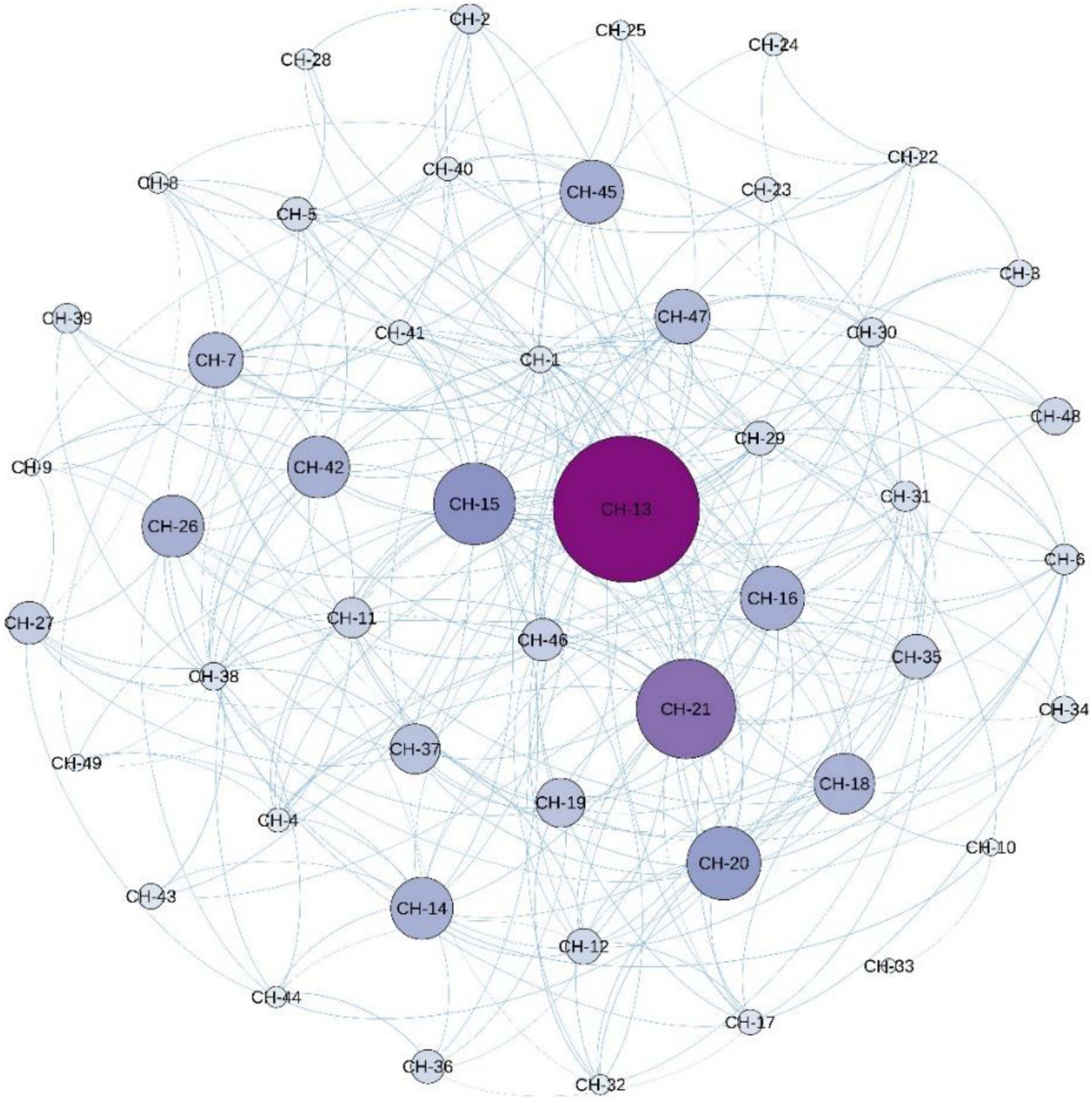

Fig. 6. Network **B** based on weighted in-degree centrality.

Poor Planning

Poor planning has been mentioned in several papers as one of the challenges in the construction sector (Leung et al. 2008; Shehu and Akintoye 2010; Milosevic et al. 2009; Cicmil et al. 2006; Yadollahi et al. 2014; Zidane and Andersen 2018; Durdyev et al. 2017; Adeyemi and Masalila 2016; Oshungade 2016; Bagaya and Song 2016; Gunduz and AbuHassan 2016).

The results of this study suggest that, among all challenges, poor planning was ranked as the most important. It is interesting to note that poor planning was ranked 1st and 10th based on analyzing Networks **B** and **A**, respectively. In other words, considering just the respondents' viewpoints (Network **A**), this challenge was ranked 10th; however, considering the cause-effect relationship among variables, poor planning would be the most critical challenge in the construction sector. Therefore, PMs and researchers in this area have to take this challenge into consideration in order to set a strategic plan. It also suggests that this issue has to be considered seriously by academic researchers in their studies.

Contractors'/Subcontractors' Financial Difficulties

Based on different studies, financial difficulties for contractors are one of the main causes of time delays in construction projects (Wong and Vimonsatit 2012; Nyoni and Bonga 2017; Fallahnejad 2013; Doloi et al. 2012; Frimpong et al. 2003; Koushki et al. 2005; Bagaya and Song 2016; Gunduz and AbuHassan 2016). Surprisingly, this challenge was ranked as the 2nd in all networks. It means that financial challenges still remain a crucial issue in the construction sector.

Poor Decision Making

Decision making is one of the essential competencies for PMs, a weakness that is the root of many problems and challenges in construction project management (Liao 2007; Chua et al. 2003; Yadollahi et al. 2014; Abbasi et al. 2020; Frimpong et al. 2003; Odeh and Battaineh 2002; Assaf and Al-Hejji 2006; Sambasivan and Soon 2007; Zidane and Andersen 2018; Wong and Vimonsatit 2012; Doloi et al. 2012; Elawi et al. 2015; Gunduz and AbuHassan 2016).

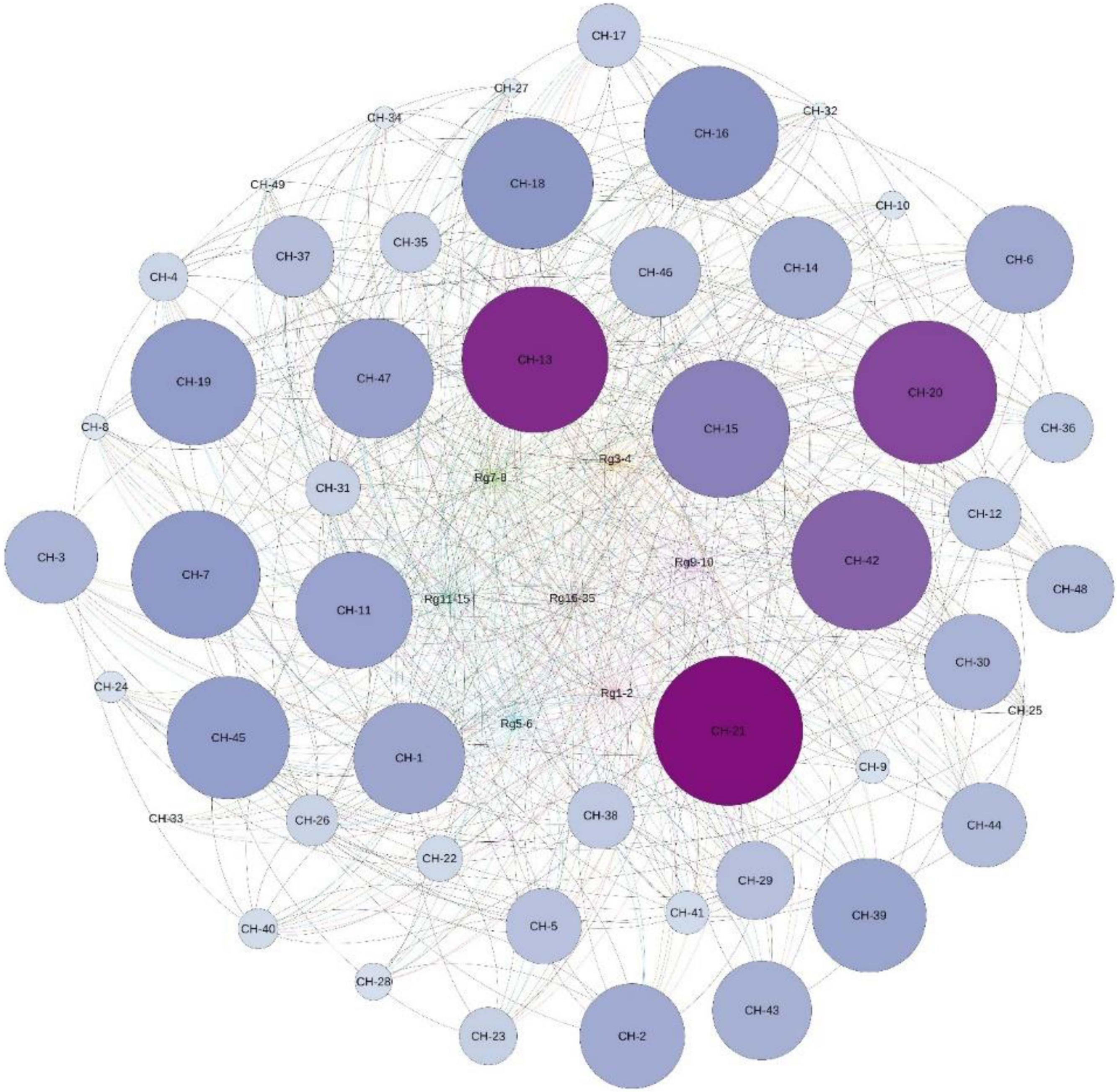

Fig. 7. Network **C**.

Based on the obtained results, poor decision making was ranked 19th and 3rd in Networks **A** and **C**, respectively. In other words, without considering the cause-and-effect relationship among variables, this challenge becomes very insignificant from the viewpoint of the experts. However, according to the ranking model presented in this article, poor decision making is one of the most important challenges that could occur for PMs in the construction sector.

Time Pressure

Given the nature of the construction industry as well as the myriad uncertainties that exist in this sector, time pressure is a routine challenge for project members. Time pressure has many causes and could negatively affect manpower productivity as well as safety management (Yitmen 2007; Sexton and Barrett 2004; Tatum 2012; Hellmund et al. 2008; Yadollahi et al. 2014). This challenge was ranked 4th in the final ranking based on Network **C**.

Rework

Studying rework is one of the most important research areas in construction management knowledge, and so far, several studies have been conducted in order to detect its causes in construction projects (Abbasi et al. 2020; Gardezi et al. 2014; Frimpong et al. 2003). Based on the final ranking, rework was ranked as the fifth challenge. Nonetheless, it is interesting to note that according to networks **A** and **B**, this challenge was very insignificant (ranked 20th and 15th based on Networks **A** and **B**, respectively).

Stressful Atmosphere

A stressful atmosphere in a construction project could reduce the potential capability of the PM. At first glance, it seems that a stressful atmosphere is less important with respect to other challenges, but it is worth mentioning that a stressful atmosphere was ranked as the 6th challenge on the list. This also confirms that the cause-and-effect relationship among variables drastically changed the ranking of the variables.

Design Alteration (Even after the Execution)

Design alteration is one of the most probable challenges that could occur in construction projects. This topic has been discussed in many articles in the last few years (Chua et al. 2003; Yadollahi et al. 2014; Abbasi et al. 2020; Frimpong et al. 2003; Sambasivan and Soon 2007; Gardezi et al. 2014; Zidane and Andersen 2018; Akogbe et al. 2013; Doloi et al. 2012; Durdyev et al. 2017; Adeyemi and Masalila 2016; Oshungade 2016; Mpofu et al. 2017; Jatarona et al. 2016; Yap and Skitmore 2018). Scholars have identified this challenge as one of the main reasons for time and cost overruns in construction projects. It is surprising to note that design alteration was ranked as the 7th challenge in all Networks (**A**, **B**, and **C**).

Workforce Turnover

Workforce turnover occurs in construction projects due to several causes and has been mentioned in several studies (Ayodele et al. 2020; Ismail and Varghese 2019). This challenge was ranked 8th and 32nd based on Network C and Network A, respectively. It means that workforce turnover is one of the hidden issues in the construction sector, and the importance of which was indicated by analyzing the cause-and-effect network of variables.

Fluctuation Rate and Economic Instability

This challenge has been discussed in several papers as one of the main causes of time delays in construction projects (Shehu and Akintoye 2010; Yadollahi et al. 2014; Abbasi et al. 2020; Orangi et al. 2011; Frimpong et al. 2003; Sambasivan and Soon 2007).

Fluctuation rate and economic instability was surprisingly ranked as the 1st challenge based on Network **A**, yet it was ranked as the 9th challenge based on the final ranking model. This conclusion shows that from the experts' viewpoint, fluctuation rate and economic instability is the most significant challenge in the Iranian construction sector, whereas by considering the cause-effect network, several challenges have a higher degree of importance with respect to it. In general, this challenge is mentioned as the most important reason for the failure of construction projects in Iran, but the findings of this research revealed that other challenges, such as poor planning or poor decision making, play a more significant role in the failure of construction projects in Iran.

Inappropriate and Unrealistic Scheduling

Inappropriate and unrealistic scheduling sometimes happens due to a lack of schedule planning and controlling skills. This topic has been mentioned in recent studies as one of the main causes of time and cost overruns in construction projects (Hwang et al. 2009; Yadollahi et al. 2014; Abbasi et al. 2020; Odeh and Battaineh 2002; Assaf and Al-Hejji 2006; Sambasivan and Soon 2007; Fallahnejad 2013; Gardezi et al. 2014). This challenge was ranked 10th in the final ranking based on Network **C**.

Conclusions and Discussion

As discussed earlier, ranking a group of variables in construction-related studies is very common and popular. By searching the scientific portals and journals, many types of research can be found that are conducted based on ranking a group of variables. In the majority of these studies, a questionnaire-based technique is applied for data gathering. In addition, all variables are considered independent. In Fig. 8, this process is shown. As can be seen, statistical analysis via mean and SD is generally used for sorting variables.

In this paper, it was argued that for ranking a group of variables, it is essential to consider the cause-and-effect relationship among variables. In Fig. 9, the process for ranking a group of variables based on cause-and-effect relationships is presented. Cause-and-effect relationships among variables are finally displayed as a directed and weighted network. By using different SNA parameters, this network could be interpreted.

However, the mentioned methods are not accurate enough and are not close to the real situation. For an accurate and reliable ranking of a group of variables, the authors proposed a novel platform

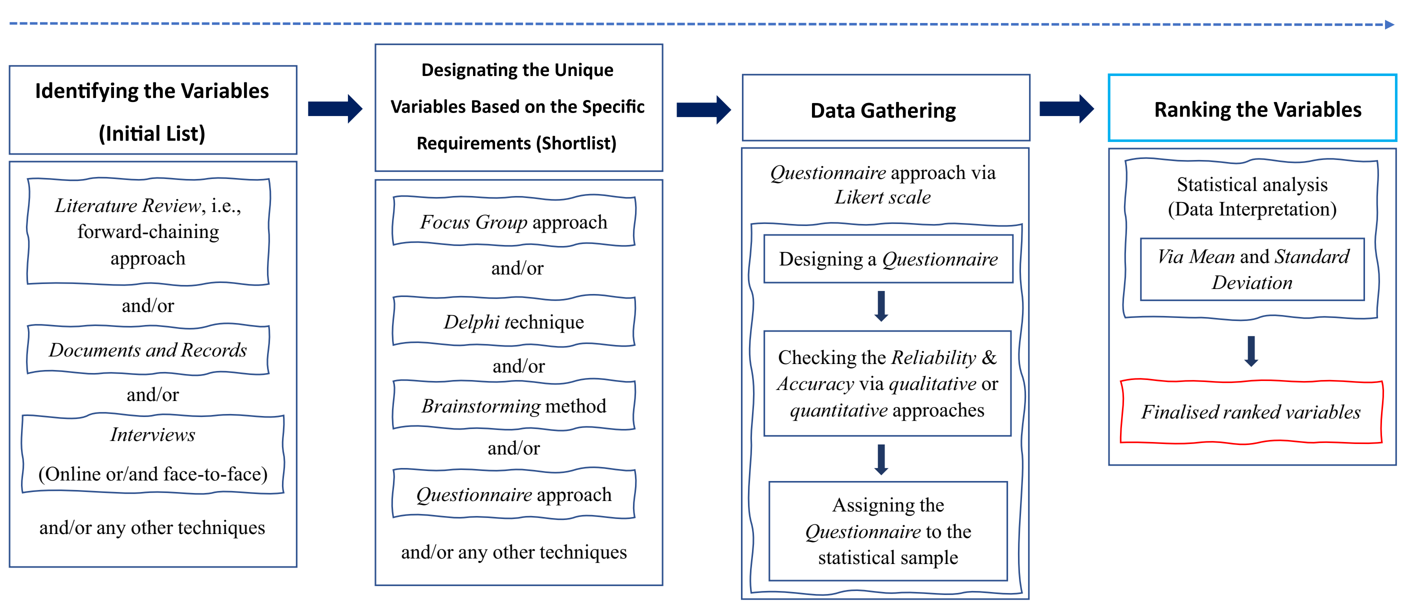

Fig. 8. Traditional approach (statistical method) for ranking a group of independent variables.

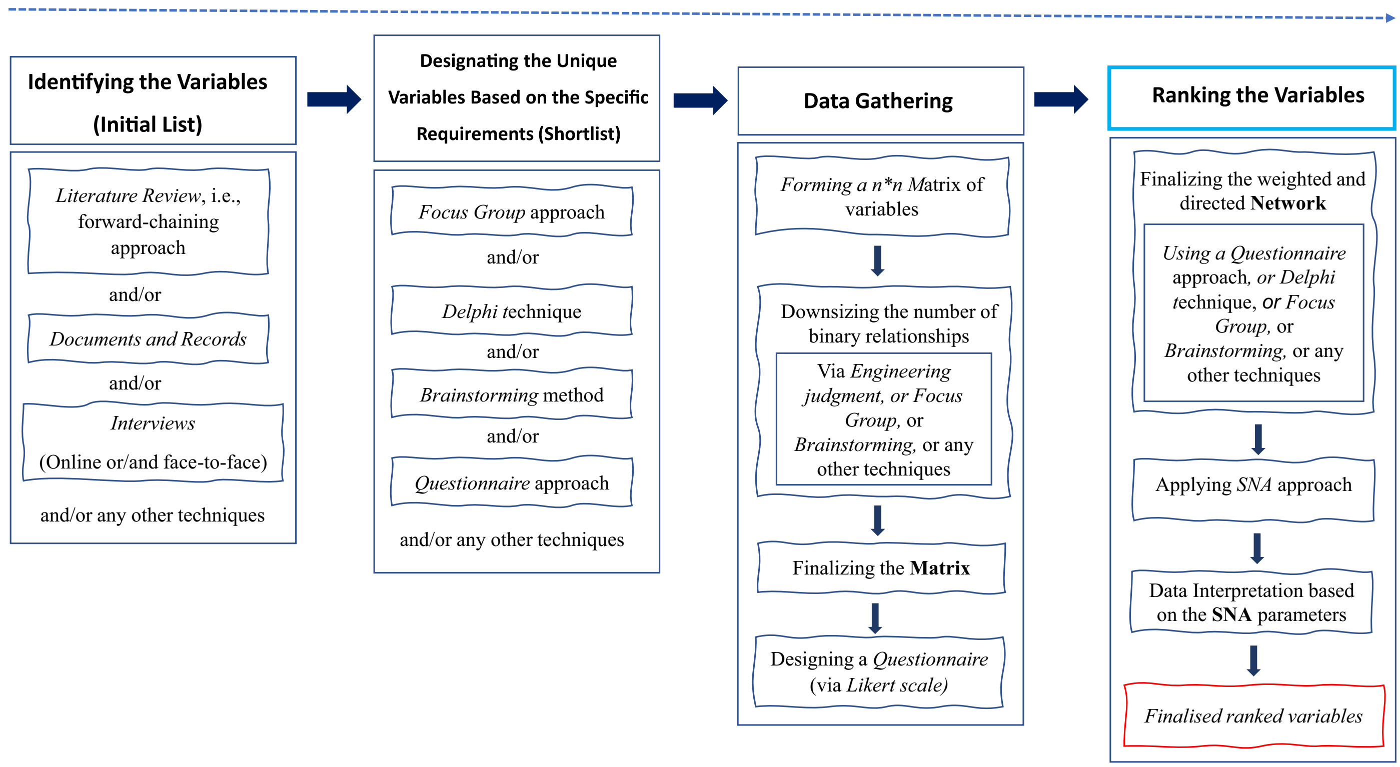

Fig. 9. Ranking a group of variables based on cause-and-effect relationships.

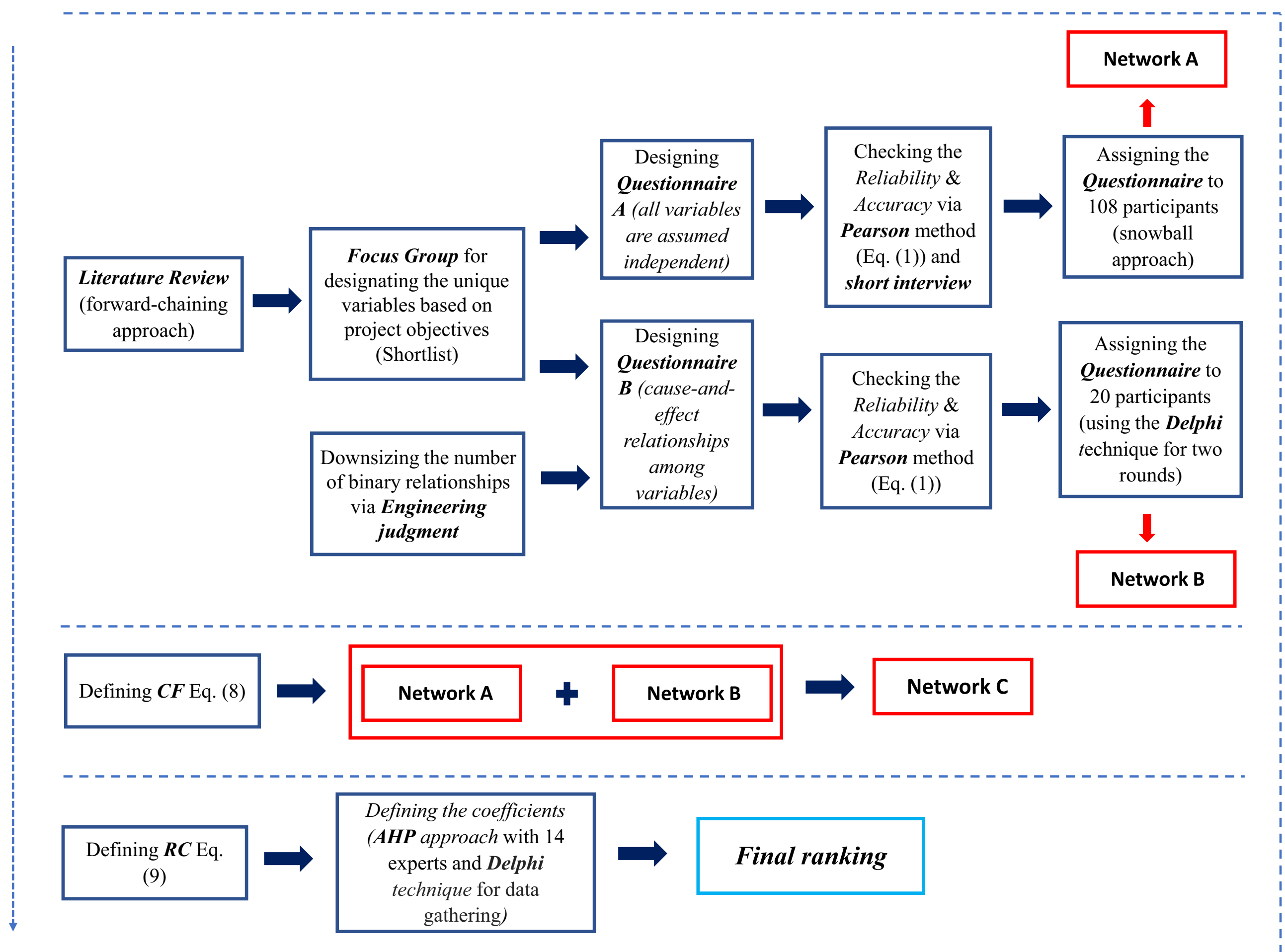

Fig. 10. Summary of all applied techniques.

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by considering both approaches. A summary of all applied techniques in this study is shown in Fig. 10.

As can be seen, a huge amount of effort was put into applying different qualitative and quantitative techniques, as well as the SNA approach, to understand the most reliable and accurate ranking of a group of variables. For this aim, three main parameters in the network analysis are used: weighted in-degree centrality, betweenness centrality, and closeness centrality.

The findings revealed that considering the cause-and-effect relationships among variables resulted in a significantly different ranking, which was closer to the real situation. This model could be used in quantitative-analytical research conducted in the realm of construction projects to obtain more reliable results.

On the other hand, different challenges that could arise for PMs in the construction sector were discussed. The findings of this research revealed that poor planning, contractors'/subcontractors' financial difficulties, poor decision making, time pressure, rework, stressful atmosphere, design alteration, workforce turnover, fluctuation rate and economic instability, and inappropriate and unrealistic scheduling are the top 10 challenges in construction projects. Based on this ranking, a new priority for construction-related studies has appeared. Detecting the causes of poor planning, or the main issues related to planning, or the level of maturity in planning, especially in developing countries, is critical for the construction industry. Moreover, financial issues in developing countries are very common in the construction sector. Working on this topic can help different stakeholders engaged in construction projects gain a deeper understanding.

Limitations

This study highlighted the importance of cause-and-effect relationships among variables in order to rank a group of variables. By comparing Figs. 8 and 10, it can be understood that the proposed approach requires considerably more effort than the traditional approach. In addition, in Eq. (8), the authors calculated the CF by considering 0.5 for W_R. In other words, the authors considered the same weight for both Networks **A** and **B** in the final ranking. Assuming any other amount for W_R, comprehensively, could change the final ranking.

In addition, the RC [Eq. (9)] is specific to this research. For any further investigation based on the proposed approach, this criterion has to be determined based on the research requirements.

Also, it has to be mentioned that as the number of variables increases, the capability of the mentioned approach decreases. Generally, a number of variables not more than 50 is acceptable for this approach. The main issue is that by increasing the number of variables, the number of binary relationships increases severely.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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