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CONSTRUCTION CHANGE ORDER MANAGEMENT PROJECT SUPPORT SYSTEM UTILIZING DELPHI METHOD

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Abstract. Change orders are a major challenge in the construction industry due to the associated time and cost impacts. Thus, managing change effectively assists in alleviating cost overruns and delays. Avoiding change orders and controlling them during project phases requires comprehensive research on the factors affecting the change orders management (COM) performance. This study contributes to existing knowledge by introducing a COM performance measurement framework to help construction professionals evaluate, track, and manage COM performance. A comprehensive literature review, personal meetings, and the Delphi technique are utilized to identify 49 performance factors, categorized into 7 COM groups. 13 Delphi panel members are selected according to purposive sampling technique. The collected data are examined through normality and reliability tests and then analyzed by Spearman's correlation coefficient, score percentage, and the mean to standard deviation ratio to decide whether to continue with the Delphi method. Consensus between the panelists is reached after the second round of Delphi by the utilization of nonparametric statistical tests. The Delphi study results are followed up by measuring the inter-rater agreement (IRA) and ranking the COM performance factors using the sum rank weighting method. Finally, an operational support system framework that takes into consideration the project life cycle of a project is developed to manage and control these factors to decrease disputes between project parties that occur due to improper COM performance.

Keywords: change orders management, Delphi study, construction project management, project success factors, change order risk assessment, planning, project sustainability, key performance indicators, cost overrun, time overrun, risk management.

Introduction

Construction projects are very complex in nature. Each activity involves multiple varying tasks. However, construction industry is the main source of economic growth in every country. When change order occur, performance of projects momentously affected. Al-Kofahi et al. (2020) define change order as "modifications or alterations to pre-existing conditions, assumptions, or requirements". Change orders (also known as variation orders) are common in construction (Shrestha & Fathi, 2019; Kermanshachi et al., 2018; Shrestha & Maharjan, 2018; Marzuki et al., 2019; Du et al., 2016; Al-Kofahi et al., 2020; Alleman et al., 2020; Khanzadi et al., 2018). Change order is inevitable aspect of construction industry and also one of the important factors in the failure of projects (Keane et al., 2010; Kermanshachi et al., 2020). Though the construction change order processes control the implementation of contracting parties' contractual commitments, disagreements and conflicts appear inevitable and increased due to poor management of change order. There are many reasons for change orders, including conflicts among construction parties; omissions, errors, or discrepancies in the contract documents; unforeseen geological conditions; unforeseen weather conditions; and mandatory changes due to statutory regulations (Kim et al., 2020; Shrestha & Maharjan, 2018). Change orders generally have a negative impact on project performance. Past studies have identified change orders as a major source of cost and time overruns, disputes, low productivity, reworks, and claims in construction projects (K. Shrestha & P. Shrestha, 2019; Gunduz & Tehemar, 2020; Gündüz et al., 2013; Msallam et al., 2015; Safapour & Kermanshachi, 2018; Moselhi et al., 2005; Shrestha & Zeleke, 2018; Safapour & Kermanshachi, 2018; Gunduz & Khan, 2018; Gunduz & Mohammad, 2020). Therefore, poor change order management (COM)

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remains the major cause for disputes, problems, and serious challenges on construction projects (Love et al., 2020), and an effective COM is getting increasing attention in the construction industry (Arcadis, 2019; Ibrahim et al., 2020b).

Many construction projects suffer change order management concerns, according to the literature, and overcoming such problems and obstacles without competent management and assistance is extremely difficult. Similarly, the present methods and frameworks for evaluating COM performance in the literature have certain flaws (K. Shrestha & P. Shrestha, 2019). The lack of research into a COM support system as well as thorough enhancement aspects are among these concerns (Gunduz & Elsherbeny, 2020). As a result, developing a support system to improve the implementation of COM requires an inclusive and thorough understanding of the performance of COM activities and practices. Support system is a set of interactive activities that are necessary and designed to assist decision makers in the construction sector in completing procedures, programs, or projects successfully (Serpell et al., 2017). To detect and solve issues and make choices, a support system model is a compilation of valuable and effective performance elements derived from a mix of raw data, documents, human expertise, and business models (Hwang et al., 2018).

Many studies have investigated to develop a performance factors for many aspects in construction industry (Gunduz et al., 2015; Gunduz & Mohammad, 2020; Gunduz & Elsherbeny, 2020; Gunduz & Tehemar, 2020). In general, performance success can be defined as meeting the stakeholders' expectations and accomplishing the intended goal (Ingle & Mahesh, 2020; Ingle et al., 2021). The definition of critical success factors was introduced in a perspective of project management as a support system by Rockart (1980). As stated by Rockart (1980) the Critical performance areas are the factors which require to be controlled and monitored by project management team in order to support and enhance the project success. Furthermore, the success performance factors are the performance support system areas in which consequences should be satisfactory to achieve the project objectives. Management of performance factors is measured in terms of project success as recommended by several literature sources in construction management (Ingle & Mahesh, 2020; Ingle et al., 2021; Gunduz & Elsherbeny, 2020; Gunduz & Tehemar, 2020; Ullah et al., 2020). Some COM performance factors are common to list, which are relevant to cost and schedule impacts, but there is no common consensus on the factors that can be considered as a support system to evaluate the success of COM construction project industry. The construction industry is concentrating more on effective management of change order (Hanna & Iskandar, 2017; Arcadis, 2019; K. Shrestha & P. Shrestha, 2019; Ibrahim et al., 2020b) and it is obvious that construction companies need a rigorous support system approach to evaluating COM in order to develop preventive measures and enhance the performance of COM and maintain their strategic edge. As indicated in "Global Construction Disputes Report" by Arcadis (2019), change orders frequently generate delays and inefficiencies which can lead to disputes, cost and schedule impacts. Furthermore, due to the absence of historical data, the ambiguity and unpredictability of expert judgments, all of which are major features of the building business (Gunduz & Elsherbeny, 2021). The COM support system framework can be used to fill a gap in the literature. As a result, early identification of performance indicators and risk assessment in the construction COM process can aid risk mitigation methods while lowering the possibility of a construction project ending in a disagreement, as well as cost and schedule consequences. The goal of this study is to create a systematic and comprehensive support system framework for evaluating COM performance in order to help the client, consultant, and contractor plan, manage, measure, monitor, and regulate COM performance efficiently. To achieve this goal, this article will provide a global appropriate and realistically implemented COM support system architecture that will greatly add to the body of knowledge in the construction engineering and management literature, as well as industry.

1. Literature review

A construction project is deemed successful once it is accomplished, without cost overruns, and within specifications. However, several researchers criticized this approach due to over reliable on maintaining the original budget and schedule area and its incapability to reflect the stakeholder's concern and goal (Tripathi et al., 2019). Change orders are unavoidable in the construction industry, are dynamic, and vary from project to project (Hanna & Iskandar, 2017; Shrestha & Maharjan, 2018). Kermanshachi and Safapour (2019) argued that change orders have both visible and implicit impacts on projects, and that defining their indirect impacts is complicated. The purpose of a change order document is to identify duties and obligations as well as to recognize the budget and timeline of the change order. Therefore, the acceptance and acknowledgement of change order by all parties is not enough to manage the change order in construction project, resolve any disputed issues, or overcome the difference of knowledge between the construction project stakeholders. There are project management success indicators that must be implemented and tracked in order to cope with the effects of change orders and disturbances on construction project performance (Love et al., 2002). In addition, investing in and implementing prevention measures to reduce the disruptions of shift order. These strategies are relevant not only to cost and scheduling, but also to interaction, risk management, and reducing problems and disputes among contracting parties (Love et al., 2020). Furthermore, the literature reveals many approaches for lack of managing change order practices in construction industry. Carefully understanding of the project in initial stages, and adequate analysis contract conditions corresponding to change orders (Gunduz et al., 2013), poor design management, i.e., insufficient preliminary study, lack of information, inexperience or incompetence of design staff, and lack of coordination between the various design disciplines (Khoshgoftar et al., 2010; Ibrahim et al., 2020a), poor communication between stakeholders (Du et al., 2016; Love et al., 2020), poor of change order systems, procedures, and guidance (Gunduz et al., 2015; Gunduz & Mohammad, 2020), unclear roles and responsibilities of change order parties (K. Shrestha & P. Shrestha, 2019), inappropriate of planning of change orders (Gunduz & Khan, 2018; K. Shrestha & P. Shrestha, 2019; Ibrahim et al., 2020a), and inadequate owner involvement and engineering support during construction (Ibrahim et al., 2020b) are some examples of poor change order management. Hence, under these circumstances, information and decision support system for each viewpoint management become a must. The following section investigates the adopted models and frameworks for COM in the literature.

1.1. Adopted change order management in the literature

Past studies highlight the importance of developing an effective support system model to mitigate the negative impacts of change orders on project performance and reduce their potential trigger project failure (Sun & Meng, 2009; Du et al., 2016; Gunduz & Khan, 2018; Lavikka et al., 2019; Gunduz & Mohammad, 2020; Al-Kofahi et al., 2020). Alnuaimi et al. (2010) argued that during the early phases of a project, change orders can be managed effectively and are preventable, potentially avoiding multiple modifications during the construction phases with respect to each industry's viewpoint. Du et al. (2019) state that the design phase should be effective, systematic, and reviewed by stakeholders to decrease the number of change orders. Zhang et al. (2012) developed a support system process to reduce the number of change orders by managing a continuous improvement loop. Furthermore, numerous policies have been introduced as support system to scholars and practitioners by the Construction Industry Institute [CII] and viewpoints to enhance the managing system of change orders (CII, 2012). Over the last decade, the number of papers about the management and control of change orders has also increased (Ibbs et al., 2007; Arain & Pheng, 2005a, 2006). Arain and Pheng (2007) developed a process-based support model, based on six principles: 1) supporting a balanced culture, 2) identifying change, 3) analyzing change, 4) executing change, 5) applying monitoring policies, and 6) learning lessons from previous variation orders. The support system model was clustered into three stages: 1) investigating, 2) studying the different choices and proposals, and 3) dominance building. Support system and predictive frameworks with respect to construction industry viewpoint were developed to assess managerial practices through identification of factors impacting construction engineering management (Viswanathan & Jha, 2019; Castillo et al., 2018; Pereira et al., 2018; Ghodrati et al., 2018; Hasan et al., 2018; Ibrahim et al., 2020a; Naji et al., 2020). Choi et al. (2020) developed a decision support model for determining the effects of alternative contracting methods on project time-cost performance. Based on this model, they conducted a series of descriptive analyses of time-performance to develop a quantitative model for evaluating factors affecting ACM (Alternative Contracting Methods) time-cost performance as a support system. Lu et al. (2019) developed an assessment support framework for asset-backed security of public–private partnerships based on the identification of critical success factors of such partnerships. They then developed an investment evaluation guide to support the decision-making process for construction project practitioners and decision makers viewpoint. Ibrahim et al. (2020a) developed a statistical support framework to mitigate the impact of out-of-sequence work on project performance. Ibrahim et al. (2021) presented a comprehensive readiness assessment framework comprising 228 factors categorized into 15 categories. This framework highlights factors that should be addressed prior to mobilization in order to improve overall productivity and project performance. Khalafallah and Shalaby (2019) developed a standard model to facilitate and automate the comparative analysis of change-order data across public-project types and sizes. The study concluded that the leading technical causes of change orders identified through record analysis were poor definition of work scope, lack of coordination with authorities, and unplanned interruptions for public-project. Efficient and effective support system for change order management is crucial to both survival and thrival of the firm viewpoint. Kermanshachi et al. (2018) proposed a dynamic support system model to explore the influence of late change orders on labor productivity and suggested management policies to control change orders in water treatment projects. Marzuki et al. (2019) developed a support framework to identify the causes of change order factors for Indonesian public infrastructure construction projects. Du et al. (2016) used discrete event simulation to optimize the number of change orders, speed up activities, and re-engineer the COM process. Al-Kofahi et al. (2020) used support system dynamics to quantify change orders' impact on labor productivity, proposing a model that can be utilized to identify the main sources that impact labor productivity for a specific type of work. Alleman et al. (2020) explored the support system by developing a relationship between change orders and delivery methods in highway construction projects, proposing mitigation policies to control the causes of change orders affecting project delivery methods in industry's view point.

Over the last twenty years, the existing model and framework for evaluating the efficiency of managing the change orders have certain limitations. These issues related to investigating only the causes of change order (Msallam et al., 2015; Khanzadi et al., 2018; K. Shrestha & P. Shrestha, 2019), serving specific geographical region and context (Msallam et al., 2015; Du et al., 2016; Senouci et al., 2016), serving specific type of construction project (Taylor et al., 2012; Kermanshachi et al., 2018; Khalafallah & Shalaby, 2019), lacking of statistical interpretation (Gunduz & Khan, 2018; Khanzadi et al., 2018; Kermanshachi et al., 2018), investigating a limited number of performance factors (Khanzadi et al., 2018; Gunduz & Mohammad, 2020), or using simple statistical analysis (i.e., linear regression) and qualitative analysis (Hanna & Iskandar, 2017; Safapour & Kermanshachi, 2018; Al-Kofahi et al., 2020). Hence, there is a distinct lack of a robust and global support system approach for the assessment of COM performance by developing a systematic and multidimensional performance factors framework in the existing models and frameworks of the literature and relevant to construction industry's viewpoint.

1.2. The Delphi approach in construction management and engineering

The construction industry relies on the combined expertise of a diverse group of experts to find solutions to common issues. This is because the industry relies so heavily on practical experience. Since the 1990s, Hallowell and Gambatese (2010) have noticed an increase in the use of the Delphi method in construction research. The Delphi method is frequently used in social science (Skulmoski et al., 2007; Dupras et al., 2020) and construction (Shrestha et al., 2019; Gunduz & Elsherbeny, 2020) research to provide a real-world knowledge in real-time (Saka & Chan, 2019). It is qualitative and quantitative research technique used to reduce bias and ensure that participants hold appropriate qualifications. The Delphi method remains a particularly useful alternative for the situation when objective data are unattainable, there is a lack of empirical evidence, or experimental research is unrealistic or unethical. Delphi is used for a problem that cannot be directly analyzed by analytical techniques, questions require intuitive judgment, and expert disagreement occurs. The goal of a Delphi study is to obtain consistent agreement from selected competent experts through updated surveys governed by a statistical analysis of the experts' response (Hallowell & Gambatese, 2010; Mansour et al., 2022). The Delphi method is recognized as a reliable method in construction engineering research (Mansour et al., 2022) and has been utilized by various researchers to identify and rank factors impacting complex processes and outcomes (Ameyaw et al., 2016; Kermanshachi & Safapour, 2019; Gunduz & Elsherbeny, 2020; Mansour et al., 2022). Delphi occupies a position close to a constructionist approach and also has the potential to generate quantified results within a positivist tradition. Compared to questionnaire surveys, Delphi offers better interaction with respondents and could potentially provide more understanding of complex problems as a support system (Sourani & Sohail, 2015).

In construction engineering and management studies, Delphi includes ease of implementation, selection of highly qualified experts, allows for experts' input, and the ability to control judgment-based bias. Therefore, Delphi is more appropriate than other subjective research approaches, such as traditional surveys or interacting groups. Ameyaw et al. (2016) reviewed 88 papers implementing the Delphi technique as a primary or component research methodology in construction engineering management. This review indicates that Delphi is a robust technique for identifying, evaluating, and forecasting purpose in areas of construction research studies covering construction industry's viewpoint, project design, project planning, project contracting issues, productivity issues, organizational issues, information technologies, cost and scheduling, construction materials and methods, risk management, project complexity indicators, and the causes of change orders. His intensive review shows that more attention has been inclined to adopt this technique within an experts specialized in relevant subject of solicitation and factors identification, by using mean or median as the most common feedback process. The appropriateness of this method as a technique is the trend of using of statistical techniques to analyze data collected in Delphi surveys. Various statistical analysis techniques utilized to measure the consensus, inter-group comparison, and correlation of the data provided by the Delphi panel which are studied in details. The credibility of Delphi studies is closely tied to the careful selection of panelists and the formulation of survey questions.

Therefore, a purposive Delphi approach was adopted to develop a qualitative and quantitative framework satisfying the criteria: extensive working experience; sound knowledge and understanding of the COM concepts in the construction industry viewpoints. Furthermore, the model will be developed based on comprehensive and multi-dimensional factors that can be utilized for evaluating the practical COM implementation in construction industry, and can be utilized for future extension of this research (Zuo et al., 2018; Kermanshachi & Safapour, 2019; Gunduz & Elsherbeny, 2020, 2021). Consequently, this study contributes to the knowledge of construction management by introducing COM model as a support system for construction practitioners though Delphi approach to assess the COM performance with the assistance of multidimensional indicators. The structure of Delphi technique by addressing the ambiguous and imprecise events and factors in construction engineering management area deliver a greater support system and application potential for this paper to identify the COM factors that affecting the construction management performance.

1.3. The support system for COM performance

A review of the literature reveals that many attempts have been made by researchers and practitioners to manage change orders and enhance overall project performance by investigating the causes, classifications, impacts, and control of change orders for different types of construction projects. However, the existing research has several significant limitations mainly due to the lack of a conceptual framework that covers the global view of COM activities, the global best practices, the success factors, and the operational procedures in one framework that can be applied to a wide range of projects such as building construction, infrastructure, roads, and industrial projects. Consequently, in order to fill this gap, this paper proposes an operational, global, systematic, and multidimensional construction COM performance framework through a Delphi technique to cover the limitations of the existing studies. This study contributes to the knowledge of construction management in two main aspects. First, the research highlights the underlying 49 factors and 7 management groups contributing to COM performance in the construction projects which are listed in Table 1, to develop a framework that mitigates the impacts of change orders throughout complex life cycle of a construction project. Second, the application of Delphi technique and the development of an operational support system framework (COM-OSSF) approach can be utilized to explore the importance of critical influences through different consensus assessments over the construction project life cycle and in other research areas.

Table 1. Change orders management groups, factors and reference number of cited research paper

COM Factors and Groups		References
G01	**Design Management**	Abad et al. (2019); Al-Kofahi et al. (2020); Ameyaw et al. (2016); Anees et al. (2013); Arain and Pheng (2005a, 2006); Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Egan et al. (2012); Graham et al. (2018); Gunduz and Elsherbeny (2020); Hanif et al. (2016); Hwang et al. (2014); Khanzadi et al. (2018); Khoshgoftar et al. (2010); Khoso et al. (2019); Love et al. (2002)
G01-01	Well-defined project's scope of work/ project brief	Al-Kofahi et al. (2020); Ameyaw et al. (2016); Arain and Pheng (2006); Brown and Hauenstein (2005); Egan et al. (2012); Graham et al. (2018); Hwang et al. (2014); Khoshgoftar et al. (2010); Love et al. (2002)
G01-02	Well-defined project objectives	Al-Kofahi et al. (2020); Ameyaw et al. (2016); Arain and Pheng (2006); Egan et al. (2012); Graham et al. (2018); Hwang et al. (2014); Khanzadi et al. (2018); Khoshgoftar et al. (2010); Khoso et al. (2019); Love et al. (2002)
G01-03	Different design alternatives/ options at conceptual and design phase	Al-Kofahi et al. (2020); Brown and Hauenstein (2005); Hwang et al. (2014); Khoshgoftar et al. (2010)
G01-04	Establishment of a project management plan	Ameyaw et al. (2016); Arain and Pheng (2006); Brown and Hauenstein (2005); Khanzadi et al. (2018); Love et al. (2002, 2020); Lu et al. (2019)
G01-05	Owner's involvement during planning and design phases	Abad et al. (2019); Al-Kofahi et al. (2020); Ameyaw et al. (2016); Anees et al. (2013); Arain and Pheng (2005a, 2006); Brown and Hauenstein (2005); Egan et al. (2012); Graham et al. (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hanif et al. (2016); Khanzadi et al. (2018); Khoshgoftar et al. (2010); Khoso et al. (2019); Love et al. (2002)
G01-06	Sufficient stipulated time for design	Delphi study panellists
G02	**Quality Management**	Chan et al. (2017); Al-Kofahi et al. (2020); Arain and Pheng (2006); Arcadis (2019); Blumberg et al. (2014); Ibbs et al. (2007); Kermanshachi et al. (2020); Love et al. (2020)
G02-01	Reviewing the contractor's project quality plan (Planning /Start-up phase)	Chan et al. (2017); Al-Kofahi et al. (2020); Arain and Pheng (2006); Arcadis (2019); Blumberg et al. (2014); Ibbs et al. (2007); Kermanshachi et al. (2020); Love et al. (2020)
G02-02	Systematic auditing for the quality implementation (Implementation / Construction phase)	Arain and Pheng (2006); Arcadis (2019); Blumberg et al. (2014)
G02-03	Reviewing the contractor's project health and safety plan	Arcadis (2019); Blumberg et al. (2014)
G02-04	Systematic auditing of contractor's health and safety plan	Arcadis (2019); Blumberg et al. (2014)
G02-05	Assignment of qualified and competent project management team	Alomari et al. (2018); Ameyaw et al. (2016); Arain and Pheng (2005a, 2006); Arcadis (2019); Blumberg et al. (2014); Egan et al. (2012); Gunduz and Mohammad (2020); Kermanshachi et al. (2020); Love et al. (2002, 2020); Lu et al. (2019)
G02-06	Establishment of a proper risk management system for changes	Abad et al. (2019); Gunduz and Mohammad (2020); Kermanshachi et al. (2020); Love et al. (2002, 2020); Lu et al. (2019)

Continue of Table 1

COM Factors and Groups		References
G02-07	Owner's timely review of changes	Al-Dubaisi (2000); Anees et al. (2013); Arain et al. (2004); Arain and Pheng (2005a, 2006); Love et al. (2002); Lu et al. (2019)
G02-08	Reviewing and regularly monitoring of the contractor's project baseline program	Arain and Pheng (2006); Arcadis (2019); Blumberg et al. (2014); Kermanshachi et al. (2020); Love et al. (2002, 2020)
G02-09	Managing design and design development during construction	Choi et al. (2020); CII (2017); Egan et al. (2012); Hallowell and Gambatese (2010); Han et al. (2012); Hanif et al. (2016); Hon et al. (2012)
G02-10	Proper verification for the quality of physical works	Anees et al. (2013); Arain et al. (2004); Arain and Pheng (2005a, 2005b, 2006, 2007); Hallowell and Gambatese (2010)
G03	**Documentation Management**	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Alnuaimi et al. (2010); Alomari et al. (2018); Arain and Pheng (2005a, 2006); Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Cohen et al. (2018); Du et al. (2016); Durdyev (2021); Ghodrati et al. (2018); Graham et al. (2018); Günhan et al. (2007); Habibi et al. (2018); Hon et al. (2012)
G03-01	Establishment of a change control system	Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Durdyev (2021); Ghodrati et al. (2018); Graham et al. (2018); Günhan et al. (2007); Hon et al. (2012); Hwang et al. (2014, 2018)
G03-02	Reviewing the sufficiency of contract documents for changes	Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Han et al. (2012); Hanif et al. (2016)
G03-03	Utilization of an electronic document management system	Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Durdyev (2021); Ghodrati et al. (2018); Graham et al. (2018); Günhan et al. (2007); Hon et al. (2012); Hwang et al. (2014, 2018)
G03-04	Regularly monitoring of major activities that have time/cost impact	Chan et al. (2017); Hallowell and Gambatese (2010)
G03-05	Regular reporting to the owner	Alnuaimi et al. (2010); Anees et al. (2013); Hallowell and Gambatese (2010); Hon et al. (2012); Hwang et al. (2018, 2014)
G03-06	Capturing previous lessons learned and best practices from causes of changes	Alomari et al. (2018); Arain and Pheng (2005a, 2006); Charkhakan and Heravi (2019); Hon et al. (2012)
G03-07	Timely reviewing of the submittals (shop drawings and material)	Arain et al. (2004); Arain and Pheng (2005a, 2006); Charkhakan and Heravi (2019); Gunduz and Elsherbeny (2020); Hallowell and Gambatese (2010)
G04	**Financial Management**	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Arain et al. (2004); Arain and Pheng (2006); Charkhakan and Heravi (2019); Hallowell and Gambatese (2010)
G04-01	Establishing of a financial management system	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Arain et al. (2004); Arain and Pheng (2006); Charkhakan and Heravi (2019); Han et al. (2012)
G04-02	Availability of additional funds for approved changes by owner	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Arain et al. (2004); Arain and Pheng (2006); Charkhakan and Heravi (2019); Han et al. (2012)
G04-03	Collecting market prices by owner for negotiations with contractor	Arain et al. (2004); Arain and Pheng (2006); Charkhakan and Heravi (2019)
G04-04	Detailed breakdown and pricing of change order components	Arain et al. (2004); Arain and Pheng (2005a, 2006); Charkhakan and Heravi (2019); Gunduz and Elsherbeny (2020)
G04-05	Timely certifying the contractor's due payments	Abad et al. (2019); Chan et al. (2017); Alaryan (2014); Al-Dubaisi (2000); Alnuaimi et al. (2010); Anees et al. (2013); Arain and Pheng (2005a, 2006); Arcadis (2019); Brown and Hauenstein (2005); Castillo et al. (2018); Charkhakan and Heravi (2019); Egan et al. (2012); El-Sabek and McCabe (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hon et al. (2012); Hwang et al. (2014)
G05	**Dispute Resolution Management**	Al-Dubaisi (2000); Alnuaimi et al. (2010); Arain and Pheng (2005a, 2006); Charkhakan and Heravi (2019); Cohen et al. (2018); Du et al. (2019); El-Sabek and McCabe (2018); Habibi et al. (2018); Hanif et al. (2016); Heravi and Charkhakan (2014); Hwang et al. (2014); Love et al. (2020); Lu et al. (2019)

Continue of Table 1

COM Factors and Groups		References
G05-01	Establishment of a claims and disputes resolution system as set out in the contract	Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Habibi et al. (2018); Hanif et al. (2016); Hwang et al. (2014); Lavikka et al. (2019); Lu et al. (2019); Luo et al. (2020)
G05-02	Well-defined change order scope	Abad et al. (2019); Chan et al. (2017); Alaryan (2014); Al-Dubaisi (2000); Alnuaimi et al. (2010); Anees et al. (2013); Arain and Pheng (2005a, 2006); Brown and Hauenstein (2005); Castillo et al. (2018); Charkhakan and Heravi (2019); Egan et al. (2012); El-Sabek and McCabe (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hon et al. (2012); Hwang et al. (2014); Love et al. (2020); Lu et al. (2019); Luo et al. (2020)
G05-03	Establishment of a clear change order process	Abad et al. (2019); Chan et al. (2017); Alaryan (2014); Al-Dubaisi (2000); Alnuaimi et al. (2010); Anees et al. (2013); Arain and Pheng (2005a, 2006); Brown and Hauenstein (2005); Castillo et al. (2018); Charkhakan and Heravi (2019); Egan et al. (2012); El-Sabek and McCabe (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hon et al. (2012); Hwang et al. (2014); Love et al. (2020); Lu et al. (2019)
G05-04	Prompt evaluation of contractor's proposals for changes including value engineering	Brown and Hauenstein (2005); Charkhakan and Heravi (2019); Egan et al. (2012); Gündüz et al. (2013); Hwang et al. (2014); Love et al. (2020); Lu et al. (2019)
G05-05	Carrying out cost-benefit analysis for changes	Arcadis (2019); Charkhakan and Heravi (2019); Hwang et al. (2014); Kim et al. (2020); Kolawole et al. (2016)
G05-06	Agreement of all concerning parties on change order time frame	Abad et al. (2019); Chan et al. (2017); Alaryan (2014); Al-Dubaisi (2000); Alnuaimi et al. (2010); Anees et al. (2013); Arain and Pheng (2005a, 2006); Brown and Hauenstein (2005); Castillo et al. (2018); Charkhakan and Heravi (2019); Egan et al. (2012); El-Sabek and McCabe (2018); Gunduz and Elsherbeny (2020); Hwang et al. (2014); Khanzadi et al. (2018); Kolawole et al. (2016); Love et al. (2020); Lu et al. (2019)
G05-07	Proposing viable solutions by the contractor for change requests to avoid disputes	Arcadis (2019); Blumberg et al. (2014); Hwang et al. (2014); Love et al. (2002, 2020); Lu et al. (2019)
G05-08	Effective negotiation of cost of claims between the contractor and owner prior to proceeding with change order	Love et al. (2020); Lu et al. (2019)
G05-09	Early detection of changes	Hanna and Iskandar (2017); Kolawole et al. (2016); Hwang et al. (2014); Love et al. (2020); Lu et al. (2019)
G05-10	Setting priorities for changes	Brown and Hauenstein (2005); Hanna and Iskandar (2017); Love et al. (2020); Lu et al. (2019)
G06	**Communication and Relationship Management**	Abad et al. (2019); Al-Dubaisi (2000); Al-Kofahi et al. (2020); Ameyaw et al. (2016); Anees et al. (2013); Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Dupras et al. (2020); Egan et al. (2012); Gunduz and Khan (2018); Gunduz and Mohammad (2020); Han et al. (2012); Hwang et al. (2018); Hwang et al. (2014); Ibrahim et al. (2020a); Karami and Olatunji (2020); Kermanshachi et al. (2020); Love et al. (2002, 2020); Lu et al. (2019)
G06-01	Regular meetings between contracting parties to discuss changes	Brown and Hauenstein (2005); Egan et al. (2012); Ibrahim et al. (2020a); Love et al. (2002, 2020)
G06-02	Early involvement of key stakeholders	Abad et al. (2019); Al-Kofahi et al. (2020); Ameyaw et al. (2016); Anees et al. (2013); Arain and Pheng (2005a); Egan et al. (2012); Graham et al. (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hanif et al. (2016); Khanzadi et al. (2018); Love et al. (2002, 2020)
G06-03	Prompt and accurate response to the contractor's queries	Anees et al. (2013); Arain and Pheng (2005a); Brown and Hauenstein (2005); Egan et al. (2012); Graham et al. (2018); Gunduz and Elsherbeny (2020); Gündüz et al. (2013); Hanif et al. (2016); Khanzadi et al. (2018); Love et al. (2002, 2020); Lu et al. (2019)

End of Table 1

COM Factors and Groups		References
G06-04	Effective management of operational issues at field level	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Al-Kofahi et al. (2020); Brown and Hauenstein (2005); Egan et al. (2012); Ibrahim et al. (2020a); Love et al. (2002); Luo et al. (2020)
G06-05	Effective management of interface among contractors and suppliers	Abad et al. (2019); Chan et al. (2017); Al-Kofahi et al. (2020); Alnuaimi et al. (2010); Brown and Hauenstein (2005); Egan et al. (2012); Ibrahim et al. (2020a); Jarkas and Mubarak (2016); Love et al. (2002, 2020); Lu et al. (2019); Luo et al. (2020)
G06-06	Proper identification of Work Breakdown Structure (WBS)	Abad et al. (2019); Chan et al. (2017); Al-Dubaisi (2000); Al-Kofahi et al. (2020); Brown and Hauenstein (2005); Egan et al. (2012); Ibrahim et al. (2020a); Kermanshachi et al. (2020); Khanzadi et al. (2018); Lu et al. (2019); Luo et al. (2020)
G06-07	Proper orientation about the contractual issues provided to the field team	Delphi study panellists
G07	**Procurement Management**	Brown and Hauenstein (2005); Egan et al. (2012); Jarkas and Mubarak (2016); Love et al. (2002, 2020)
G07-01	Early identification of lead items during design stage	Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Love et al. (2002)
G07-02	Reviewing subcontractors' pre-qualification and competency system	Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Egan et al. (2012); Ibrahim et al. (2020); Jarkas and Mubarak (2016); Love et al. (2002, 2020); Luo et al. (2020)
G07-03	Reviewing the contractor's proposed key management staff to handle the project	Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Egan et al. (2012); Love et al. (2002, 2020); Luo et al. (2020)
G07-04	Utilizing trained and skilled labors	Arcadis (2019); Blumberg et al. (2014); Brown and Hauenstein (2005); Love et al. (2002)

2. Research methodology

The research methodology includes three phases, specifically: (1) identifying of the COM performance factors in respect to construction industry' viewpoint; (2) data collection and analysis; and (3) results discussion, developing operational support system framework, validating and conclusion. The first phase focuses on identifying the critical factors through a systematic literature review of construction COM practices, followed by a series of semi-structured interviews with eight construction experts to verify the identified factors, categorize key factors into project management process group, and the design of the study's initial questionnaire. Phase two is concerned with data collection and analysis processes, which include the setting of criteria for expert selection, as well as two rounds of Delphi research and data analysis. Round one begins with the dissemination of the primary questionnaire sample to experts in order to obtain valuable advice and concludes with the analysis of the obtained data for normality, reliability, and consensus. The questionnaire was updated by a second round to incorporate the first round feedback and new identified critical factors. At the end, the collected data was analyzed for normality, instrument reliability, consensus analysis, and comparison of intergroup. Last phase, developing and validating of an operational support system framework (COM-OSSF) based on COM performance factors of the construction expert's viewpoint, then conclusion and research implications. Figure 1 presents the research methodology and procedure to develop an operational support system framework in respect of construction expert's viewpoints.

2.1. Identifying of change order management (COM) performance factors

Factors that define and demonstrate the performance of COM for construction projects were identified by conducting a comprehensive literature review. The research approach to identify COM performance factors has three main phases: selection of the journal, selection of the article, and analysis of the paper. Highly ranked journals in construction engineering research were chosen, and further potentially relevant publications were identified through databases such as Scopus, Wiley Online Library, American Society of Civil Engineers (ASCE), Taylor & Francis Online, the International Journal of Project Management (IJPM), IEEE Xplore library, Elsevier, and Emerald. Relevant articles were then selected from among candidates published between 2000 and 2020 using the title, abstract, and keywords. The keywords used included "change orders", "variation orders", "control change orders", "managing change orders", "modeling of change orders", "success factors in change orders", and "construction change management". Final selection of papers for the literature review was based on the following criteria:

(1) primary topic was COM and reducing the impact of the change orders; (2) significant discussion of techniques and tools related to controlling and managing the change orders in construction engineering management; and (3) application of a detailed technique to measure the performance of COM. 168 articles focusing on COM studies were identified through this process, with further review of these articles conducted with the assistance of experts involved in the Delphi process to identify the most relevant publications describing significant COM factors. Subsequently, face-to-face meetings with the eight experts were conducted as their experiences enhanced the data collected in the study (Blumberg et al., 2014). The experts had over 27 years' experience on average of international projects and all held managerial positions. Some also hold PhDs in construction management. The factors identified in the literature were presented as preliminary questionnaire items to elicit the experts' views and opinions to cover: (1) any missing factors that could be added; (2) any redundant or overlapping factors; (3) relevance of the COM factors for the industry; (4) improving the language; and (5) improving the characteristics and quality of the survey. The comments, notes, and feedback received from the experts led to improvements in the preliminary questionnaire including shortening of questionnaire items, use of clearer and briefer language, and removal of overlapping factors. Notes were collected from the interviews, and content analysis was conducted to produce meaningful information ahead of the Delphi study.

COM performance factors were categorized by Delphi experts into seven project management process groups: G01: Design Management, G02: Quality Management,

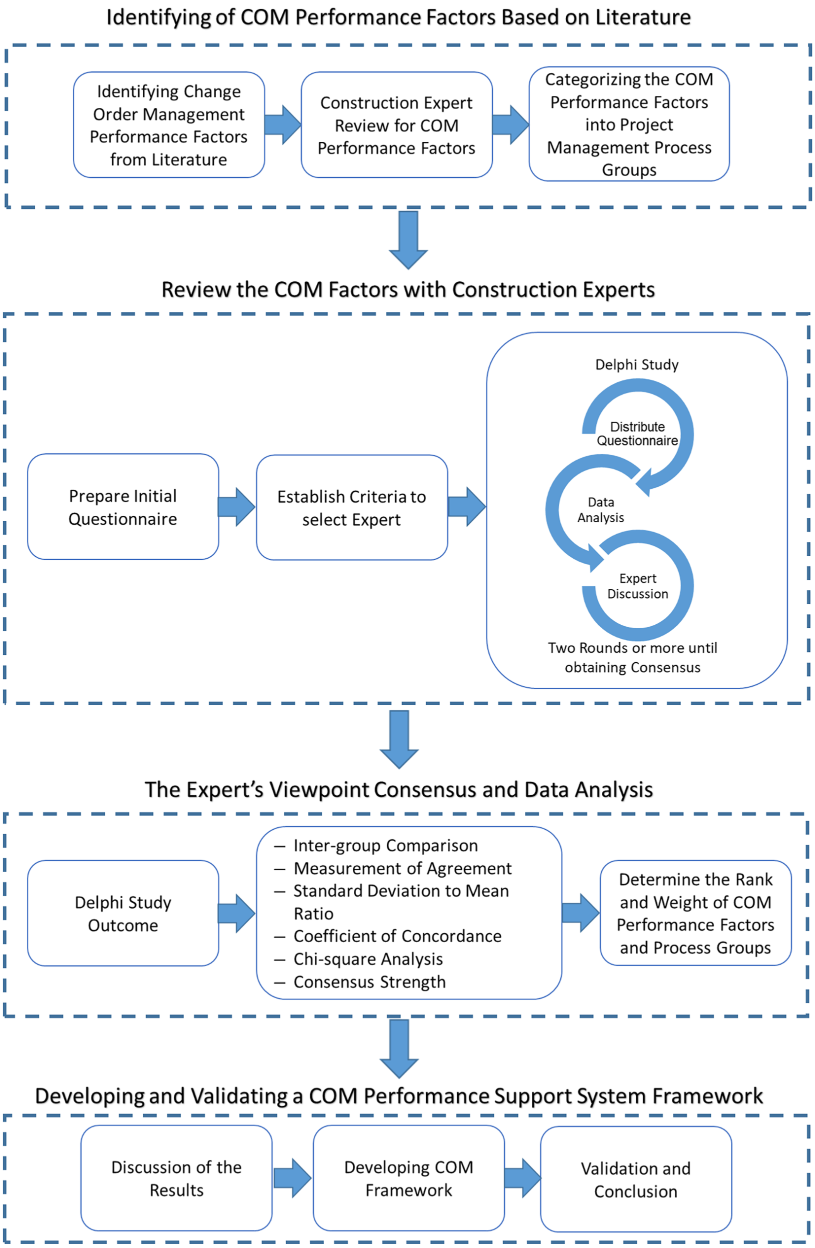


Figure 1. Research methodology for developing a COM support system

G03: Documentation Management, G04: Financial Management, G05: Dispute Resolution Management, G06: Communication and Relationship Management, and G07: Procurement Management. Leading effective projects requires not only strong general leadership skills, but also a methodological and responsive set of core processes and abilities (Project Management Institute [PMI], 2016). Success on one project can be duplicated in subsequent projects and may lead to more contacts and additional opportunities. While no two projects will be identical, mastering a standard set of industry-wide processes can leverage more effective project management strategies and can yield to increased professional advancement. The integrative approach of essential process groups, also referred to as the traditional approach to project management, yields positive results for project leaders who take the time to understand how the different process groups overlap and support success throughout all phases of the project (PMI, 2016). Process groups shall be well-defined and well-structured. Sorting COM factors into process groups furnish the ability to obtain a successful each phase of a construction project (Gunduz & Elsherbeny, 2020, 2021). By developing a tracking phase-checklists between process groups, forces the workflow into a pace where status checks are regularly occurred and monitored (Kermanshachi et al., 2020). For example, COM workflow from the design management to the communication management process groups, a status checklist shall be implemented to ensure that the identified stakeholders were communicated with throughout the project. Therefore, categorizing COM factors into project management process groups will enhance the function of the work breakdown structure (WBS) and split the implementation of COM by different disciplines of construction project team. An extensive literature review, interviews with different nationalities of construction professionals' experts, and the Delphi study led to the identification of 49 unique factors on 7 process groups concerning the performance of COM which are shown in Table 1.

2.2. Delphi method and panelists selection criteria

The method begins with carefully selecting a defined number of qualified experts (panelists). Panel members are unknown to each other and answer a set of updated questionnaires across several rounds. Chan et al. (2017) conclude that a successful Delphi study is essentially governed by the panelists involved in the study and is highly affected by their level of consensus. In literature, there is no agreement on the minimum number of experts that should participate in Delphi studies (Alomari et al., 2018; Gunduz & Elsherbeny, 2020). Ameyaw et al. (2016) reviewed 88 research papers and indicated that the majority of the previous researchers used 8–20 experts in their Delphi studies. Another study by Hallowell and Gambatese (2010) recommended only 8–12 experts. Gunduz and Elsherbeny (2020) used 17 experts in their study. The quality of the output depends mainly on the experts involved in a Delphi study, and the success of the whole process is profoundly affected by the unbiased judgment (Chan et al., 2017). Therefore, in this research, to ensure the validity of this Delphi study, the researchers utilized the guidelines proposed by Hallowell and Gambatese (2010), and Gunduz and Elsherbeny (2020) regarding the methodology for selecting panelists in a Delphi study. Moreover, a purposive sampling method is used for choosing the panel members (Oppong et al., 2021). It is also known as judgment, selective and non-probability sampling technique utilized to identify potential respondents, which comprised a small member of individuals with construction expertise and familiarity with construction change orders management to participate in the study. The sample was determined using a variety of parameters, including years of experience, working division, organization type, and position. Hence, 13 panelists were nominated in accordance with predetermined conditions: (1) experts with extensive practical experience in all type of construction projects (i.e., buildings, infrastructure, industry, etc.) and (i.e., 15 years or more); (2) successful records of completion of at least two megaprojects; (3) involvement in project construction management and good knowledge of COM; (4) registered professional or postgraduate degree; and (5) willingness to participate in a multi-round survey/interview.

Each round produces new information for panelists to use in the next round, allowing the experts to modify their assessments. The Delphi rounds are continued until a consensus is reached (Sourani & Sohail, 2015). Typical Delphi processes involve two or three survey rounds. Round one seeks feedback on a specific issue from panelists in face-to-face conversation and then converts it into a more structured questionnaire. Round two asks the panelists to rate the questionnaire items. Within round two, initial points of disagreement and agreement between the panelists can be identified (Sourani & Sohail, 2015). Round three provides consolidated results (feedback) from the previous round and asks the panelists to freely reconsider the ratings. In each subsequent round, the researcher prepares an anonymous brief of the panelists' assessments (commonly in terms of mean, median or deviation) from the previous survey round and asks the experts to reassess their previous opinion taking into consideration the opinions of other panelists (Ameyaw et al., 2016; Mansour et al., 2022). The COM performance factors were determined and ranked after two rounds of Delphi process according to their influence level on the construction process. The following are the main steps used to execute the Delphi study in this research:

1) Establish the criteria to select experts and identify their names;
2) Send an invitation with a cover letter to experts and determine the minimum number of experts required;
3) Prepare an initial questionnaire with piloting for successive rounds;

4) Distribute the questionnaire for ranking and justification;
5) Collect and analyze the data. Evaluate the results;
6) Average the estimates from all experts (using median and mean); for each expert, calculate the deviation from the mean;
7) Send the deviations in the estimates back to the experts for revision/reassessment;
8) Repeat steps 5–7 until the consensus is reached and the criteria are met;
9) Report the final results and conclusions.

Five-point Likert scales are commonly used (Ozdemir, 2016; El-Sabek & McCabe, 2018; Gunduz & Elsherbeny, 2020; Kermanshachi & Safapour, 2019; K. Shrestha & P. Shrestha, 2019). Ameyaw et al. (2016) conclude that half of the identified Delphi papers adopted a Likert scale to quantify the opinions of experts on a specific subject using different expression of linguistic scales. Thus, five points scale is utilized in this paper, which is commonly used to sustain measurement accuracy.

2.3. The components of support system for evaluating COM performance

After the literature and the semi-structured interviews with eight professionals, 47 COM performance factors were identified and categorized into 7 main COM performance project management process groups. The COM factors and groups are the structure elements of an operational support system for evaluating the COM performance. To analyze the support system components and evaluate the expert's consensus, a preliminary questionnaire was developed. The questionnaire comprised of three main parts. Part one included questionnaire about the survey and items about the respondents' backgrounds. Part two involved items regarding the rating of 47 factors on COM performance. Part three included items regarding the rating of 7 process groups on COM performance. To test the questionnaire content by third party, the questionnaire was distributed to 20 construction experts and obtained 100% response rate and positive feedbacks.

3. Data collection and characteristics

Data characteristics include demographic information about the participants, tests of data normality, and internal reliability of the questionnaire. The first Delphi questionnaire was circulated to the 13 experts listed above for their scores and feedback. The data were collected in two rounds of the Delphi survey using a five-point Likert scale: 5 is Extremely Important, 4 is Very Important, 3 is Moderately Important, 2 is Slightly Important, and 1 is Not at All Important (Ozdemir, 2016; Gunduz & Elsherbeny, 2020) with a response rate of 100%.

An additional two factors were identified and developed with the professionals after the first cycle of the Delphi study: G01-06: Sufficient stipulated time for design; and G06-07: Proper orientation about contractual issues provided to the field team, which are shown in Table 1.

3.1. Delphi panelists' demographics

The term "Delphi Panelists" refers to experts, professionals or researchers with in depth knowledge and sound experience in the field of a study (Ameyaw et al., 2016). Table 2 shows the characteristics of the 13 panelists who were involved in the Delphi study. The panelists hold high qualifications and extensive experience in construction. The panelist experts had previous training on managing of change orders and 12 had change management certificates. Their distribution according to their organization type is as follows: two experts were owners, three were consultants, and eight were contractors. Five experts dealt with public projects and eight dealt with private ones. It is

Table 2. Characteristics of the Delphi panelists

No.	Organization Type	Current role	Education Level	Years of Experience
1	Consultant	Project Director	Ph.D.	28
2	Contractor	General Manager	Master's degree	30
3	Owner	Project Manager	Master's degree	30
4	Contractor	Contracts Manager	Master's degree	30
5	Consultant	Claims Manager	Master's degree	25
6	Contractor	Planning and Risk Manager	Master's degree	27
7	Contractor	Engineering Manager	MBA	23
8	Contractor	Control Manager	Master's degree	29
9	Owner	Project Manger	Ph.D.	27
10	Consultant	Sr. Quantity Surveyor	Bachelor's degree	33
11	Contractor	Project Manager	Bachelor D. and PMP Certified	28
12	Contractor	Contracts Manager	Bachelor D. and PMP Certified	27
13	Contractor	Training and Development Manager	Ph.D. in Construction Management	20

Note: COM – Change Orders Management; D – Degree; Ph.D. – Doctor of Philosophy; MBA – Master of Business Administration; PMP – Project Management Professional.

also worth noting here that eight participants were working in Qatar at the time of data collection and had international, worldwide experience while the other five are from Canada, Kingdom of Saudi Arabia (KSA), United Arab Emirates (UAE), Sweden and Australia.

3.2. Normality test

The normality test is a key test to determine whether or not data are normally distributed and was thus the first statistical test to be done prior proceeding with the next examination. Kalaian and Kasim (2012) state that statistical methods for nonparametric data are appropriate for studies with fewer than 30 participants which use non-normal distribution data. Nonparametric tests are also referred to as distribution-free tests (Megha & Rajiv, 2013). The normality test calculates the correlation between the sample data and its normal scores. If the correlation coefficient is close to "1", the population is said to be normal. Furthermore, if the p-value significance value (the probability that the observed difference could have occurred if the null hypothesis were correct, i.e., by random chance) is less than the level of significance (the accepted chance of incorrectly rejecting the null hypothesis) of the test, the null hypothesis is rejected and the data are said to be not normally distributed. Otherwise, the data are normally distributed. The Ryan-Joiner statistic in the Minitab 19 software package was utilized to check the normality of the data for the first and second rounds. The results in Figure 2 show that data significantly deviate from a normal distribution, based on a significance level of 0.05.

All factors and groups have p-values of less than 0.005 in both rounds 1 and 2. Therefore, the null hypothesis is rejected, and data are considered to deviate significantly from a normal distribution. Consequently, nonparametric estimates are used in the next section.

3.3. Reliability test for the Delphi questionnaire

The reliability test is another key statistical test defined as the degree of consistency, with which the attribute is being measured. Reliability increases as repeated measurements made by the instrument show reduced variation. Cronbach's alpha coefficient values were used to measure the

Table 3. Cronbach's alpha for rounds 1 and 2 of the Delphi study

Cronbach's Alpha (α)	Type of experts (panelists)			
	Overall	Owner	Consultant	Contractor
Round 1				
Factors	0.957	0.952	0.959	0.961
Groups	0.951	0.955	0.947	0.951
Round 2				
Factors	0.957	0.943	0.967	0.961
Groups	0.936	0.934	0.933	0.942

reliability of the questionnaire data. These are usually used for multiple Likert scales in a survey or questionnaire to validate the reliability of the scale. The Cronbach's alpha value should be between 0 and 1; a value close to 1 means that the internal consistency is greater. Cohen et al. (2018) set the following guidelines for the Cronbach's alpha coefficient: 1) 0.90 very highly reliable; 2) 0.80–0.90 highly reliable; 3) 0.70–0.79 reliable; 4) 0.60–0.69 minimally reliable; and 5) < 0.60 unacceptably reliability. Cronbach's alpha was used here to measure the internal consistency for each expert group, each sector in each round, and the mean of the whole group of the questionnaire. Table 3 shows that the Cronbach's alpha values were calculated by SPSS software (Laerd Statistics, 2018) fall above 0.9 for two rounds. Hence, the panelist's responses are reliable and consistent enough for further analysis (Chan et al., 2017).

Based on the obtained results for the normality and reliability tests of the Delphi data and questionnaire, the outcomes offer a point of commencement for the descriptive statistical analysis of the Delphi study, presented in the next section.

4. The experts' consensus and data analysis

The initial stage in this study was intended to analyze the closure of the Delphi iterative round and reach consensus among the panelists. The settlement of the rounds takes place if the desired level of agreement has been reached. Nonparametric data requires nonparametric statistical

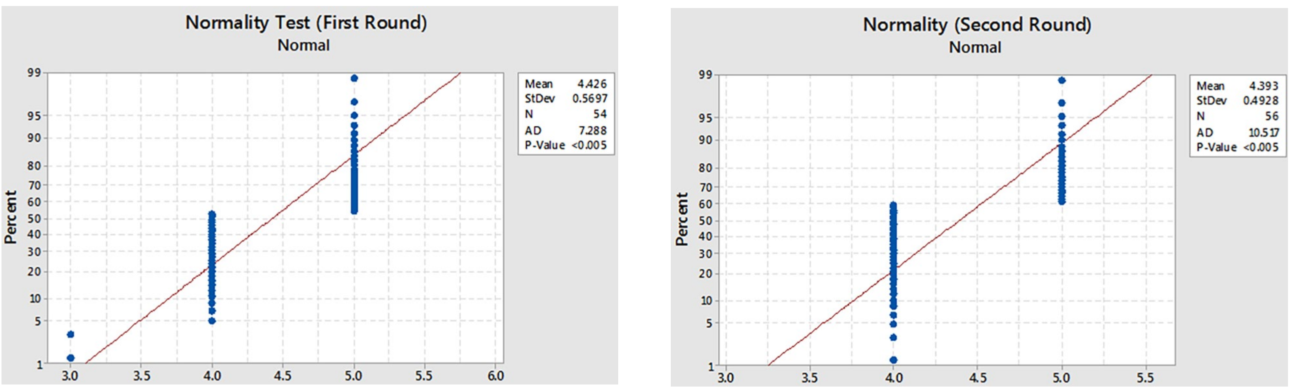


Figure 2. Normality test for the first and second rounds of the Delphi study

methods to make decisions about terminating the Delphi rounds among panelists with iterative rounds (Hallowell & Gambatese, 2010; Ameyaw et al., 2016). However, Ameyaw et al. (2016) conclude that 40 out of 88 papers using the Delphi technique reached the desired consensus after two or three rounds. The decision to terminate the Delphi round was done based on two methods: the inter-group comparison (Spearman's rank correlation coefficient) and measurement of agreement (mode value). The statistical methods used in evaluating the inter-group agreements between the panelists are standard deviation, Kendall's coefficient of concordance (W), and Chi-square (χ^2). In the third stage, the inter-rater agreement (IRA) method was utilized to assess the consensus and correlation strength among the feedback from the panelists. In the last stage, the rank sum weight method was utilized to rank the COM factors and groups. SPSS Statistics (26) was utilized to carry out the analysis.

4.1. Termination of Delphi round based on the inter-group comparison (Spearman's rank)

Likert data are normally considered ordinal data in recognized Delphi studies. Hence, Spearman's rank correlation coefficient (ρ) was used to compare the inter-group correlation (Kalaian & Kasim, 2012; Hon et al., 2012; Gunduz & Tehemar, 2020; Gunduz & Elsherbeny, 2020). If the calculated coefficient value ρ is higher than the critical value at the significance level (i.e., 0.05), there is a consistency among the panelists' groups (Ke et al., 2010). This test does not require the assumptions of normality or homogeneity of variance. The closer ρ is to 1, the greater the correlation (ρ = 1 represents perfect agreement), while ρ near to or less than zero indicates no agreement among rankings from the two consecutive rounds (Kalaian & Kasim, 2012). ρ is given by Eqn (1):

$$\rho = 1 - \frac{6\sum_{1}^{f} d_i^2}{a\left(a^2 - 1\right)}, \qquad (1)$$

where: d_i is the difference between the panelist ranks for the "i" factor from two successive rounds; f is the total number of factors; a is the total number of panelists involved in the Delphi study.

The critical value of Spearman's coefficient, at α = 0.05, n = 13, is 0.566. The minimum calculated is ρ = 0.73 for the COM factors and ρ = 0.98 for the COM factor groups, which is greater than the critical value of Spearman's coefficient and is close to 1. Consequently, the relationship is significantly strong between the first and second rounds. Although the panelists changed their ratings in the second round, the correlation is significant. Therefore, the study can be terminated after the second round.

4.2. Terminating of the Delphi round based on measurement of agreement (the mode value)

Statistical measurement of consensus depends on the criteria assigned to measure the level of consensus. Based on the literature, the consensus level differs among research papers, and each paper has defined a range for their criteria (Ameyaw et al., 2016). Based on previous studies, the criteria established to measure the level of consensus in this study are: (1) a mode score of at least 85% of experts' agreement within 3 of the 5 categories of importance (3, 4 & 5 rates), in comparison to 80% (Gunduz & Elsherbeny, 2020); (2) a mode value of more than 3.5, in comparison to 3.25 or higher (Gunduz & Elsherbeny, 2020); and (3) a standard deviation to mean ratio (SDMR) below 30% (Hallowell & Gambatese, 2010; Ameyaw et al., 2016; Gunduz & Elsherbeny, 2020; Kermanshachi & Safapour, 2019). The mode has been chosen over the mean because it better reflects the central tendency of the ordinal scale without taking into consideration the outliers, and because most ratings clustered around only two to three points (El-Sabek & McCabe, 2018). The value of the mode was calculated as the percentage of a number of selections in a Likert scale of 3, 4, and 5 to the overall number of selections for each individual factor. The results of the first and second rounds are presented in Table 4.

Accordingly, the panelists agreed on 47 factors (94%) in the first round and on 49 factors (99.8%) in the second round. Hence, in the first round, a significant consensus

Table 4. Experts' rating of the COM factor groups

Round 1								Round 2							
	Likert Scale								Likert Scale						
COMF. Group Code	1	2	3	4	5	Score (%)	Mode	COMF. Group Code	1	2	3	4	5	Score (%)	Mode
G01	0	0	0	2	11	100	5	G01	0	0	0	1	12	100	5
G02	0	1	5	6	1	92	4	G02	0	0	3	9	1	100	4
G03	0	0	0	6	7	100	5	G03	0	0	0	5	8	100	5
G04	0	0	1	8	4	100	4	G04	0	0	0	6	7	100	5
G05	0	0	0	2	11	100	5	G05	0	0	0	0	13	100	5
G06	0	1	0	4	8	92	5	G06	0	0	0	4	9	100	5
G07	0	1	1	11	0	92	4	G07	0	0	2	11	0	100	4

Note: COMF – Change Orders Management Factor.

was reached by the respondents, which was further enhanced in the second round. Consensus was achieved for all groups in both rounds. The expert consensus met the second criteria (the mode shall be higher than 3.5) for most factors at the end of the first round, with mode values of 4 and 5 on all factors except G02-03 and G02-04, where the mode was only 3. However, the mode values of round 2 changed to 4 and 5, respectively, meaning both were more than 3.5 and were thus condition values to meet the consensus. The respondents suggested that two new factors be incorporated into the study (i.e., G01-06 and G06-07). Although the percentage of agreement was very high in the first round, the second round was continued to provide feedback to the respondents and to examine the agreement on the additional two factors identified in the first round. Moreover, for the COM performance factor groups, the first and second criteria for expert consensus were met, whereby a mode score of at least 85% of experts' agreement with 3 of the 5 categories of importance for all COM factor groups in the first round and 100% expert agreement for the second round. The analysis of the third criteria (SDMR) will be explained in the next section.

4.3. Standard and absolute deviations

Standard deviation is a vital tool that has been broadly adapted to measure consensus in past research (Günhan et al., 2007; Gunduz & Elsherbeny, 2020; Kermanshachi & Safapour, 2019). As mentioned earlier, several researchers utilize SDMR, and less than 30% is considered acceptable (Hallowell & Gambatese, 2010; Ameyaw et al., 2016; Gunduz & Elsherbeny, 2020; Kermanshachi & Safapour, 2019). The main advantage of this method is its ability to capture the variance among the opinions of experts. Consequently, this method is more conservative than other methods. Table 5 shows the agreement based on an SDMR percentage of 30%.

The agreement was reached for all but 6 factors (G02-01, G02-02, G02-03, G02-04, G02-06 and G07-01) in the first round, while agreement was reached for all factors in the second round, thus meeting the third criteria. Moreover, for the COM factor groups, agreement was reached in the first round and was enhanced in the second round. Therefore, the Delphi study was terminated based on the results of the second round and the significant consensus among the Delphi panelists.

4.4. Kendall's coefficient of concordance

The coefficient of concordance (*W*) is another method utilized to examine the level of concordance (consensus) between the involved parties (Hon et al., 2012; Gunduz & Elsherbeny, 2020; Kermanshachi & Safapour, 2019). It is suitable for ordinal data collected from a Likert scale (Cohen et al., 2018). The consensus level between the panelists is assessed according to the variances among the mean scores for the different factors (Hon et al., 2012). A *W* value one of 1 indicates perfect consensus. In practice, the *W* value should increase in succeeding rounds. According to Hon et al. (2012), the *W* range is 0.234 to 0.600, and Chan et al. (2017) recommend not using Kendall's *W* if the number of subjects is fewer than seven, when Chi-Square analysis should be used instead. The null testing hypothesis for Kendall's coefficient of this study is H_0: Panelists' rankings are not correlated; the alternative hypothesis is H_1: Panelists rankings are correlated.

If the p-value, the null hypothesis is rejected and there is a correlation among the panelists' rankings. Alternatively, if the p-value >0.05, then the null hypothesis cannot be rejected. Table 5 shows the descriptive statistical test results for the COM factors and COM factor groups for rounds 1 and 2.

In Table 5, the first-round shows values of *W* ranging from 0.411 to 0.497, and the overall *W* is 0.411. The second round shows higher *W* values, ranging from 0.544 to 0.670 with an overall *W* of 0.544. Hence, the results of the second-round meet Hon's criteria, and there is a significant improvement in the consensus among experts.

Table 5. Measurement of consensus for COM factors and groups based on SDMR – Rounds 1 and 2

Round 1				Round 2			
COM Factor Code	Mean (M)	Standard Deviation (SD)	SD/Mean (%)	COM Factor Code	Mean (M)	Standard Deviation (SD)	SD/Mean (%)
COM Factors							
G01-01	4.77	0.44	9.19	G01-01	5.00	0.00	0.00
G01-02	4.54	0.78	17.10	G01-02	4.15	0.38	9.04
G01-03	3.69	0.75	20.34	G01-03	3.46	0.88	25.34
G01-04	3.54	0.78	21.94	G01-04	4.00	0.00	0.00
G01-05	4.46	0.78	17.40	G01-05	4.23	0.44	10.37
G01-06	–	–	–	G01-06	4.08	0.28	6.80
G02-01	3.23	1.17	36.08	G02-01	4.00	0.00	0.00
G02-02	3.46	1.05	30.33	G02-02	4.00	0.00	0.00
G02-03	3.08	1.04	33.73	G02-03	4.00	0.00	0.00
G02-04	3.08	1.12	36.24	G02-04	4.00	0.00	0.00

End of Table 5

Round 1				Round 2			
COM Factor Code	Mean (M)	Standard Deviation (SD)	SD/Mean (%)	COM Factor Code	Mean (M)	Standard Deviation (SD)	SD/Mean (%)
G02-05	4.23	1.17	27.55	G02-05	4.00	0.00	0.00
G02-06	3.69	1.18	32.02	G02-06	4.00	0.00	0.00
G02-07	4.54	0.88	19.33	G02-07	5.00	0.00	0.00
G02-08	3.85	0.99	25.66	G02-08	4.00	0.00	0.00
G02-09	4.31	0.75	17.44	G02-09	5.00	0.00	0.00
G02-10	3.54	0.97	27.34	G02-10	4.31	0.85	19.84
G03-01	4.77	0.44	9.19	G03-01	5.00	0.00	0.00
G03-02	4.92	0.28	5.63	G03-02	5.00	0.00	0.00
G03-03	3.92	0.86	21.98	G03-03	4.00	0.00	0.00
G03-04	4.54	0.52	11.43	G03-04	5.00	0.00	0.00
G03-05	4.15	0.69	16.58	G03-05	4.00	0.00	0.00
G03-06	4.15	0.90	21.64	G03-06	4.00	0.00	0.00
G03-07	3.85	0.69	17.91	G03-07	4.00	0.00	0.00
G04-01	4.00	0.82	20.41	G04-01	4.23	0.44	10.37
G04-02	4.23	0.73	17.14	G04-02	4.31	0.48	11.15
G04-03	4.00	0.41	10.21	G04-03	4.08	0.28	6.80
G04-04	4.62	0.51	10.97	G04-04	4.62	0.51	10.97
G04-05	4.31	0.48	11.15	G04-05	4.31	0.48	11.15
G05-01	4.77	0.60	12.56	G05-01	4.85	0.38	7.75
G05-02	4.69	0.63	13.44	G05-02	4.77	0.44	9.19
G05-03	4.92	0.28	5.63	G05-03	4.92	0.28	5.63
G05-04	4.46	0.52	11.63	G05-04	4.46	0.52	11.63
G05-05	4.15	0.55	13.35	G05-05	4.15	0.55	13.35
G05-06	4.77	0.44	9.19	G05-06	4.77	0.44	9.19
G05-07	4.15	0.69	16.58	G05-07	4.23	0.60	14.16
G05-08	4.77	0.44	9.19	G05-08	4.77	0.44	9.19
G05-09	4.85	0.38	7.75	G05-09	4.85	0.38	7.75
G05-10	4.31	0.63	14.63	G05-10	4.31	0.63	14.63
G06-01	4.46	0.78	17.40	G06-01	4.62	0.51	10.97
G06-02	3.85	0.80	20.82	G06-02	4.00	0.58	14.43
G06-03	4.46	0.78	17.40	G06-03	4.62	0.51	10.97
G06-04	4.08	0.86	21.15	G06-04	4.23	0.60	14.16
G06-05	3.77	1.09	28.97	G06-05	4.15	0.69	16.58
G06-06	4.46	0.66	14.80	G06-06	4.54	0.52	11.43
G06-07	–	–	–	G06-07	4.31	0.48	11.15
G07-01	4.00	1.22	30.62	G07-01	4.38	0.77	17.51
G07-02	3.77	0.93	24.59	G07-02	4.08	0.49	12.11
G07-03	3.62	0.87	24.06	G07-03	4.00	0.41	10.21
G07-04	3.15	0.80	25.39	G07-04	3.38	0.77	22.69
COM Factor Groups							
G01	4.85	0.38	7.75	G01	4.92	0.28	5.63
G02	3.54	0.78	21.94	G02	3.85	0.55	14.42
G03	4.54	0.52	11.43	G03	4.62	0.51	10.97
G04	4.23	0.60	14.16	G04	4.54	0.52	11.43
G05	4.85	0.38	7.75	G05	5.00	0.00	0.00
G06	4.46	0.88	19.66	G06	4.69	0.48	10.24
G07	3.77	0.60	15.90	G07	3.85	0.38	9.76

The p-value is less than 0.05 except among the panelists in the "owner" category. In the second round, the p-value is less than 0.05 for all experts' classifications, including the overall panel experts. Thus, the null hypothesis is rejected, and the panelists' rankings are related to each other. The analysis concludes that the consensus among participants is significant. The first round presents values of *W* that are ranging from 0.511 to 0.967, and the overall *W* is 0.549. Meanwhile, the second round shows an improvement in the values (range 0.634 to 1.00) and the overall value of *W* is 0.634. The outcomes of the second round are significant and match the Hon's results and criteria. Moreover, there is a significant improvement in the p-value; in the first round, it is more than 0.05 for the consultant and owner subgroups. In the second round, all p-values are lower than 0.05; consequently, the null hypothesis is rejected. The researchers conclude that the panelists' rankings are related to each other and that the consensus among them is significant.

4.5. Chi-square analysis

Chi-square (χ^2) analysis is used to assess the consistency in the experts' rankings. As recommended by Ameyaw et al. (2016) and Chan et al. (2017), χ^2 should be implemented if the number of factors is greater than seven. A level of consensus among the panelists is reached if the calculated Chi-square value is greater than the critical Chi-square value from the Chi distribution table corresponding to the same degree of freedom at a level of significance of 0.05 (Hon et al., 2012; Ameyaw et al., 2016; Chan et al., 2017; Gunduz & Elsherbeny, 2020). Hence, the null hypothesis for this study is H_0: panelists' rankings do not correlate with each other. The alternative hypothesis is H_1: panelists' rankings correlate with each other.

The results of the statistical tests can be seen in Table 6.

Table 6 shows that the critical Chi-square values are 12.59, 62.804, and 65.152 for the degrees of freedom of 6, 46, and 48, respectively, at 95% confidence intervals.

Table 6. Statistical test results for COM factors and groups – Rounds 1 and 2

COM Factors					COM Factor Groups				
Statistical Analysis		Expert Profession			Statistical Analysis		Expert Profession		
	Overall	Owner	Consultant	Contractor		Overall	Owner	Consultant	Contractor
Round 1					Round 1				
Number of experts (n)	13	2	3	8	Number of experts (n)	13	2	3	8
Spearman's Coefficient (ρ)	0.93	0.98	0.91	0.88	Spearman's Coefficient (ρ)	1	1	1	0.99
Kendell's Coefficient (W)	0.411	0.459	0.497	0.455	Kendell's Coefficient (W)	0.549	0.967	0.511	0.683
Chi-Square (χ^2)	245.753	52.548	68.605	167.315	Chi-Square (χ^2)	42.83	11.60	9.21	32.77
Degree of Freedom (df)	46	46	46	46	Degree of Freedom (df)	6	6	6	6
P-Value	0	0.053	0.047	0	P-Value	0.000	0.062	0.053	0.000
Round 2					Round 2				
Number of experts (n)	13	2	3	8	Number of experts (n)	13	2	3	8
Spearman's Coefficient (ρ)	0.99	1	0.99	0.98	Spearman's Coefficient (ρ)	1	1	1	0.99
Kendell's Coefficient (W)	0.544	0.588	0.670	0.602	Kendell's Coefficient (W)	0.634	1.000	0.763	0.686
Chi-Square (χ^2)	339.67	65.49	96.53	231.13	Chi-Square (χ^2)	49.43	13.65	13.73	32.92
Degree of Freedom (df)	48	48	48	48	Degree of Freedom (df)	6	6	6	6
P-Value	0	0.015	0	0	P-Value	0.000	0.000	0.016	0.000

The calculated Chi-square values as shown in Table 6 are greater than the critical values, except for the owner category in round one. In round two, the Chi-square values increased, and all calculated values are larger than the critical value. Moreover, the Chi-square values for the overall factors are larger than the critical value in both rounds. Therefore, the null hypothesis is rejected and there is a significant association between the experts' rankings at the 0.05 significance level. Furthermore, the calculated Chi-square value for the COM factor groups is greater than the critical value, except for the owner and consultant expert categories in round one. Again, in round two, the Chi-square values increased, and all calculated values are larger than the critical values. Therefore, the null hypothesis is rejected and there is a significant association between the expert rankings at the 0.05 significance level.

4.6. Assessment of correlation and consensus strength

Brown and Hauenstein (2005) proposed the use of the inter-rater agreement (IRA) approach to measure the strength of consensus among the participants. This method has been utilized by many researchers (Brown & Hauenstein, 2005; LeBreton & Senter, 2008; Gunduz & Elsherbeny, 2020). The use of IRA can eliminate the impacts of sample size, scale, and participant number compared to other methods. The agreement index (A_g) interprets the agreement in terms of the ratio of the observed variance of the ranking set to the variance of a uniform distribution. Brown and Hauenstein (2005) present A_g to measure of agreement index, as shown in Eqn (2):

$$A_g = 1 - \frac{2SD^2\left(n-1\right)}{n\left[M\left(H+L\right)-M^2-HL\right]}, \quad (2)$$

where: SD – item standard deviation; H – highest ranking value (in this paper, it is 5); L – lowest ranking value (in this paper, it is 1); M – mean value of the rankings for a single item; n – number of panelists in the Delphi round.

Brown and Hauenstein (2005) established the following interpretation of IRA values: values between 0.00 and 0.30 indicate "lack of agreement"; between 0.31 and 0.50 indicate "weak agreement"; between 0.51 and 0.70 indicate "moderate agreement"; between 0.71 and 0.90 indicate "strong agreement"; and between 0.91 and 1.00 indicate "very strong agreement". Negative values indicate equivalent strengths of disagreement.

Zahoor et al. (2017) suggest establishing the mean intervals scale as follows: mean scores of less than 1.5 indicate that an item is "not important at all"; scores between 1.51 and 2.50 indicate it is "slightly important"; between and 2.51 and 3.50 indicate it is "moderately important"; between 3.51 and 4.50 indicate it is "very important"; and scores above 4.5 indicate it is "extremely important". In the present study, the IRA technique was used to evaluate the strength of the consensus in the second round and to validate the other test statistics, as shown in Table 7 for the COM factors and groups.

For the COM factors, the A_g value ranges from 0.53 to 1.00, except for factor G07-01. Therefore, the agreement percentage after the second round is more than 98%, which is significant and supports the results of the consensus analysis. Moreover, the importance level is either extremely important or very important for all but two factors. This reflects the importance of these factors for COM performance. For the COM factor groups, the A_g value range is the same as for the factors, namely from 0.53 to 1.00. The consensus strength is significant with a 100% agreement level, and all groups are at the extremely important or very important level. The outcomes of the IRA study support the level of agreement results by the mode values, mean scores, concordance coefficient, and Chi-square analysis, and the data are reliable for further analysis.

4.7. Rank sum weight analysis

Kermanshachi and Safapour (2019) argue that the significance criteria for weighting an analysis are divided into two: (1) quality of the descriptive statistics and (2) clarity of the results. The application of the sum weights method was conducted based on verifications and proofs as a typical prediction tool and a better method than regression weights. Moreover, according to their study, this tool receives the highest Kendell's coefficient (W) of close to one. Rank sum weighting normalizes the rank's weight for each factor. A factor's weight is determined by the ratio of each rank to the sum of the total ranking scores. Hence, the ranking of the factor can be determined using the aggregated factor weight. In this respect, each factor's ranking is calculated based on the total sum scores using Eqn (3):

$$S_{TFn} = \sum_{i=1}^{N} F_i, \quad (3)$$

where: F_i – factor's ranking score collected from each expert (1 to 5); N – number of experts involved in the study; n – number of factors; and S_{TFn} – sum of ranking scores assigned to each factor.

Next, Wt_n is the weighting's score for each factor and is calculated by dividing each sum of ranking score by the sum of all factors' scores, as in Eqn (4):

$$Wt_n = \frac{S_{TFn}}{ST}, \quad (4)$$

where: ST – the sum of all factors' scores.

Table 8 shows the weight scores and rankings for the 49 COM factors and groups after the second round of this study.

Although the ranking weights are different between the different factors and groups, these differences are minor and not significant. Factors G01-01, G02-07, G02-09, G03-01, G03-02, and G03-04 have the highest weights among individual factors, and COM factor group G05 has the highest weight among factor groups.

Table 7. Strength of agreement in the second round for the COM factors and groups

Factor	Mean (M)	Standard Deviation (SD)	A_g	Consensus	Importance Level	Factor	Mean (M)	Standard Deviation (SD)	A_g	Consensus	Importance Level
G01-01	5	0	1	V.S.A.	E.I.	G05-01	4.85	0.38	0.56	M.A.	E.I.
G01-02	4.15	0.38	0.9	S.A.	V.I.	G05-02	4.77	0.44	0.59	M.A.	E.I.
G01-03	3.46	0.88	0.63	M.A.	M.I.	G05-03	4.92	0.28	0.53	M.A.	E.I.
G01-04	4	0	1	V.S.A.	V.I.	G05-04	4.46	0.52	0.73	S.A.	V.I.
G01-05	4.23	0.44	0.86	S.A.	V.I.	G05-05	4.15	0.55	0.79	S.A.	V.I.
G01-06	4.08	0.28	0.95	V.S.A.	V.I.	G05-06	4.77	0.44	0.59	M.A.	E.I.
G02-01	4	0	1	V.S.A.	V.I.	G05-07	4.23	0.6	0.73	S.A.	V.I.
G02-02	4	0	1	V.S.A.	V.I.	G05-08	4.77	0.44	0.59	M.A.	E.I.
G02-03	4	0	1	V.S.A.	V.I.	G05-09	4.85	0.38	0.56	M.A.	E.I.
G02-04	4	0	1	V.S.A.	V.I.	G05-10	4.31	0.63	0.68	M.A.	V.I.
G02-05	4	0	1	V.S.A.	V.I.	G06-01	4.62	0.51	0.66	M.A.	E.I.
G02-06	4	0	1	V.S.A.	V.I.	G06-02	4	0.58	0.79	S.A.	V.I.
G02-07	5	0	1	V.S.A.	E.I.	G06-03	4.62	0.51	0.66	M.A.	E.I.
G02-08	4	0	1	V.S.A.	V.I.	G06-04	4.23	0.6	0.73	S.A.	V.I.
G02-09	5	0	1	V.S.A.	E.I.	G06-05	4.15	0.69	0.67	M.A.	V.I.
G02-10	4.31	0.65	0.66	M.A.	V.I.	G06-06	4.54	0.52	0.7	M.A.	E.I.
G03-01	5	0	1	V.S.A.	E.I.	G06-07	4.31	0.48	0.81	S.A.	V.I.
G03-02	5	0	1	V.S.A.	E.I.	G07-01	4.38	0.77	0.48	W.A.	V.I.
G03-03	4	0	1	V.S.A.	V.I.	G07-02	4.08	0.49	0.84	S.A.	V.I.
G03-04	5	0	1	V.S.A.	E.I.	G07-03	4	0.41	0.9	V.S.A.	V.I.
G03-05	4	0	1	V.S.A.	V.I.	G07-04	3.38	0.77	0.72	S.A.	M.I.
G03-06	4	0	1	V.S.A.	V.I.	COM Factor Groups					
G03-07	4	0	1	V.S.A.	V.I.	G01	4.92	0.28	0.93	V.S.A	E.I.
G04-01	4.23	0.44	0.86	S.A.	V.I.	G02	3.85	0.55	0.53	M.A.	V.I.
G04-02	4.31	0.48	0.81	S.A.	V.I.	G03	4.62	0.51	0.76	S.A.	E.I.
G04-03	4.08	0.28	0.95	V.S.A.	V.I.	G04	4.54	0.52	0.7	M.A.	E.I.
G04-04	4.62	0.51	0.66	M.A.	E.I.	G05	5	0	1	V.S.A.	E.I.
G04-05	4.31	0.48	0.81	S.A.	V.I.	G06	4.69	0.48	0.73	S.A.	E.I.
						G07	3.85	0.38	0.62	M.A.	V.I.

Note: W.A. – Weak Agreement; M.A. – Moderate Agreement; S.A. – Strong Agreement; V.S.A. – Very Strong Agreement; M.I. – Moderately Important; V.I. – Very Important; E.I. – Extremely Important.

Table 8. Sum weights ranking for the COM factors and groups (second round)

Factor	W_t	Sum Weight Ranking	Factor	W_t	Sum Weight Ranking	Factor	W_t	Sum Weight Ranking
G01-01	0.024	1	G03-04	0.024	1	G06-01	0.022	13
G01-02	0.02	28	G03-05	0.019	34	G06-02	0.019	34
G01-03	0.016	48	G03-06	0.019	34	G06-03	0.022	13
G01-04	0.019	34	G03-07	0.019	34	G06-04	0.02	24
G01-05	0.02	24	G04-01	0.02	24	G06-05	0.02	28
G01-06	0.019	31	G04-02	0.02	19	G06-06	0.021	16
G02-01	0.019	34	G04-03	0.019	31	G06-07	0.02	19
G02-02	0.019	34	G04-04	0.022	13	G07-01	0.021	18
G02-03	0.019	34	G04-05	0.02	19	G07-02	0.019	31
G02-04	0.019	34	G05-01	0.023	8	G07-03	0.019	34
G02-05	0.019	34	G05-02	0.022	10	G07-04	0.016	49
G02-06	0.019	34	G05-03	0.023	7	COM Factor Groups		
G02-07	0.024	1	G05-04	0.021	17	G01	0.156	2
G02-08	0.019	34	G05-05	0.02	28	G02	0.122	6
G02-09	0.024	1	G05-06	0.022	10	G03	0.147	4
G02-10	0.02	19	G05-07	0.02	24	G04	0.144	5
G03-01	0.024	1	G05-08	0.022	10	G05	0.159	1
G03-02	0.024	1	G05-09	0.023	8	G06	0.149	3
G03-03	0.019	34	G05-10	0.02	19	G07	0.122	6

5. Discussion of results

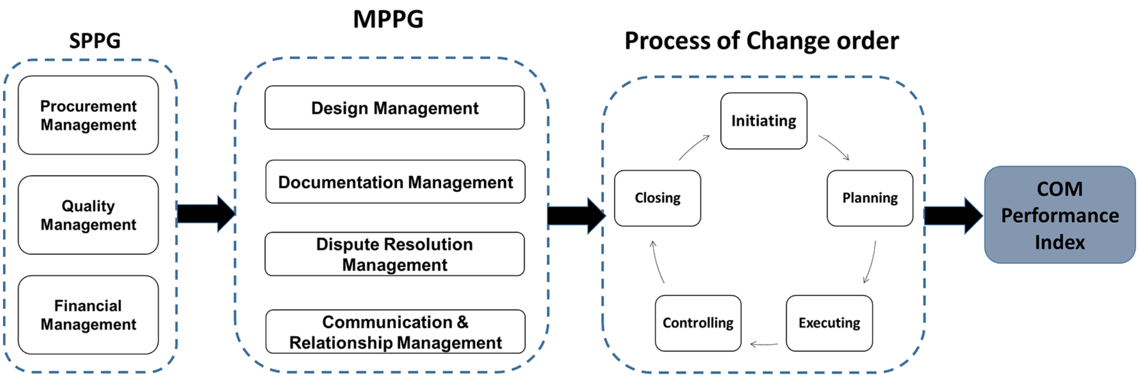
The collected data was analyzed according to Spearman rank-order correlation, score percentage, and mean to standard deviation ratio; after round two, the results are significant and meet the criteria established in existing literature (Hallowell & Gambatese, 2010; Kalaian & Kasim, 2012; Ameyaw et al., 2016; Gunduz & Elsherbeny, 2020; Kermanshachi et al., 2020). The ranking of the factors and the consensus among the experts were examined through simple mode scoring, mean scoring, Kendall's concordance coefficient, and a Chi-Square test, which also met the requirements for significance (Alomari et al., 2018; Dupras et al., 2020). The agreement strength was measured through the IRA indicator (Mansour et al., 2022), as shown in Table 6, and a significant level of agreement is found, and all groups are at the extremely important or very important level and inline with previous literature' result (Gunduz & Elsherbeny, 2020). According to PMI, process groups shall be well-defined and well-structured in order to facilitate the monitoring and tracking the performance activities by project team through the construction project lifecycle. Sorting COM factors into process groups furnish the ability to obtain a successful each phase of a construction project (PMI, 2016). Hence, COM performance factors were categorized into project management process group to develop a tracking phase-checklists between process groups, forces the workflow into a pace where the status of COM performance checklists are regularly occurred and monitored (Gunduz & Elsherbeny, 2021). Forty-nine COM performance factors were identified and categorized into 7 project management process groups through a comprehensive literature and professional experts' viewport as structure for an operational support system elements to evaluate the COM performance in the construction industry.

The most vital COM process groups, classified as "Extremely Important" with a consensus of strong or moderate agreement between the Delphi participants, are G01 – Design Management; G03 – Documentation Management; G04 – Financial Management; G05 – Dispute Resolution Management; and G06 – Communication and Relationship Management. The factors of these groups are tools to drive, manage, and control the change orders in each phase of the construction projects as a support system framework to evaluate the COM performance in each project phase (Shipton et al., 2014). This emphasizes that change orders are inevitable and should be managed ahead to minimize the potential impact of these orders (Khalafallah & Shalaby, 2019; Khoso et al., 2019). The research results clearly reveal that COM factors vary throughout the project dynamic phases (Kermanshachi et al., 2018). The authors attribute the significance of any process group to its own importance, the factors associated with the group, and its impact on other groups as well. The outcomes of the strength of agreement in the second round for the COM factors and groups in Table 7 furnish the strategic and operational support system goals in the context of the main project COM governance guides and management activities. The factors established for the design and documentation management groups give the competence of the COM to apply the administrative procedures to control the project. The significant importance of the design and documentation process groups are related to three main objectives: defining the strategic project challenges early on; initiating project management; and implementing corrective and mitigation measures (Han et al., 2012). The strategic issues include well-defined project's scope of work, establishment of a project management plan, owner's involvement during planning and design phases, and sufficient stipulated time for design at the early stage of project (Palaneeswaran et al., 2014). Documentation and record management is another principal responsibility of the COM. The COM parties discharge the obligations of the project team through a formal documentation and recording system. The system includes, but is not limited to, change order document and amendments; quality control records (material and vendor submittals, shop drawings, approvals, and inspection requests); site records; progress and status reports; completion records (as-built drawings, completion certificates, final account, and snags); contractual notifications (claims, notifications, and evaluations); financial records (payment certificates and variations); meetings; and other correspondences (Gunduz & Elsherbeny, 2020, 2021). Moreover, this study reveals that the Dispute Resolution Management group contains the most critical COM factors. Change orders are potential sources of contractual problems and disputes in the construction industry. The literature reveals that disputes occur throughout the project phases and that there are various identified causes of disputes. Consequently, the occurrence of disputes between project parties can be mitigated and prevented through management of the relevant factors, such as by conducting regular meetings between contracting parties to discuss changes, ensuring early involvement of key stakeholders, prompt and accurate responses to contractor queries, effective management of operational issues at the field level, proper identification of the work breakdown structure (WBS) and proper orientation about the contractual issues provided to the field team (Alleman et al., 2020; Luo et al., 2020).

The results indicate that these performance factors have a significant effect on COM throughout project operations (Wuni & Shen, 2020). This suggests that it is vital for project leaders and managers to establish a COM support system and follow the administration and implementation of this system throughout all phases of the project (Hwang et al., 2018; Wuni & Shen, 2020). Furthermore, project teams must concentrate on COM performance factors and support the project COM leader to achieve the identified objectives. Poor COM would be avoided by the appropriate and efficient execution of each process group through a qualified team acting to achieve the project's goals. Hence, developing an operational support system framework will point out the weaknesses of COM performance and guide the construction practitioners to reduce or eliminate the impact of the poor COM (Zuo et al., 2018).

6. An Operational Support System Framework for COM (COM-OSSF)

The proposed COM-OSSF is based on the consensus of construction experts on the 49 contributory factors affecting the performance of COM. Figure 3 shows the proposed Operational Support System Framework (COM-OSSF) that illustrates the seven COM process groups throughout the project life cycle. Based on sum weights ranking for the COM factors and process groups, the COM-OSSF is divided into two COM group factors, the Main Performance Process Groups (MPPG) and the Subsidiary Performance Process Groups (SPPG), consisting of all performance factors developed following the Delphi study. The MPPG include design, dispute resolution, communication and relationships, and documentation management. The SPPG include financial, quality, and procurement management. The developed framework demonstrates the process of assessing and evaluating the performance of COM. The COM-OSSF consists of four main components addressing the full life cycle of change order management: SPPG, MPPG, Process of Change Order, and COM performance. There is a strong correlation and interaction between these four components and overall COM performance. Each component process comprises collaborative effort and can be implemented in one or more project life cycle phases. Operationally, the process presented in Figure 3 consists of dynamic and interrelated factors and cannot be isolated from each other, thereby requiring integrated teamwork rather than individual effort. Industry professionals can reduce the COM concerns in several ways and may see numerous benefits from utilizing the proposed framework. The COM-OSSF can be applied as both a quantitative and a qualitative approach. As a qualitative approach, the project management team can apply the proposed framework as a guideline to establish control policies for implementation of MPG to assess COM performance. The model can guide continual enhancement practice and provide early warning of underperforming practices which may require improvement efforts. As a quantitative approach, the COM-OSSF can be used by a project management team as a way to measure performance. The values calculated using this framework can be utilized to quantify overall COM performance to express the linguistic scale. Dispute resolution management was ranked as the most significant factor in our analysis; accordingly, in Figure 4 an Operational Dispute Prevention Guideline (ODPG) is developed and introduced to support the COM-OSSF based on dispute management performance factors.



**Note*: SPPG is Subsidiary Performance Process Group; MPPG is Main Performance Process Group

Figure 3. Operational Support System Framework (OSSF)

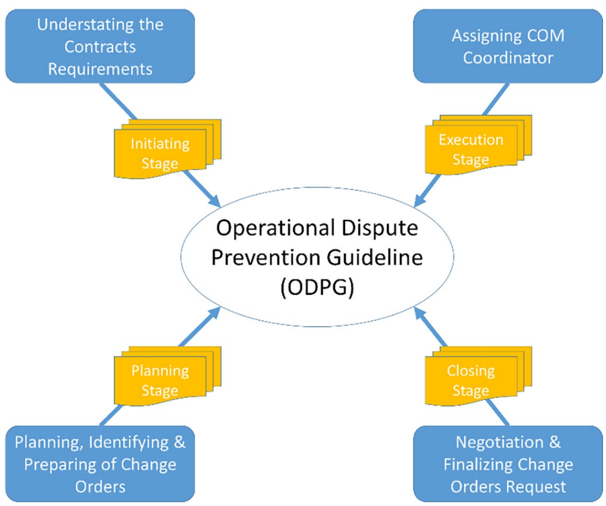


Figure 4. Operational Dispute Prevention Guideline (ODPG)

The first step of the ODPG is understanding the contract's requirements and verifying the sufficiency of the contract documents for COM. Each project has a unique COM; thus, each project team has to understand the requirements of their unique contract and comply with the COM procedure as incorporated in that contract. The second step is nominating and assigning a COM coordinator from each main construction party at the commencement of the project and construction works. The coordinator should regularly monitor the project status and have extensive experience and knowledge of COM. Having a COM coordinator will be advantageous for all project parties and will promote the development of a harmonious relationship between the parties to facilitate the implementation of efficient and effective COM performance factors. The third step is planning, identifying, and preparing for project change orders. The main objective of this step is to be proactive and preventive rather than relying on responsive action. Frequent meetings to plan, recognize, and prepare for anticipated change orders in the project is the most challenging step in COM, but it will eliminate delays in the schedule and avoid expensive disputes. Moreover, preparing inclusive change order documents will increase the quality of the prepared records. This exercise reflects the criticality and importance of invested time while compiling a comprehensive and well-defined change order to avoid revisions and time loss. The fourth step is effective negotiation and finalization of the change order request between owner and contractor within the timeframe. Change orders that continue without progress or monitoring will become costly at a later stage. These four steps comprise the core of the ODPG, which can enhance the COM performance factors to achieve a successful project.

6.1. Model validation

As validation, the proposed framework was examined on one ongoing project in Qatar. Qatar utilizes the FIDIC Red Book remains the contract of preference (Gunduz & Elsherbeny, 2020). Therefore, based on the literature, there is not much difference between the general conditions of contracts in Qatar and the FIDIC Red Book. Therefore, the validation of the research output through the Qatari projects validates the model for other international projects as well. The framework was tested on a real infrastructure project in State of Qatar, comprising the installation, testing, and commissioning of underground mechanical and electrical utilities. The project's contract value was 750 million US dollars. As of the time of writing, the project has completed its construction phase and is under testing in preparation for the commissioning phase. Two meetings with the project management team were conducted in which they were asked to evaluate and assess the project's COM performance. Each performance factor was assessed by the project team on a scale from 0 to 100. The participants were asked to assign a performance value according to the following interpretation: Very Poor indicates a score between 0 and 20; Poor indicates between 21 and 40; Moderate indicates between 41 and 60; Good indicates between 61 and 79; and Very Good indicates between 80 and 100. Operational Support System Framework (OSSF) was circulated to the project team as an audit tool for check implementation. After three months of introducing OSSF, participants recorded the degree of implementation for each key factor with evidence. Also, the participants identified the factors that were "not applicable" and/or that "cannot be measured." Participants admitted the framework benefit to track the degree of implementation for existing activities of COM in construction project. Furthermore, they admitted it was enhanced the knowledge and improved the concept of COM between the construction team. Based on the participants' input score for COM performance factors, and the weight outputs for each factor and process group though sum weight ranking analysis, the evaluation score output for the process groups are presented in Table 9.

Table 9. Evaluation outputs for process group

Process Group No.	Performance Value	Interpretation of Performance Value
GF01	80	Very good
GF02	78	Good
GF03	81	Very good
GF04	60	Moderate
GF05	71	Good
GF06	88	Very good
GF07	75	Good

As validated, COM framework supports the construction team practitioners to ensure that the COM delivers the successful project objectives. Using COM framework in different ways will deliver a reliable tool that will support and increase operational efficiency and effectiveness, minimize contractual problems, improve project control, and trace staff performance at the successive project life phases through improved compliance, awareness, visibility, monitoring, and control over the COM performance actions. Hence, the construction project management shall pay attention on these critical COM factors to decrease disputes that may be developed due to improper performance of those factors.

Conclusions

Effectively managing change orders can facilitate the delivery of a successful project and prevent disputes among the project parties. Based on the comprehensive literature review, it was ascertained that so far, no study has developed a systematic and an operational support system framework based on the comprehensive key and critical factors on COM though applying the qualitative Delphi technique. Hence, this study contributes to the existing knowledge by introducing a COM performance measurement framework to support construction professionals successfully evaluate, track, control, and manage COM performance. 49 COM factors were determined and classified into seven project management process groups through a comprehensive literature review, Delphi study, and face-to-face interviews with professional experts.

Initially, the data demonstrated the applicability of nonparametric analysis following normality and reliability tests. Subsequently, the data were analyzed through Spearman rank-order correlation, score percentage, and mean to standard deviation ratio. The outcomes were significant and met the required criteria. The COM factors' ranking and consensus were then examined through simple mode scoring, mean scoring, ranking, concordance coefficient (W), and Chi-Square test (χ^2). After the second round, the results met al. the required criteria. In the third stage, the Delphi study results were followed by measurement of the agreement strength through the IRA indicator, which was found to be significant with all factor groups at the extremely important or very important level. Finally, the factors were ranked using the sum rank weighting method to identify the relevant weights for each COM factor and group. The results show that the management of the dispute resolution, design, documentation; and communication groups have the highest ranking and are thus considered as the main performance process groups (MPPG). Meanwhile, the financial, procurement, and quality management groups have a lower ranking and are considered the subsidiary performance process groups (SPPG).

These results were used to develop an Operational Support System Framework (COM-OSSF) as a support system to assess the performance of COM. The COM-OSSF is a dynamic support model with their factors provides an opportunity to utilize the model as a qualitative and a quantitative throughout a project to assess the implementation of performance factors, thereby helping practitioners to control and manage change orders, prioritize their resources, and direct their work attention to achieving significant project performance. Hence, this model will assist project managers and industry professionals in delivering a successful project on time and on budget.

Based on the Delphi outcomes and sum weight ranking, the dispute resolution management group obtains the highest score. Therefore, an Operational Dispute Prevention Guideline (ODPG) was extracted from the framework as an operational execution tool to control and monitor change orders, enhance the awareness of the COM factors, and reduce and eliminate disputes between the project parties. The guideline is divided into four crucial steps, which can be implemented as a dispute avoidance structure. Moreover, partnering and alliance strategies can be utilized as strategic collaboration policies to manage change orders.

Validation of an Operational Support System Framework (COM-OSSF) on a real case study for ongoing construction project demonstrates the robustness and reliability of the framework as a technique that will support and increase operational efficiency and effectiveness. Furthermore, COM-OSSF will minimize contractual problems, improve project control, and trace staff performance at the successive project life phases.

Despite the significant amount of data reported and valuable findings, this study has limitations that can be addressed in future work. These are primarily the result of using subjective data as the basis for analysis. Future studies for the existing COM-OSSF model should also be extended through development of an assessment performance framework and identification of the latent relationships using fuzzy structural equation modeling. This will allow for the development of a more robust model and pave the way for quantifying the COM performance index for any construction project. This would allow broader conclusions to be drawn about the performance of each COM factor using actual field data from current construction projects.

Research implications and future recommendation

In conclusion, there are significant implications from the results obtained. The authors draw the attention of the project management team to the significant support system for enhancing the COM process throughout the project life cycle. Furthermore, the authors recommend that the support system of COM framework establish further practical and reasonable performance indicators that will allow project management parties to monitor overall project success and develop action plans and strategic policies for underperforming areas. The practical implementation of the COM-OSSF assessment model in construction project demonstrates that there is a drawback in managing the change order risks. Thus, it is recommended to restructure the risk management activities against the poor performance on COM. Furthermore, client, project management team, consultant might increase the number of qualified staff in order to support COM policies and reduce poor COM-related risk effectively. The proposed support system model's findings are intended to help industry practitioners' benchmark COM success and increase the possibility of introducing a proper COM process in their projects. Furthermore, it is anticipated that the effects of adopting the proposed COM-OSSF evaluation model would result in the launch of development projects within COM administrations to enhance low-performing areas within COM process groups. Implementing those factors is necessary since they address the fundamental construction COM tasks for the majority of conventional construction projects. While identification of key factors and developing the COM-OSSF, the authors consider all type of projects (buildings, infrastructure, industry, etc.) and all construction practitioners' viewpoint (i.e., clients, project management team, consultants, contractors). Hence, the developed framework is comprehensive, systematic and operational; serves and applicable for all type of projects and all construction parties; and can be utilized to monitor and control the implementation of COM performance factors. The proposed framework would enhance the researchers and construction practitioners to develop an operational and assessment model such as Fuzzy or SEM model to quantify and evaluate the implementation of COM in construction industry.

Data availability

Data generated or analyzed during the study are available from the corresponding author by request.

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