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The impact of Engineering, Procurement and Construction (EPC) Phases on Project Performance: A Case of Large-scale Residential Construction Project

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Abstract: The Construction Industry is a complex and fragmented industry worldwide with regards to its supply chain, products, and processes, and is faced with a similar dilemma as faced by manufacturers during its time in past decades. Scope, time, and cost are the triple constraints of project management and leading factors in defining the project performance. Productivity and efficiency of each construction project is measured through its triple constraints, therefore the factors that affect project success are significantly important. Despite the importance of understanding project performance indicators, few empirical studies have been conducted over the last decade in terms of analyzing the factors that determine the performance of high-rise buildings in Engineering, Procurement, and Construction (EPC) projects. Hence, the aim of this paper is to analyze and rank EPC critical activities across large-scale residential construction projects in Iran, by using the TOPSIS method as a multi-attribute group decision-making technique. Results indicate that engineering design, project planning and controls are significant factors contributing to the project performance. In addition, engineering has a pivotal role in project performance and this significance is followed by the construction phase. On the contrary, all believe procurement is more important than Construction phase.

Keywords: EPC projects; project Performance; triple constraints; TOPSIS

1. Introduction

The project is a short-term attempt that seeks to create a product or service. The aim of the project is to identify and achieve its respective owner's goals. Projects are frequently carried out by the project team as a means of attaining the organizations crucial plan or service production [1]. Project management forms the foundation of every construction project. Construction projects are a multi-faceted and highly organized operation, consisting of many tasks focused solely and in conjunction with the singular purpose of constructing a building or structure [2]. Cost, time, and scope have been the triple constraints of Project Management Triangle (PMT) for many years. These constraints have been linked with measuring the project management success [3,4].

The construction industry represents a significant percentage of many countries Gross Domestic Product (GDP). According to World Bank, developing countries are responsible for approximately 6–9% of the GDP [5,6], therefore the success of the construction industry often leads to the promotion and maintenance of long-term economic growth and stability. In recent years, multiple attempts have been made to improve construction project productivity and success rates, which frequently represent the fundamental principles for the successful implementation of the projects management and optimization. The construction projects success is the main foundation of management and control procedures of the current project and detailed planning for future projects [7].

Construction projects generally involve complex and fragmented multi-tasks, which are carried out by several professionals and non-professionals within the Project Life Cycle (PLC), which include engineering, procurement, and construction (EPC) phases. Construction projects comprise building and infrastructure projects and need accurate coordination to meet project success. Accordingly, the construction industry is often confronted with dilemmas in its processes which cause poor performance. As such, the construction industry is left embattled by the resulting flow-on effects of low efficiency and productivity [8].

The significance of these inefficiencies within the construction industry is heightened in terms of cost and time overruns. Hussin, Rahman [9] revealed that 14% of project contract sum is consumed by cost overruns, while time overrun happens to more than 70% of all construction projects, and 10% of projects materials end up as waste material.

The successful implementation of construction projects in the competitive construction market plays a significant role in the company's success. Meanwhile, the construction companies that are able to manage their resources (material, human, financial, equipment, and time) achieve high performance efficiency. Construction projects are complex with regard to variety of works, budget, duration, and the number of parties involved [10].

The construction industry, as any other industry, needs to be continuously improved. The principle behind this continuous improvement has come from the PDCA cycle (Plan, Do, Check, Act) which was initially introduced in manufacturing and was later utilized in the construction industry [11]. PDCA is highly dependent on continuous measurement. It is an iterative four-step management method applied in enterprises for the control and continual improvement of processes and products [12]. There have also been a lot of other approaches towards efficiency enhancement in the construction industry, which is the preventive factor from poor performance. One of these trends is derived from the Toyota Production System (TPS) that is looking for waste minimization, effort maximization, and secure profit to end users. TPS has originated from the approach which is called Lean Production (LP). The international group for lean construction identified lean construction (LC) to define a method for the purpose of designing and implementing construction activities to minimize waste in construction industry in terms of time, cost, and quality [13]. In addition to LC, there have been other approaches towards better management of construction projects including adoption of Total Quality Management (TQM), which is a management theory focused on improving an organization's ability to deliver quality to its customers on a continuously improving basis. Six Sigma and ISO 9001:2000 can also enhance the organization's efficiency by reducing the number of defects [14].

The construction industry is a project-specific industry and assessment of the overall performance of construction projects is difficult due to the lack of development of standard procedure. The project nature, the effective project management tools, and the adoption of innovative management approaches are the Critical Success Factors (CSF) for construction projects [15]. Meanwhile, CSF should be determined at the inception of the project, therefore, by focusing on these factors which are the main inputs of the project management system, the likelihood of project success is most likely increased. CSF explicitly influence the main goals of the project including time, cost, and scope [16–20], however, CSF depends on the nature and type of construction projects and includes cost, time, quality, satisfaction, management, safety, technology, organizations, environment, and resources [21,22]. Time, cost, and quality are, however, the three predominant performance evaluation dimensions in the construction industry, also known as the Iron Triangle or Project Management Triangle [22].

Despite the application of various theories, techniques, and tools, the construction industry is still suffering from inefficiency in terms of time and cost overruns and poor quality globally, which can threaten the entire life of the projects and lead to delays, disputes, and losses. [23]. Iran's construction industry has also not been an exception and suffers from inefficiencies which arise from several factors that finally affect time, cost, and scope of the projects [18,23].

There is lack of comprehensive research to explore factors causing poor performance of large-scale residential construction projects (residential construction projects above 5000 square meters) with regard to project phases (EPC) in Iran. Meanwhile, the prioritization of these factors and their interaction with project performance have also not been studied. Therefore, this research aims to identify and prioritize the factors that affect construction project management triangle (CPMT) with regards to project phases (EPC) in constructing large-scale residential buildings in Iran's construction industry.

2. Literature Review

2.1. Management Practices in Construction Project Triangle Success

The concept of lean construction (LC) continues to expand. LC has been defined in numerous ways, however the following explanations are among the most updated ones [24]. Co-founders of the Lean Construction Institute (LCI), Greg Howell and Glenn Ballard, see lean construction approach as a construction management procedure [25,26]. Lean construction has its roots in TPS and is a novel way of designing and implementing construction projects that are uncertain and complex [27]. The Construction Industry Institute (CII) has defined lean construction as the constant process of waste elimination, fulfilment of customer expectations and requirements, concentration on whole value stream, and seeking perfection throughout all aspects within the operation of constructing a project [28–30].

Several initiatives play a significant role in order to yield improvement for construction projects. These initiatives include; Lean Construction (LC), Total Quality Management (TQM), Six Sigma, and ISO 9001:2000. These initiatives have a close connection to Critical Success Factors (CSF), which is a management term through which the success of a company or an organization is ensured and is the most important factor that is related to project performance. According to [31,32], project performance is determined by performance measurement, which is identified as evaluation of performance relevant to project success in terms of time, cost, and quality.

2.2. Factors Affecting Construction Project Triangle Success

Many researchers have highlighted the causes and effects of poor construction project management. Ogunde, Joshua [33] have highlighted the most important criteria of construction projects, which include monetary stability, work progress, quality standard, health and safety, relationships with stakeholder, resources, management capabilities, contractual and claim disputes, and reputation.

Among the aforementioned factors, time and cost measurement are increasingly important due to its capability to establish a crucial benchmark for the purpose of assessment of the project performance and project efficiency [34]. It is also mandatory to determine the reasons for incomplete tasks as planned. Often, the analyst role might have been assigned to a project scheduler or other staff who have been educated in the principles of the construction lean methodology, however, traditional measurements are no longer applicable [35]. Traditional construction management tools do not address productivity, because they encompass cost overruns and schedule slippages [28,30,35].

Time, cost, and quality are the three most essential elements of construction projects, which are used to determine and measure the efficacy of project success. These three elements exist throughout the entire project lifecycle, commencing with the planning and design stages and culminating with the final handover stage [36]. Ensuring a sustainable balance across these elements with reference to the construction projects success is critical, particularly so in the execution of duties required and targets set for the main stakeholders attached to the project, most especially with sub-contractors. These stakeholders are often left at the mercy of the deadline imposed by the construction project and the considerable financial burden yielded when the agreed upon targets are not met [37]. According to [38], there are a number of risks that can affect the project's success. These relate to time and cost overruns, including, but not limited to, accidents, fluctuation of price, material inadequacy, and inclement weather.

Chou, Irawan [39] conducted research about the construction professional's knowledge of project management. In this study a model was suggested, where the effects of various factors on the project's success where correlated against the areas of knowledge which were studied. These areas of knowledge included project scope, time, cost and quality of the project, procurement management, risk, human resources, and communication [40–42]. Poor performance of construction projects, especially in terms of time overruns and delays, cost overruns, and quality defects has drawn the attention of many construction practitioners and researchers [43].

Several researchers have identified Stakeholder satisfaction as an additional, yet major index for measuring the prosperity of the construction project [44]. They have gone further in recognizing that this index is equally as important as the previously mentioned elements of time, cost, and quality in relation to the measurement of construction performance [45]. They have cited this index as a crucial component of mutual stakeholder satisfaction [46].

Other researchers have since noted a clear distinction between the "projects success" and "projects management success", where the first phrase places emphasis on measurement against overall success of the overall objectives of the project and the second phrase relies more on measurement against the traditional measures of project performance, such as time, cost, and quality [47].

Numerous studies in recent years have been carried out to identify the factors influencing time and cost overruns in construction projects worldwide [48,49]. These factors include deficiencies in contract management, payments for the completed works, materials which are imported, alteration in design, and deficiencies in subcontractors and supplier's performance. In addition to the aforementioned factors, a combination of variables inclusive of poor labor productivity, material shortages, inaccuracies in the estimation of required materials, fluctuations in the cost of materials, in addition to insufficient experience with the project type and location have been identified as the main reasons for project time and cost overruns in the construction of a high-rise building in Indonesia. Other factors which caused poor efficiency relating to the construction project were identified in Hong Kong, including mistakes and discrepancies in design, poor site management and supervision, and delays in approvals [50].

There have also been several studies within the construction industry focused on project control [51,52]. The aim of project control is to confirm that projects finish on-time, within budget, and meet the agreed upon objectives. Project control in practice is undertaken by project or construction managers and comprises continuous measurement of the project progress and taking correction actions wherever necessary. In the past few decades several project control techniques have been adopted, such as Gantt Bar Chart, Program Evaluation and Review Technique (PERT), Critical Path Method (CPM), and Graphical Evaluation and Review Technique (GERT). Meanwhile, several software packages have become accessible that support the methodology behind the mentioned techniques, such as Microsoft Project, Primavera, and more [50,53].

Generally, planning and scheduling are a required necessity for all construction projects. Each construction activity includes several tasks; therefore, planning is a regular technique that identifies which tasks should be completed, the resources (labor, materials, and equipment) that are needed, and by the time they are needed. Each schedule indicates the whole plan in graphical form, which would be in the format of a bar chart. This chart shows activities on a horizontal time scale (on the basis of days, weeks, months, or even years, which actually depends on the complexity of the project). The master scheduling plan is typically generated before the commencement of the construction phase by the experienced estimators [28,54,55].

A study conducted by [56] on the influence of deviations from specific standards of delivered materials in construction projects indicated that lack of communication (communication failure) among all relevant parties included in a construction project led to deficiencies in the construction performance.

Generally, since the construction industry is a labor intensive industry and laborer's are getting paid on a regular basis, time management can assist in controlling the costs of wages [57].

Meanwhile, working with any delays or behind schedule can retard the overall duration of the project, especially when a group of workers should execute a specific task, or any material should be used in the construction site. Inevitably, if construction projects are not completed within their allocated time span, then the contract can be terminated because of the breach of duty, therefore construction disputes may arise and payment loss will be imposed to the construction company [58]. Based on studies conducted by [58,59], two of the most important causes of poor project performance are manageable and non-manageable, which are illustrated in Table 1.

Table 1. The most important factors causing construction project's inefficiency.

Factors	
1. Manageable	1.1 Flows (Resources and information inadequacy) 1.2 Conversion (Poor planning, poor design, improper implementation and execution, insufficient quality) 1.3 Management (Ineffective control, poor allocation, poor dispensation)
2. Non-Manageable	2.1 Failure in external methods 2.2 Environmental issues

In addition to prior descriptions of wasted time, construction poor performance is caused by several factors, including contractor, consultant, or labor related, such as inefficient site management, problems with sub-contractors, poor scheduling, monetary problems, and inexperienced crews, as well as absenteeism [60–63]. Moreover, there are other reasons that create delay which are not under control of project participants, such as economy instability, natural disaster, revolutions, and inclement weather, and there are causes that are created by the owners (clients), such as changes in design or late payments [64–67].

Poor performance can happen due to unexpected events. Unexpected events can influence construction performance severely. One study [68] has highlighted the three main categories of delay caused by unexpected events; delay to commencement, extension of the time span, and suspension of work during the execution of the project.

The main causes of construction project management poor performance are different in different countries and depend on their construction culture. Some researchers have highlighted the most important causes of poor performance that are common in many countries. According to [66,69,70], the major causes of delays in construction projects are inadequate and poor supervision of construction site, problems due to inefficient working of subcontractors, planning and scheduling problems, contractors lack of experience, changes in design during construction phase, late delivery of materials, unpredictable geological conditions, difficulties and shortages in providing materials, equipment, and manpower, delays in payment from owners, contractors' monetary difficulties, design deficiencies, excessive bureaucracy and paperwork in obtaining work permits, harsh weather conditions, economic loss due to inflation or fluctuation, and slow pace toward decision making processes.

2.3. Factors Affecting EPC Project Success

A study conducted by [71] indicates the differences and similarities between Iranian and Nigerian construction culture regrading causes and effects of delay. This study highlights the effects of strong communication among parties from both consultant and contractor views and how this affects construction efficiency. Another study conducted by [72] revealed the identification and prioritization of the key success factors of mass construction projects in Iran. One study [73] has identified and evaluated the factors influencing success of gas, oil, and petrochemical contractors. This study has also considered the projects of a well-known oil and gas company in Iran and presented a model for the success of such types of projects.

In another study, project success has been predicted and evaluated by using the indexes of the business environment and development model. Determination of the importance of the key factors influencing project success in oil and gas projects by identifying them has also been carried out by another researcher [74].

In addition, another study has conducted by [75] based on evaluation of key factors of the success of the project management in the South Pars Project, the largest gas project in Iran. The identification and evaluation of the key success factors in project-based organizations was performed by [76]. There have been other studies regarding the identification of success factors of healthcare projects in Iran [77].

EPC phases in projects are complex due to transactions involving a series of construction tasks to complete a specific asset within a certain time. EPC phases are the most critical phases of the construction projects, which are related to project success. Some researchers have identified three aspects of project success in EPC phases of projects; execution process, the project value, and client satisfaction. Another researcher has emphasized on the importance of time, cost, quality, and satisfaction of customers in EPC phases [78]. Generally, the success of complex construction projects is strongly related to their lifecycle performance and the performance of each EPC phase can be attributed to the triangle of time, cost, and quality [79]. Several studies have explored the ways that construction project stakeholders affect the performance of the project. In these studies the relationship among owners, contractors, consultants, suppliers, and sub-contractors have been studied [41]. Collaborative relationships among construction parties, information sharing and communication, continual improvement, mutual objectives, dynamic problem solving, equitable risk allocation, supplier and subcontractor selection criteria, trust, and measuring project outcomes in EPC phases of construction projects have been considered by other researchers [80]. The use of time, cost, and quality as critical success factors of construction projects for the purpose of construction project performance evaluation have widely been studied by several researchers [42], however, there is great need to understand these critical success factors with regard to EPC phases of the construction projects and to identify and prioritize the factors that can affect critical success factors of the project in the different phases of EPC and affect project performance.

Although there have been several studies investigating construction project management success factors in Iran, there have been few studies identifying and prioritizing the factors causing poor performance in residential construction projects. In addition, the evolution of one model for all construction projects is not reasonable because of dissimilarity in size, nature, and level of complexity of the projects. Regardless of the valuable research, it should be noted that the accurate identification and prioritization of factors causing poor performance depends on comprehensive analysis and investigation of the projects, expert's judgements, and literature review. Therefore, the identification and prioritization of the factors causing poor performance of residential projects in Iran has not been studied specifically, and such research is necessary more than ever.

While all the above studies, to various extents, helped with better understanding the problems associated with poor efficiency in construction projects, there are some limitations.

1. Although several studies have highlighted the causes and effects of poor performance in the construction industry, only a limited number of them have focused on Iran's construction industry, especially for residential buildings.
2. Identification, prioritization, and interaction of factors causing poor construction performance with regard to engineering, procurement, and construction (EPC) in constructing residential buildings in Iran has been far from the researcher's attention.
3. There is a significant need for up-to-date data.

This paper identifies and prioritizes the most relevant factors that cause construction project management poor performance in terms of time, cost, and quality in constructing residential buildings in Iran.

3. Theoretical Framework

Some researchers have studied factors that affect construction project poor performance in Iran's construction industry, yet there has not been adequate study on identification, categorization, and prioritization of these factors according to engineering, procurement, and construction (EPC) phases of the project. EPC includes three steps in each construction project: (1) Engineering (design); (2) procurement; and (3) construction. Each of these three phases include factors that affect construction project performance regarding the project triangle (time, cost, and scope).

The formation of a conceptual framework has been illustrated in Figure 1.

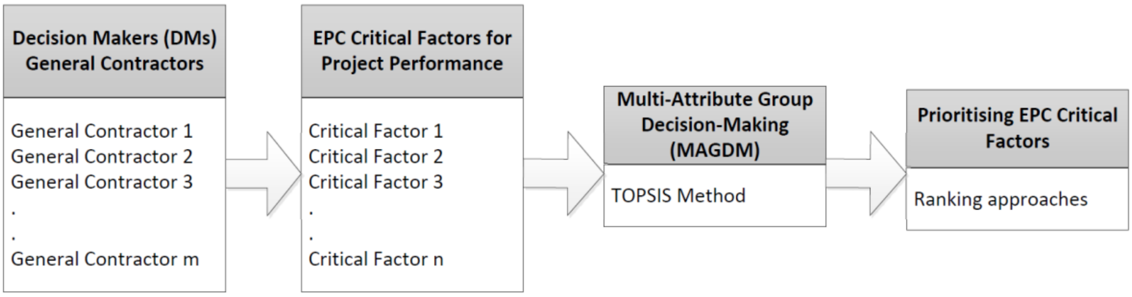

Figure 1. Conceptual diagram for a decision making model.

4. Materials and Methods

Residential buildings in Iran have the greatest number of users among all construction projects which have been the focus of this research. There were several Iranian entities that participated in this research, including public construction companies, private construction companies, city councils, and construction engineering organizations. Therefore, they were selected as a sampling frame in this research.

The research methodology began with formulating a problem statement and identifying objectives of the study. The first step of conducting this research was formed based on reviews of literature to identify main factors that influence poor performance in constructing residential buildings in Iran's construction industry. Then, operationalization of established factors into a questionnaire was carried out. Subsequently, pilot testing of the questionnaire was carried out and the developed format of the questionnaire was formed. The developed questionnaire included the factors causing poor performance of residential buildings in Iran with regard to EPC phases of the project.

4.1. Step 1: Identify Factors

A systematic investigation will identify most of the relevant critical factors in the literature based on the developed conceptual framework that construction contractors need to implement for EPC project management and achieve better performance for large-scale construction projects. The list of factors identified is presented in Table 2. This study draws critical factors from previous studies as potential critical factors for the project performance for EPC projects.

Table 2. Attributes and Initial Measurement indicators.

Project Phase	Indicator	EPC Project Performance Attributes	Reference
Engineering (X_1)	X_{11}	1. Poor design	[33,38,45,46]
	X_{12}	2. Poor project planning	
	X_{13}	3. Poor estimation	
	X_{14}	4. Design incompletion	
Procurement (X_2)	X_{21}	5. Insufficient stakeholder engagement	[56–58,62]
	X_{22}	6. Dispute	
	X_{23}	7. Reputation loss	
	X_{24}	8. Long-lead item delivery	
Construction (X_3)	X_{31}	9. Poor site supervision	[60,61,63,64,66,67,69]
	X_{32}	10. Poor project control	
	X_{33}	11. Changes in project execution	
	X_{34}	12. Late delivery of onsite construction materials (late or on time)	
	X_{35}	13. Poor quality of construction materials	
	X_{36}	14. Redo of deficient tasks	
	X_{37}	15. Inadequate or inefficient equipment or machinery	
	X_{38}	16. Sub-contractor's poor conditions	
	X_{39}	17. Skilled workforce	
	X_{40}	18. Changes in workforce	
	X_{41}	19. Accidents or incidents	
	X_{42}	20. Excessive bureaucracy	
	X_{43}	21. Inclement weather	

4.2. Step 2: Collect Data and Evaluate EPC Contractors

Data was collected from local EPC companies accredited by Iran Construction Engineering Organization to apply to the model developed in Step 1. The questionnaires were then distributed to relevant parties of Iran's construction industry. The questionnaire's structure is based on two parts. The first part is to attain the respondent's background and experience in the construction industry, including qualification, position in the company, years of experience, business activity, and the nature of the company. The second part was framed based on major causes of poor performance in constructing residential buildings in Iran's construction industry.

Data achieved using questionnaires from respondents was gathered and quantitatively analyzed. A total number of 100 questionnaires (hard and soft copies) was distributed to the all parties involved in the construction industry in Iran, including clients, consultants, contractors, sub-contractors, and suppliers, who have been engineers, architects, project managers, engineer assistants, quantity surveyors, and foremen. The respondents' working experience ranged from less than three years to more than 30 years and they had different levels of education from Diploma to PhD. However, only 40 questionnaires were returned, which constitutes a sum of a 40 percent response rate. EPC contractors were asked to rate individual questions on a seven-point Likert scale pertinent to their project performance approaches developed in Table 2.

4.3. Step 3: Develop a Group Decision-Making Model and Data Analysis

A mathematical optimization model based on multi-attribute group decision-making was developed to combine the factors identified in Step 1 and collected in Step 2 into a composite decision-making matrix that best represents the range of approaches used in project performance by EPC contractors in Iran. Multi-attribute group decision-making is an optimization technique which can address the problem of conflicting conditions [81]. The aim of multi-attribute decision-making is to select the most desirable project management approaches that have the highest degree of performance for all of the relevant EPC contractors. In multi-attribute decision-making, decision-makers need to select or rank the alternatives that are associated with commensurate or conflicting attributes. In order to index the various factors, a multi-attribute decision making technique is required [81–83].

In this paper, a non-compensatory approach is introduced for the ranking of project management approaches in terms of their impact on project performance, using the original TOPSIS, known as the elimination and choice translating reality method, which is a widely used multi-attribute group decision-making method [84]. This approach provides solutions to performance activities and selection problems of transport infrastructure involving multiple conflicting objectives, particularly when compensation among the criteria is not allowed. By producing a decision matrix and a criteria sensitivity analysis, TOPSIS can be applied to perform a reasonable strategy selection for a particular application, including a logical ranking of considered EPC contractors [81–86].

TOPSIS is an effective method for analyzing and ranking alternatives and uses the Net Concordance (NC) value from the best solution and Net Discordance (ND) value from the worst solution [85,86]. TOPSIS concurrently takes into account both NC and ND distances to calculate a Net Concordance Dominance (NCD) value [87]. The NCV notion is derived from prospect theory, which is used to identify the ideal point from which a compromised solution would have the shortest distance. In this paper, TOPSIS and the notion of NCV is used to develop score values for each project management approaches in each engineering, procurement, and construction phase to rank the most critical factors for project performance.

5. Results

Table 3 presents the respective Net Concordance Dominance (NCD) value obtained from the TOPSIS procedure. The table shows that FR2-project planning (NDC = 0.92), FR10-project control in procurement (NDC = 0.84), and FR1-detailed design (NDC = 0.79) have a greater focus than other critical factors for project performance based on EPC head contractor's perspective.

Table 3. Ranking EPC critical factors on project performance in large-scale residential construction projects by head contractors.

Indicator	ID	EPC Performance Related Indicators	NC	ND	NCD	RANK
X_{11}	FR1	Poor design	0.82	0.75	0.79	3
X_{12}	FR2	Poor project planning	0.91	0.92	0.92	1
X_{13}	FR3	Poor estimation	0.41	0.32	0.37	20
X_{14}	FR4	Design incompletion	0.54	0.42	0.48	14
X_{21}	FR5	Insufficient stakeholder engagement	0.76	0.54	0.65	6
X_{22}	FR6	Dispute	0.5	0.33	0.42	15
X_{23}	FR7	Reputation loss	0.31	0.44	0.38	18
X_{24}	FR8	Long-lead item delivery	0.6	0.15	0.38	18
X_{31}	FR9	Poor site supervision	0.34	0.75	0.55	11
X_{32}	FR10	Poor project control	0.89	0.78	0.84	2
X_{33}	FR11	Changes in project execution	0.37	0.45	0.41	16
X_{34}	FR12	Late delivery of onsite construction materials	0.5	0.55	0.53	12
X_{35}	FR13	Poor quality of construction materials	0.75	0.82	0.79	3
X_{36}	FR14	Redo of deficient tasks	0.46	0.52	0.49	13
X_{37}	FR15	Inadequate or inefficient equipment or machinery	0.35	0.45	0.4	17
X_{38}	FR16	Sub-contractor's poor conditions	0.46	0.66	0.56	10
X_{39}	FR17	Skilled workforce	0.55	0.58	0.57	9
X_{40}	FR18	Changes in workforce	0.79	0.35	0.57	8
X_{41}	FR19	Accidents or incidents	0.66	0.89	0.78	5
X_{42}	FR20	Excessive bureaucracy	0.55	0.69	0.62	7
X_{43}	FR21	Inclement weather	0.48	0.24	0.36	21

In addition, the TOPSIS analysis shows that the engineering phase has a pivotal role in project performance. Table 4 shows the ranking and the significance of EPC phases on project performance.

Table 4. Ranking EPC phases and their impact on project performance.

EPC Phase	NC	ND	NCD	RANK
Engineering	0.670	0.603	0.636	1
Procurement	0.655	0.550	0.454	3
Construction	0.553	0.403	0.572	2

Table 4 shows that the engineering phase of EPC projects has a leading role in project performance and on the contrary of the clients' perspective, construction is more important than procurement phase in EPC projects for well-performed projects.

6. Discussions

Although several researchers have studied some causes of construction project's poor performance in Iran, there is a vital gap in identification, categorization, and prioritization of these factors in residential construction projects which have been the focus of this study [88–91]. The residential construction projects play a significant economic role regarding the project's stakeholders and resources involved in many economies [92]. Poor construction performance resulting from poor project planning and control is among the most critical issues affecting project success [91–93]. This paper reports on a recent study that specifically aims to prioritize head contractors' EPC activities for better project performance in a broader project management context. The most substantive outcome of this research is clear confirmation that head or general contractors believe that developing engineering design standards is the main critical factor for successful projects. In fact, the engineering phase of large-scale residential construction projects has achieved the first rank in this study, which emphasizes that design and planning at the beginning of the projects are crucial [94]. Many residential construction projects in Iran have not been successful due to the poor aforementioned factors [92,94]. Financial benefits generally play the most significant role in a project's initiation in Iran's construction industry, which is common among all project's stakeholders [95,96]. This issue leads to acceleration in project initiation without adequate and precise design, estimation, and planning. Therefore, the project success is transforming into project failure [90]. After engineering, construction, and procurement have achieved second and third ranks, respectively.

Regarding indicators themselves, all participant EPC general contractors in this study also believe that precise project planning in engineering and project control in construction should be taken to prevent project failure. Meanwhile, quality of construction materials in the construction phase and proper and detailed design in the engineering phase have proven to be effective tasks for improving EPC project performance. To date, such measures have proven ineffective in high-rise building projects and this is a main concern for engineers, project managers, clients, and other stakeholders [62]. Future research should seek to improve the effectiveness and efficiency of engineering standards, and so guide building development to less hazardous locations and less vulnerable structures.

A further benefit of the results of this paper is that the critical factors for better performance in EPC projects of different general contractors can be directly compared in project management terms. Individual builders or developers can benchmark their project management activities against other comparable contractors. Funding agencies can utilize the values of TOPSIS technique in prioritizing the allocation of resources to the head contractors.

7. Conclusions

The results from this research will inform clients, planners, engineers, architects, and economists as they develop more quantitative indicators and standards for project performance, set targets, and make improvements over time. Clients also can use the TOPSIS indicators developed in this paper for comparing the contractors in the tender stage to assign the job to the best contractors, in terms of history of past performance. The TOPSIS technique provides a more realistic form of modelling for multi-attribute group decision making because it allows for trade-offs between engineering, procurement, and construction activities. This study has focused on the project triangle (cost, time, and scope) due to the fact that these factors are more tangible for project's stakeholders for the purpose of assessing project success. However, factors such as safety, sustainability, and satisfaction can also be discussed as project success measures.

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References

1. Mahmood, A.; Asghar, F.; Naoreen, B. "Success factors on research projects at university" an exploratory study. *Procedia-Soc. Behav. Sci.* **2014**, *116*, 2779–2783. [CrossRef]
2. Martens, M.L.; Carvalho, M.M. Key factors of sustainability in project management context: A survey exploring the project managers' perspective. *Int. J. Proj. Manag.* **2017**, *35*, 1084–1102. [CrossRef]
3. Joslin, R.; Müller, R. The relationship between project governance and project success. *Int. J. Proj. Manag.* **2016**, *34*, 613–626. [CrossRef]
4. Larson, E.W.; Gray, C.F. *A Guide to the Project Management Body of Knowledge: Pmbok (®) Guide*; Project Management Institute: Newtown Square, PA, USA, 2015.
5. Kenny, C. *Construction, Corruption and Developing Countries. Policy*; Research Working Paper, No. WPS 4271; World Bank: Washington, DC, USA, 2007.
6. Lopes, J.; Oliveira, R.; Abreu, M.I.J.P.E. The sustainability of the construction industry in sub-saharan africa: Some new evidence from recent data. *Procedia Eng.* **2017**, *172*, 657–664. [CrossRef]
7. Zavadskas, E.K.; Vainiūnas, P.; Turskis, Z.; Tamošaitienė, J. Multiple criteria decision support system for assessment of projects managers in construction. *Int. J. Inf. Technol. Decis. Mak.* **2012**, *11*, 501–520. [CrossRef]
8. Olanrewaju, A.L.; Abdul-Aziz, A.-R. *Building maintenance processes, principles, procedures, practices and strategies*; Springer: Singapore, 2015; Building Maintenance Processes and Practices; pp. 79–129. [CrossRef]
9. Hussin, J.M.; Rahman, I.A.; Memon, A.H. The way forward in sustainable construction: Issues and challenges. *Int. J. Adv. Appl. Sci.* **2013**, *2*, 15–24. [CrossRef]
10. Zavadskas, E.K.; Vilutienė, T.; Turskis, Z.; Šaparauskas, J. Multi-criteria analysis of projects' performance in construction. *Arch. Civ. Mech. Eng.* **2014**, *14*, 114–121. [CrossRef]
11. Neyestani, B.; Juanzon, J.B.P. *Developing an Appropriate Performance Measurement Framework for Total Quality Management in Construction, and Other Industries*; University Library of Munich: Munich, Germany, 2016.
12. Oakland, J.; Marosszeky, M. *Total Construction Management: Lean Quality in Construction Project Delivery*; Routledge: Abington, UK, 2017.
13. Babalola, O.; Ibem, E.O.; Ezema, I.C. Implementation of lean practices in the construction industry: A systematic review. *Build. Environ.* **2018**, *148*, 34–43. [CrossRef]
14. Peljhan, D.; Marc, M. Total quality management and performance management systems: Team players or lonely riders? *Total Qual. Manag. Bus. Excell.* **2018**, *29*, 920–940. [CrossRef]
15. Akinade, O.O.; Oyedele, L.O.; Ajayi, S.O.; Bilal, M.; Alaka, H.A.; Owolabi, H.A.; Bello, S.A.; Jaiyeoba, B.E.; Kadiri, K.O. Design for deconstruction (dfd): Critical success factors for diverting end-of-life waste from landfills. *Waste Manag.* **2017**, *60*, 3–13. [CrossRef]
16. Gudienė, N.; Banaitis, A.; Podvezko, V.; Banaitienė, N. Identification and evaluation of the critical success factors for construction projects in lithuania: Ahp approach. *J. Civ. Eng. Manag.* **2014**, *20*, 350–359. [CrossRef]
17. Lin, G.; Shen, G.Q.; Sun, M.; Kelly, J. Identification of key performance indicators for measuring the performance of value management studies in construction. *J. Construct. Eng. Manag.* **2011**, *137*, 698–706. [CrossRef]
18. Maghsoodi, A.I.; Khalilzadeh, M. Identification and evaluation of construction projects' critical success factors employing fuzzy-topsis approach. *KSCE J. Civ. Eng.* **2018**, *22*, 1593–1605. [CrossRef]
19. Tripathi, K.; Jha, K. An empirical study on performance measurement factors for construction organizations. *KSCE J. Civ. Eng.* **2018**, *22*, 1–15. [CrossRef]
20. Love, P.E.D.; Teo, P.; Morrison, J.; Grove, M. Quality and safety in construction: Creating a no-harm environment. *J. Construct. Eng. Manag.* **2016**, *142*, 05016006. [CrossRef]
21. Ramlee, N.; Tammy, N.J.; Raja Mohd Noor, R.N.H.; Ainun Musir, A.; Abdul Karim, N.; Chan, H.B.; Mohd Nasir, S.R. Critical success factors for construction project. In *AIP Conference Proceedings*; AIP Publishing: Penang, Malaysia, 2016.

22. Sibiya, M.; Aigbavboa, C.; Thwala, W. Construction projects' key performance indicators: A case of the South African construction industry. In Proceedings of the 2015 International Conference on Construction and Real Estate Management, Lulea, Sweden, 11–12 August 2015; pp. 954–960.
23. Haslinda, A.N.; Xian, T.W.; Norfarahayu, K.; Hanafi, R.M.; Fikri, H.M. Investigation on the Factors Influencing Construction Time and Cost Overrun for High-Rise Building Projects in Penang. *J. Phys. Conf. Ser.* **2018**, *995*, 012043. [CrossRef]
24. Tommelein, I.D. Journey toward lean construction: Pursuing a paradigm shift in the aec industry. *J. Construct. Eng. Manag.* **2015**, *141*, 04015005. [CrossRef]
25. Dave, B.; Kubler, S.; Främling, K.; Koskela, L. Opportunities for enhanced lean construction management using internet of things standards. *Autom. Construct.* **2016**, *61*, 86–97. [CrossRef]
26. Shabehpour, N. An Investigation of the Implementation of Lean Philosophy within a Specialty Trade. Master's Thesis, University of British Columbia, Vancouver, BC, Canada, 2016.
27. Chiarini, A.; Baccarani, C.; Mascherpa, V. Lean production, Toyota production system and kaizen philosophy: A conceptual analysis from the perspective of zen buddhism. *TQM J.* **2018**, *30*, 425–438. [CrossRef]
28. Forbes, L.H.; Ahmed, S.M. *Modern Construction: Lean Project Delivery and Integrated Practices*; Crc Press: Boca Raton, FL, USA, 2010.
29. Goetsch, D.L.; Davis, S.B. *Quality Management for Organizational Excellence*; Pearson: Upper Saddle River, NJ, USA, 2014.
30. Hanseth, O.; Lyytinen, K. Design theory for dynamic complexity in information infrastructures: The case of building internet. In *Enacting Research Methods in Information Systems*; Springer: Berlin, Germany, 2016; pp. 104–142.
31. Bonham, D.R.; Goodrum, P.M.; Littlejohn, R.; Albattah, M.A. Application of data mining techniques to quantify the relative influence of design and installation characteristics on labor productivity. *J. Construct. Eng. Manag.* **2017**, *143*, 04017052. [CrossRef]
32. Bianchi, C.; Cosenz, F.; Marinković, M. Designing dynamic performance management systems to foster sme competitiveness according to a sustainable development perspective: Empirical evidences from a case-study. *Int. J. Bus. Perform. Manag.* **2015**, *16*, 84–108. [CrossRef]
33. Ogunde, A.; Joshua, O.; Amusan, L.M.; Akuete, E. Project management a panacea to improving the performance of construction project. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 1234–1242.
34. Sears, S.K.; Sears, G.A.; Clough, R.H.; Rounds, J.L.; Segner, R.O. *Construction Project Management*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
35. Albliwi, S.A.; Antony, J.; Arshed, N.; Ghadge, A. Implementation of lean six sigma in Saudi Arabian organisations: Findings from a survey. *Int. J. Qual. Reliab. Manag.* **2017**, *34*, 508–529. [CrossRef]
36. Mir, F.A.; Pinnington, A.H. Exploring the value of project management: Linking project management performance and project success. *Int. J. Proj. Manag.* **2014**, *32*, 202–217. [CrossRef]
37. González, P.; González, V.; Molenaar, K.; Orozco, F. Analysis of causes of delay and time performance in construction projects. *J. Construct. Eng. Manag.* **2013**, *140*, 04013027. [CrossRef]
38. Ahmad Zaini, A.; Adnan, H.; Che Haron, R. Contractors' Approaches to Risk Management at the Construction Phase in Malaysia. In Proceedings of the International Conference on Construction Project Management (ICCPM), Chengdu, China, 1 December 2010.
39. Chou, J.-S.; Irawan, N.; Pham, A.-D. Project management knowledge of construction professionals: Cross-country study of effects on project success. *J. Construct. Eng. Manag.* **2013**, *139*, 04013015. [CrossRef]
40. Demirkesen, S.; Ozorhon, B. Impact of integration management on construction project management performance. *Int. J. Proj. Manag.* **2017**, *35*, 1639–1654. [CrossRef]
41. Meng, X. The effect of relationship management on project performance in construction. *Int. J. Proj. Manag.* **2012**, *30*, 188–198. [CrossRef]
42. Ngacho, C.; Das, D. A performance evaluation framework of development projects: An empirical study of constituency development fund (cdf) construction projects in Kenya. *Int. J. Proj. Manag.* **2014**, *32*, 492–507. [CrossRef]
43. Lo, T.Y.; Fung, I.W.; Tung, K.C. Construction delays in Hong Kong civil engineering projects. *J. Construct. Eng. Manag.* **2006**, *132*, 636–649. [CrossRef]
44. Zeng, S.; Ma, H.; Lin, H.; Zeng, R.; Tam, V.W. Social responsibility of major infrastructure projects in china. *Int. J. Proj. Manag.* **2015**, *33*, 537–548. [CrossRef]

45. Davis, K. A method to measure success dimensions relating to individual stakeholder groups. *Int. J. Proj. Manag.* **2016**, *34*, 480–493. [CrossRef]
46. Oppong, G.D.; Chan, A.P.; Dansoh, A. A review of stakeholder management performance attributes in construction projects. *Int. J. Proj. Manag.* **2017**, *35*, 1037–1051. [CrossRef]
47. Ogunlana, S.O. Beyond the 'iron triangle': Stakeholder perception of key performance indicators (kpis) for large-scale public sector development projects. *Int. J. Proj. Manag.* **2010**, *28*, 228–236.
48. Arditi, D.; Nayak, S.; Damci, A. Effect of organizational culture on delay in construction. *Int. J. Proj. Manag.* **2017**, *35*, 136–147. [CrossRef]
49. Cheng, Y.-M. An exploration into cost-influencing factors on construction projects. *Int. J. Proj. Manag.* **2014**, *32*, 850–860. [CrossRef]
50. Olawale, Y.A.; Sun, M. Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. *Construct. Manag. Econ.* **2010**, *28*, 509–526. [CrossRef]
51. Mubarak, S.A. *Construction Project Scheduling and Control*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
52. Kerzner, H.; Kerzner, H.R. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*; John Wiley & Sons: Hoboken, NJ, USA, 2017.
53. Tonchia, S. *Industrial Project Management*; Springer: Berlin, Germany, 2018; Available online: https://link.springer.com/book/10.1007%2F978-3-662-56328-1#authorsandaffiliationsbook (accessed on 30 December 2018).
54. Nicholas, J.M.; Steyn, H. *Project Management for Engineering, Business and Technology*; Routledge: Abington, UK, 2017.
55. Zareei, S. Project scheduling for constructing biogas plant using critical path method. *Renew. Sustain. Energy Rev.* **2018**, *81*, 756–759. [CrossRef]
56. Darvik, L.; Larsson, J. The Impact of Material Delivery-Deviations on Costs and Performance in Construction Projects. Master's Thesis, Chalmers University of Technology, Göteborg, Sweden, 2010.
57. Jollands, S.; Akroyd, C.; Sawabe, N. Core values as a management control in the construction of "sustainable development". *Qual. Res. Account. Manag.* **2015**, *12*, 127–152. [CrossRef]
58. Jiang, H.; Lin, P.; Qiang, M.; Fan, Q. A labor consumption measurement system based on real-time tracking technology for dam construction site. *Autom. Construct.* **2015**, *52*, 1–15. [CrossRef]
59. Gamil, Y.; Rahman, I.A. Identification of causes and effects of poor communication in construction industry: A theoretical review. *Emerg. Sci. J.* **2018**, *1*. [CrossRef]
60. Subramani, T.; Sruthi, P.; Kavitha, M. Causes of cost overrun in construction. *IOSR J. Eng.* **2014**, *4*, 1–7. [CrossRef]
61. Enshassi, A.; Arain, F.; Al-Raee, S. Causes of variation orders in construction projects in the gaza strip. *J. Civ. Eng. Manag.* **2010**, *16*, 540–551. [CrossRef]
62. Fallahnejad, M.H. Delay causes in iran gas pipeline projects. *Int. J. Proj. Manag.* **2013**, *31*, 136–146. [CrossRef]
63. Kazaz, A.; Ulubeyli, S.; Tuncbilekli, N.A. Causes of delays in construction projects in turkey. *J. Civ. Eng. Manag.* **2012**, *18*, 426–435. [CrossRef]
64. Gunduz, M.; Nielsen, Y.; Ozdemir, M. Fuzzy assessment model to estimate the probability of delay in turkish construction projects. *J. Manag. Eng.* **2013**, *31*, 04014055. [CrossRef]
65. Gündüz, M.; Nielsen, Y.; Özdemir, M. Quantification of delay factors using the relative importance index method for construction projects in turkey. *J. Manag. Eng.* **2012**, *29*, 133–139. [CrossRef]
66. Keane, P.J.; Caletka, A.F. *Delay Analysis in Construction Contracts*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
67. Naoum, S.G.; Alyousif, A.-R.T.; Atkinson, A.R. Impact of national culture on the management practices of construction projects in the united arab emirates. *J. Manag. Eng.* **2013**, *31*, 04014057. [CrossRef]
68. Zou, P.X.; Zhang, G. Managing risks in construction projects: Life cycle and stakeholder perspectives. *Int. J. Construct. Manag.* **2009**, *9*, 61–77. [CrossRef]
69. Aziz, R.F.; Abdel-Hakam, A.A. Exploring delay causes of road construction projects in egypt. *Alex. Eng. J.* **2016**, *55*, 1515–1539. [CrossRef]
70. Jarkas, A.M.; Haupt, T.C. Major construction risk factors considered by general contractors in qatar. *J. Eng. Des. Technol.* **2015**, *13*, 165–194. [CrossRef]
71. Oshodi Olalekan, S.; Rimaka, I. A comparative study on causes and effects of delay in nigerian and iranian construction projects. *Asian J. Bus. Manag. Sci.* **2013**, *3*, 29–36.
72. Minaie, H. *Identifying Success Factor in Mass Buildings Construction*; Tehran University: Tehran, Iran, 2013.

73. Shokouhinia, M. *Analysis of Success Factor in Aria-Petro-Gas Company*; Tehran University: Tehran, Iran, 2010.
74. Piran, M. *Identifying Success Factor in Oil and Gas Project*; Tehran University: Tehran, Iran, 2010.
75. Abolhasani, A. *Assessment of Success Factor in Construction Project*; Tehran University: Tehran, Iran, 2012.
76. Dalirpour, A. *Analysis of Success Factor on the Project-Based Organization*; Tehran University: Tehran, Iran, 2012.
77. Doulabi, R.Z.; Asnaashari, E. Identifying success factors of healthcare facility construction projects in Iran. *Proc. Eng.* **2016**, *164*, 409–415. [CrossRef]
78. Nguyen, H.T.; Hadikusumo, B. Impacts of human resource development on engineering, procurement, and construction project success. *Built Environ. Proj. Asset Manag.* **2017**, *7*, 73–85. [CrossRef]
79. Habibi, M.; Kermanshachi, S.; Safapour, E. Engineering, procurement and construction cost and schedule performance leading indicators: State-of-the-art review. In Proceedings of the Construction Research Congress, ASCE, New Orleans, LA, USA, 2–4 April 2018.
80. Pal, R.; Wang, P.; Liang, X. The critical factors in managing relationships in international engineering, procurement, and construction (iepc) projects of chinese organizations. *Int. J. Proj. Manag.* **2017**, *35*, 1225–1237. [CrossRef]
81. Jahantigh, F.F.; Malmir, B.; Avilaq, B.A. Engineering, S. Economic risk assessment of epc projects using fuzzy topsis approach. *Int. J. Ind. Syst. Eng.* **2017**, *27*, 161–179.
82. Jang, W.; Hong, H.-U.; Han, S.H.; Baek, S.W. Optimal supply vendor selection model for lng plant projects using fuzzy-topsis theory. *J. Manag. Eng.* **2016**, *33*, 04016035. [CrossRef]
83. Abbaspour, M.; Toutounchian, S.; Dana, T.; Abedi, Z.; Toutounchian, S. Environmental parametric cost model in oil and gas epc contracts. *Sustainability* **2018**, *10*, 195. [CrossRef]
84. Safa, M.; Shahi, A.; Haas, C.T.; Hipel, K.W. Supplier selection process in an integrated construction materials management model. *Autom. Construct.* **2014**, *48*, 64–73. [CrossRef]
85. Jato-Espino, D.; Castillo-Lopez, E.; Rodriguez-Hernandez, J.; Canteras-Jordana, J.C. A review of application of multi-criteria decision making methods in construction. *Autom. Construct.* **2014**, *45*, 151–162. [CrossRef]
86. Zavadskas, E.K.; Turskis, Z.; Kildienė, S. State of art surveys of overviews on mcdm/madm methods. *Technol. Econ. Dev. Econ.* **2014**, *20*, 165–179. [CrossRef]
87. Chen, C.-T. Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets Syst.* **2000**, *114*, 1–9. [CrossRef]
88. Pournader, M.; Tabassi, A.A.; Baloh, P. A three-step design science approach to develop a novel human resource-planning framework in projects: The cases of construction projects in USA, Europe, and Iran. *Int. J. Proj. Manag.* **2015**, *33*, 419–434. [CrossRef]
89. Vahdani, B.; Mousavi, S.M.; Mousakhani, M.; Hashemi, H. Time prediction using a neuro-fuzzy model for projects in the construction industry. *J. Optim. Ind. Eng.* **2016**, *9*, 97–103.
90. Banihashemi, S.; Hosseini, M.R.; Golizadeh, H.; Sankaran, S. Critical success factors (csfs) for integration of sustainability into construction project management practices in developing countries. *Int. J. Proj. Manag.* **2017**, *35*, 1103–1119. [CrossRef]
91. Zarei, B.; Sharifi, H.; Chaghouee, Y. Delay causes analysis in complex construction projects: A semantic network analysis approach. *Prod. Plan. Control* **2018**, *29*, 29–40. [CrossRef]
92. Ghoddousi, P.; Hosseini, M.R. A survey of the factors affecting the productivity of construction projects in Iran. *Technol. Econ. Dev. Econ.* **2012**, *18*, 99–116. [CrossRef]
93. De Carvalho, M.M.; Patah, L.A.; de Souza Bido, D. Project management and its effects on project success: Cross-country and cross-industry comparisons. *Int. J. Construct. Manag.* **2015**, *33*, 1509–1522. [CrossRef]
94. Sha'ar, K.; Assaf, S.; Bambang, T.; Babsail, M.; Fattah, A.A.E. Design–construction interface problems in large building construction projects. *Int. J. Construct. Manag.* **2017**, *17*, 238–250. [CrossRef]

95. Yousefi, V.; Yakhchali, S.H.; Khanzadi, M.; Mehrabanfar, E.; Šaparauskas, J. Proposing a neural network model to predict time and cost claims in construction projects. *J. Civ. Eng. Manag.* **2016**, *22*, 967–978. [CrossRef]
96. AlNasseri, H.; Aulin, R. Assessing understanding of planning and scheduling theory and practice on construction projects. *Eng. Manag. J.* **2015**, *27*, 58–72. [CrossRef]