Research Article

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Identification of the main causes of risks in engineering procurement construction projects

https://doi.org/10.1515/jmbm-2022-0029
received March 15, 2022; accepted April 08, 2022

Abstract: Many risks have adverse consequences for construction projects' objectives such as quality, schedule, and cost. As engineering procurement construction (EPC) contracts gradually become one of the most common types used in implementing major large-scale construction projects, identifying common risk types and analyzing their root causes is important for developing measures to decrease and eliminate future risks in these types of contracts. The information about the main causes of risks was collected *via* well-structured questionnaires addressed to construction sector professionals and preparing lists of main potential risks in EPC/construction projects through reviewing literature studies, books, and articles related to this topic. The findings indicate that several causes of risks are more critical for the project including causes related to contract, design and execution, subcontractors, systems, and equipment. The study's results revealed that the absence of risk management implementation in the EPC construction project is a root cause of the lack of planning and control of the project.

Keywords: EPC, construction project, risks, risk management

1 Introduction

Every construction project requires effective contract risk management. The risks in construction projects vary depending on the type of contract, because each contract type has its project life cycle. If contract risk management is not adequately managed and controlled, the project as a whole may not achieve its objectives. The processes of performing project risk management encompass risk management planning, identification, analysis, response planning, and risk control on a project. The cause of implementing risk management in projects is to enhance the possibility of positive occurrences and their impact while decreasing the probability and impact of negative events [1]. Due to various intrinsic factors (complication, scope, organization, renovation, lifecycle duration, and magnitude of changes), every project has its ambiguity which is related to risk, which is likely to affect the project's success and applicable consequence unless they are managed appropriately. A risk is an unexpected event or a sequence of events that, if they occur, will have an impact on achieving its objectives. It is composed of the likelihood of a possible threat or opportunity occurring, as well as the magnitude of the impact on its objectives [2].

The goal of project risk management is to lower the chances of the project and its stakeholders failing to reach its objectives. It allows project managers to set priorities, allocate resources, and implement actions and processes that lessen the chances of the project failing to meet its objectives [3]. For this uncertainty, these risks should be managed as control risks, and the project's overall management should adjust for the uncertainty associated with these various types of risks. It would be impractical for the project manager to simply focus on the disadvantages of the ground conditions. Moreover, the project manager should not expect that things will turn out better than predicted just because he or she wants them to [4]. Only the project manager has the authority to decide which risks are desirable [5]. Under an engineering procurement construction (EPC) approach, the owners have to deal with one general Contractor. This major Contractor, on the other hand, could be a set of companies that engage with the Employer as "one Entity." The Employers' obligations, for example allowing access to the site and paying the agreed-upon amount, are reduced to a minimum level under the EPC contract, the contractor undertakes all other responsibilities and risks connected

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with project construction, design, erection, and commissioning as well as the associated interface risks [6]. EPC contracts entail a substantial shift in responsibility from the client to the contractor [7].

2 Methodology

2.1 Collecting data methods

There are two parts to the data collection method utilized in this study:

- Review literature studies, books, and articles related to this topic.
- Surveys: a combination of two methods, including in-person meetings and questionnaires, were utilized to collect the information needed. The purpose of the questionnaire was to present potential hazards identified through a literature analysis to experts and get their feedback on specific risks connected to the project under consideration. For this purpose, a specialist briefing session was arranged to discuss project risks and questionnaire items. The demographic sample method was used among project managers from several departments. Finally, 66 professionals completed the questionnaire, as well as provided feedback and suggestions on how to identify relevant risks.

2.2 Reviewing previous studies to identify potential risks in EPC projects

Risk identification in EPC projects was divided into three phases according to the life cycle for this contract type, and these phases are engineering, procurement, and construction as shown in Tables 1–3. It can be managed project risks, if it is possible to identify the important sources of risk and taking proactive actions to minimize failure modes and improve project success [8–10].

2.3 Potential risks in the EPC projects

The importance of several risks highlighted by experts was validated when the results of tests performed on data obtained from the surveys were assessed. This indicates that these are the most important risks in this study, while "risks irrelevant to the project" and "less important risks" were not recognized as shown in Table 4.

3 Techniques for root cause analysis

3.1 Fishbone diagram (Ishikawa)

Ishikawa diagrams, cause and effect tests, and fishbone diagrams are all terms for diagrams that simulate a skeleton of a fish when viewed as a whole. The fishbone diagram helps the team identify and focus on root cause analysis by describing potential causes of problems in a structured manner. Cause-and-effect analysis sequence can be a simple analysis that relates to a large number of causes and their order, but it can also be supplemented with other representation and hierarchical aspects for risk management. This diagram type identifies all

Table 1: Potential risks in the engineering phase

No.	Risks	Supporting research studies
1	Inaccurate cost estimation for the engineering phase	[11,12]
2	Inaccurate time estimation for the engineering phase	[13,14]
3	Lack of management and trained personnel	[15,16]
4	Design errors	[17,18]
5	Technical drawings that are inappropriate and inadequate	[19]
6	Reduced design time and a faster transition to the execution stage	[20]
7	Delay in receiving the project's initial permits	[21]
8	Insufficient feasibility studies	[22]
9	Inexperienced project managers	[23]
10	Changes resulting from political events	[24]
11	Internal policy changes in the organization	[25]
12	Changes to the scope of the project's work	[26]
13	A shortage of necessary resources	[27]
14	Changes in the requirements of the employer	[28]

Table 2: Potential risks in the procurement phase

No.	Risks	Supporting research studies
1	Inaccurate cost estimation for the procurement phase	[11,12]
2	Inaccurate time estimation for the procurement phase	[13,14]
3	Supplying poor quality equipment and materials	[29]
4	Variation in the cost of materials and equipment	[30]
5	A delay in the delivery time of some materials and equipment	[31]
6	Manufacturers' selection of equipment and materials is inappropriate	[32]
7	Lack of project planning and control in the procurement phase	[33]
8	Bureaucracy and lack of collaboration exist in the procurement department	[34]
9	Changes resulting from political events	[24]
10	Delay in technical inspection	[35]
11	Poor international communication	[36]
12	Equipment and construction materials have poor quality control	[37]
13	Damage to equipment during transportation	[38]
14	Financial issues associated with the contractors in the procurement and supplying phase	[39]
15	Lack of data and documentation	[40]
16	Changes to rules regulating insurance, taxation, and other matters	[41]

Table 3: Potential risks in the construction phase

No.	Risks	Supporting research studies
1	Inaccurate cost estimation for the procurement phase	[11,12]
2	Inaccurate time estimation for the engineering phase	[13,14]
3	Delays caused by the long process of obtaining permits required	[31]
4	Incompetent subcontractors	[15]
5	Lack of skills and technical workers	[16]
6	Poor planning and management in the construction phase	[33]
7	Unexpected disasters such as floods, earthquakes, etc.	[42]
8	Changes resulting from governmental and political developments	[24]
9	Errors in testing materials and equipment	[43]
10	Poor inspection process, quality control, and quality assurance	[44]
11	Employing unskilled engineers in monitoring	[16]
12	The project manager's performance was poor	[33]

Table 4: Risks that have been highlighted by the experts

Engineering phase	Procurement phase	Construction phase
Inaccurate cost estimation for the engineering phase	Inaccurate cost estimation for the procurement phase	Inaccurate cost estimation for the procurement phase
Inaccurate time estimation for the engineering phase	Inaccurate time estimation for the procurement phase	Inaccurate time estimation for the engineering phase
Management and staff with qualified skills are in short supply	Financial issues associated with the contractors in the procurement and supplying phase	Delays caused by the long process of obtaining permits required
Design errors (weaknesses or cover design)	Lack of data and documentation	Incompetent subcontractors
Technical drawings that are inappropriate and inadequate	Lack of project planning and control in the procurement phase	Lack of skills and technical workers
Delay in receiving the project's initial permits	Delay in technical inspection	Employing unskilled engineers in monitoring
Inexperienced project managers		
Insufficient feasibility studies		Poor performance of the project site manager
Internal policy changes in the organization		

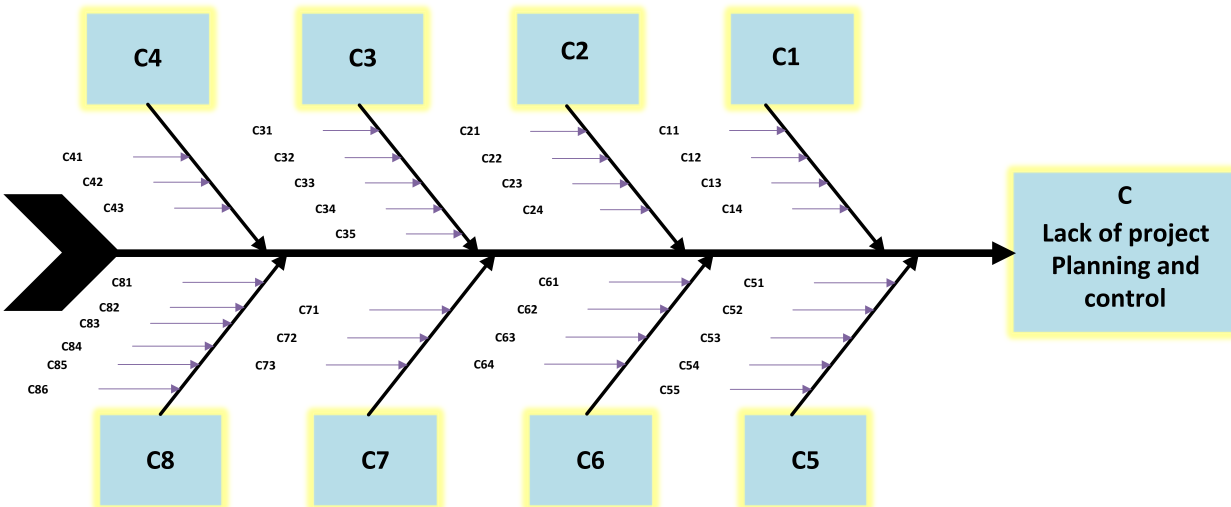

Figure 1: Fishbone diagram for causes of lack of project planning and control.

possible contributing factors to a problem (Figure 1). This can aid in finding resolutions after the fishbone diagram has gathered and displayed all the desired information [45].

3.2 Pareto analysis

A Pareto chart is a graphical tool used in Pareto analysis. A Pareto chart is a bar chart that displays the relative importance of issues in an easy-to-understand format.

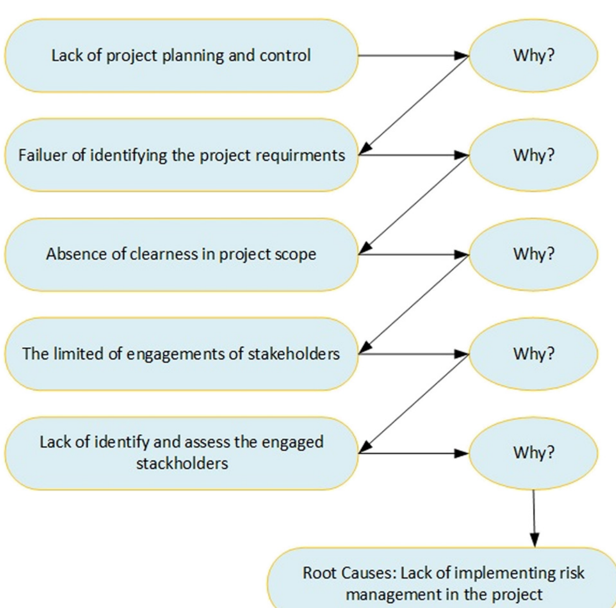

Figure 2: The relationships between these causes.

The tallest bar reflects the most significant difficulty (*e.g.*, the one with the largest cost, frequency, or another metric), followed by the next tallest bar, and so on. To collect data for Pareto charts, a check sheet might be used [46].

3.3 5-Whys for root cause analysis

The 5-why method aids in the identification of cause-and-effect relationships in a problem or failure event. It is useful when the true source of a problem or situation is not obvious. The 5-why method aids in the identification of cause-and-effect links in a problem or failure event. It is useful when the true source of an issue or situation is not obvious. Using the 5-whys is a quick and easy technique to try to solve a problem without having to conduct a lengthy, resource-intensive inquiry [47]. A case study of analyzing the risk causes in an EPC construction project implemented in Iraq, by using the 5-why technique to find the root causes of lack of planning and control in the project and showing the relationships between these causes are illustrated in Figure 2.

4 Diagnosing lack of project planning in Iraq

To identify and analyze root causes for the lack of project planning and control in Iraqi construction projects, a survey analytic approach was used which is important

Table 5: Main causes of risks with their codes

Main cause	Code	Secondary cause	Code
Equipment	C1	Lack of a mechanism to manage the equipment	C11
		The inability for evaluating the equipment's productivity	C12
		Equipment was overused	C13
		Lack of equipment maintenance	C14
Labors	C2	Using inexperienced or incompetent operator staff	C21
		Labor income and salaries are at a low level	C22
		Lack of worker coordination	C23
		Lack of an active labor management system	C24
Systems	C3	Failure to implement a safety program	C31
		Modern management practices and computer programs are not utilized	C32
		Insufficient quality control and inspection	C33
		Failure to adhere to a cost-management strategy	C34
		Managing a large number of projects at the same time	C35
		Improper material selection and utilization by contract standards	C41
		Improper inspection and testing of materials before usage	C42
		Lack of coordination between contractors and suppliers	C43
Design and execution	C 5	The owner's design criteria are unclear	C51
		Designers with insufficient experience and knowledge	C52
		Lack of compliance with specifications cited in the working report	C53
		Lack of collaboration between the designer and the owners	C54
		Financial issues arising during execution	C55
Subcontractors	C6	Improper supervision of subcontractors	C61
		Unexperienced subcontractors	C62
		Lack of coordination between general contractor and subcontractor	C63
		Lack of evaluation for subcontractor performance	C64
Site staff	C7	Lack of coordination between contractor's personnel and supervisors	C71
		The contractor's personnel have a low level of skill and experience	C72
		Supervisory staff with little experience and ineptitude	C73
Contract	C8	Lack of collaboration between contracting parties	C81
		The contractor's personnel have a low level of skill and experience	C82
		Lack of familiarity with the regulations to implement governmental contracts no. 2 of 2014 and attachments to these regulations	C83
		Lack of knowledge of any official instruction issued from the Ministry of Planning of Iraq	C84
		Insufficient experience in the use of (EPC) standard bid documents which are considered the best solution to implement governmental contracts, assure stability of procedures, and reduce administrative and financial corruption	C85
		Inadequate management contract disputes	C86

Table 6: Main groups of risk issues with their frequencies

Main cause	Frequency	Relative frequency (%)	Cumulative relative frequency (%)
Contract causes (C8)	16	24.24	24.24
Design and execution causes (C5)	14	21.21	45.45
Subcontractors' causes (C6)	11	16.67	62.12
Systems causes (C3)	9	13.64	75.76
Equipment causes (C1)	7	10.7	86.36
Labors causes (C2)	4	6.06	92.42
Materials causes (C4)	3	4.55	96.97
Site staff causes (C7)	2	3.03	100
Total	66		

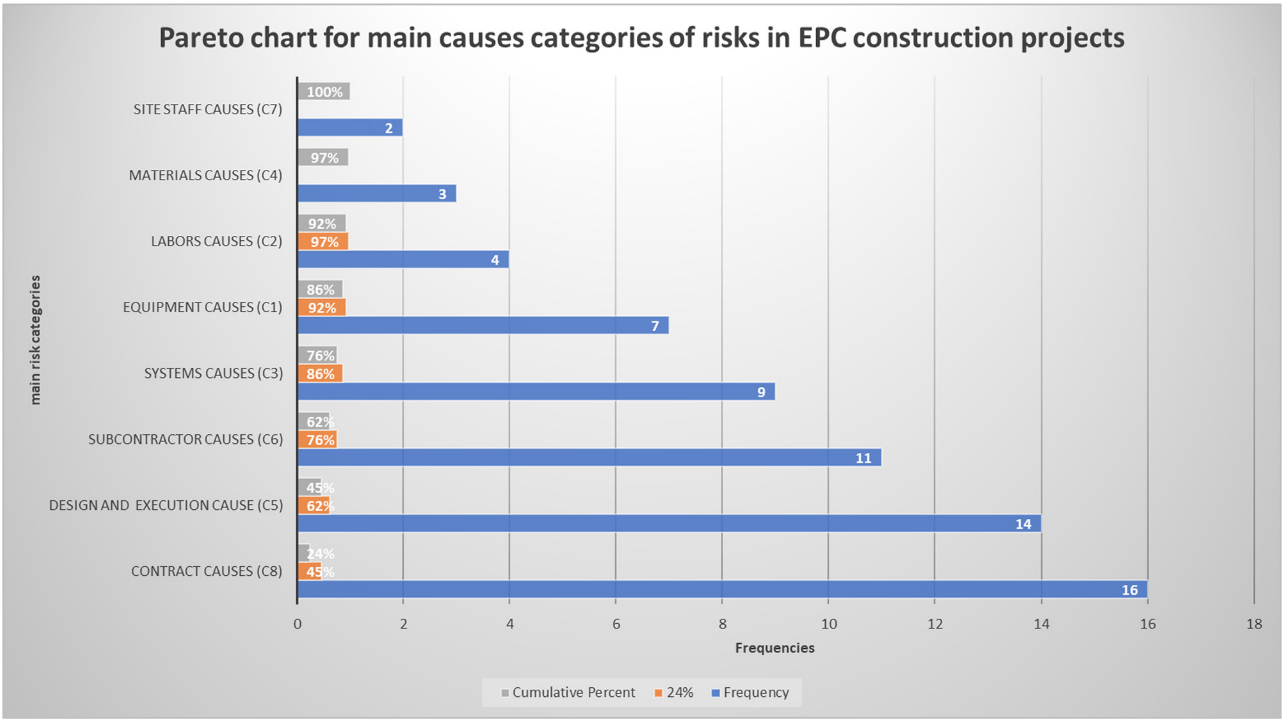

Figure 3: Pareto chart for main risk causes in EPC projects.

for root cause analysis. In this study, the researcher also used a literature review, an expert questionnaire, and personal interviews with people who were chosen for their expertise and qualifications. Various groups were engaged to determine the causes for the lack of project planning and control in construction projects in Iraq (contract causes, labor causes, system causes, material causes, design and execution causes, subcontractors' causes, site staff causes, and equipment causes) as shown in Table 5.

To get an idea of the importance of each risk cause groups, the Pareto analysis was used after making a survey consisting of 80 distributed forms. After collecting and analyzing the frequencies by using the frequency procedures in SPSS, only 66 forms were considered while the others were neglected because of the lack of the information provided.

Table 6 demonstrates the number of occurrences of each risk cause groups with their relative accumulative values to present the Pareto chart (Figure 2) for the main causes of risks and their weight of effects.

As mentioned above, the main causes for lack of planning and control in EPC construction projects in Iraq were grouped into eight groups, contract causes (C8) and design and execution causes (C5) are the principal triggers, followed by subcontractors' causes (C6), system causes (C3), equipment causes (C1), labor cause (C2), material causes (C4), and site staff cause (C7). The contract group causes (C8), design and execution cause group (C5), group of subcontractor causes (C6), group of system causes (C3), and group of equipment causes (C1) are considered to account for 75.76% of the problem in the Pareto chart (Figure 3). By focusing on these five main triggers, 75.76% of the issue (lack of planning and control in projects) will be resolved.

5 Conclusion

- The main causes of risk in EPC construction projects in Iraq have been identified and diagnosed and then represented in group lists that demonstrated these main risks. Each group of risks had secondary causes that contributed to the major risks which need more tracking and observation. Pareto analysis revealed that only 75.76% of the main causes are related to contract causes, design and execution causes, subcontractors' causes, the system causes, and equipment causes, while minimal reasons in labor causes, material causes, and site staff cause categories.
- The results of using the 5-why analysis on a case study of the Iraqi EPC construction project revealed that the absence of risk management implementation in the

EPC construction project is a root cause for the lack of planning and control of the project.

Funding information: The authors state no funding involved.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Conflict of interest: Authors state no conflict of interest.

References

[1] Project Management Institute, Inc. A guide to project management body of knowledge, (PMBOK). 5th ed. 2013.
[2] Massimo P. Project life cycle economics cost estimation, management, and effectiveness in construction projects. Farnham, UK: Ashgate Publishing; 2015.
[3] Cooper DF, Grey S, Raymond G, Walker P. Project Risk Management Guidelines: Managing Risk in Large Projects and Complex Procurements. Hoboken (NJ), USA: John Wiley & Sons; 2005.
[4] Hopkin P. Fundamentals of risk management, understanding, evaluating, and implementing effective risk management. 4th ed. Lodon: Kogan Page Ltd; 2017.
[5] Morris PWG, Pinto JK. The Wiley Guide to Managing Projects. Hoboken (NJ), USA: John Wiley & Sons; 2004.
[6] Hagner M. Engineering, Procurement and Construction Contracts for Large Scale Projects: A Practical Guide to EPC Contracting and Claim Management. Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); 2013.
[7] Cova B, Chauri PN, Salle R. Project marketing: beyond competitive bidding. Chichester: John Wiley & Sons; 2002.
[8] Wenger A, Mauer V, Cavelty MD. International handbook on risk analysis and management. Center for Security Studies at ETH Zurich. Swiss Federal Institute of Technology; 2008.
[9] Kendrick T. Identifying and managing project risk, essential tools for failure-proofing your project. 2nd ed. Hoboken, New Jersey: Prentice Hall; 2000.
[10] Nurdiana A, Susanti R. Assessing risk on the engineering procurement construction (EPC) project from the perspective of the owner: a case study. JIC-CEGE 2019. 2020;506:012040.
[11] Gransberg DD, Riemer C. Impact of inaccurate engineer's estimated quantities on unit price contracts. J Const Eng Manag ASCE. November 2009;135(11):1138–45.
[12] Christensen P, Dysert LR, Bates J, Burton D, Creese RC, Hollmann J. Cost estimate classification system – as applied in engineering, procurement, and construction for the process industries. AACE International Recommended Practices; 2005.
[13] Dysert L, Elliott BG. The estimate review and validation process. AACE International Annual Meeting and 2nd World Congress of Cost Engineering, Project Management, and Quantity Surveying at Calgary, Alberta, Canada; 2000.
[14] Simushi S, Wium J. Time and cost overruns on large projects: understanding the root cause. J Const Devel Countries Time Cost Overruns Large Projects. 2020;25(1):129–46.
[15] Auwalin I, Nyasulu A, Kittayaapinant S. Labour Supply and Skills Shortage in Australia. KnE Soc Sci. 2019;3(13):1249–1265.
[16] Horbach J, Rammer C. Labor shortage and innovation. Germany: ZEW - Leibniz Centre for European Economic Research. 2020.
[17] Vashishtha U, Bawaniya V, Paul VK. Design errors in building construction projects. Int Res J Eng Technol (IRJET). July 2020;7(7):3850.
[18] Peansupapa V, Ly R. Evaluating the impact level of design errors in structural and other building components in building construction projects in Cambodia. Proc Eng. 2015;123:370–8.
[19] Abdullah WS, Ali Qaradaghi AM. Measurable mistakes in architecture the effect of designer's experience on the propagation of mistakes in architectural design – residential buildings in Al Sulaymaniyah city as a case study. J Eng. January 2021;27(1):89–111.
[20] Mejlænder-Larsen Ø. Improving transition from engineering to construction using a project execution model and BIM. ITcon. 2018;23:324–339.
[21] Muhammed TA. Delay in construction projects [dissertation]. Sulaymaniyah: The American University of Iraq, Sulaimani; 2015.
[22] Mohammed SR, Naji HI, Hussein Ali R. Impact of the feasibility study on the construction projects. 2nd International Conference on Sustainable Engineering Techniques (ICSET); 2019 Mar 6–7; Baghdad, Iraq.
[23] Pollack J, Algeo C. Project managers and change managers contribution to success. Int J Manag Proj Business. 2016;9(2):3.
[24] Akwei C, Damoah IS, Amankwah-Amoah J. The effects of politics on the implementation of government programs/projects: insights from a developing economy. P&P. 2020;48(6):1161–1201.
[25] Aronsson F, Huusko A, Wansulin V. Internal and external forces of organizational change in project management a case study on a collaborative project [dissertation]. Västerås: Mälardalen University; 2021.
[26] Nahod M-M. Scope control through managing changes in construction projects. Organ Technol Manag Constr. 2021;4(1):438–447.
[27] Irugal Bandara IBMMS. Effects of resource planning on construction project delays in Sri Lanka. A Research Project Submitted in Partial Fulfillment of the Requirements for the Higher National Diploma in Civil Engineering; 2018.
[28] Bojesson C. Improving project performance in product development [dissertation]. Västerås: Mälardalen University; 2015.
[29] Danso H. Poor workmanship and lack of plant/equipment problems in the construction industry in Kumasi, Ghana. GE-IJMR. 2014;2(3):60–70.
[30] Kincannon L, Franchet Y. Sources and methods construction price indices. Luxembourg: Statistical Office of the European Community.
[31] Rahman MM, Yap YH, Ramli NR, Dullah MA, Shamsuddin MSW. Causes of shortage and delay in material supply: a preliminary study. Mater Sci Eng. 2017;271.
[32] Shahbazi S. Material efficiency management in manufacturing [dissertation]. Västerås: Mälardalen University; 2015.
[33] Khalid FJ. The impact of poor planning and management on the duration of construction projects: a review. MECSJ. 2017;2:161–81.

[34] Decarolis F, Giuffrida LM, Iossa E, Mollisi V, Spagnolo G. Bureaucratic competence and procurement outcomes. ZEW – Centre for European Economic Research Discussion Paper No. 19-057; 2019.
[35] Jodejko-Pietruczuk A, Nowakowski T, Webińska-Wojciechowska S. Time between inspections optimization for technical object with time delay. J Polish Saf Reliab Assoc. 2013;4(1):35–42.
[36] Hendrith M. The effects culture and communication have on business [dissertation]. Murray (KY), USA: Murray State University; 2018.
[37] Albert I, Shakantu W, Ibrahim S. The effect of poor materials management in the construction industry: a case study of Abuja, Nigeria. Acta Structilia. 2021;28(1):142–167.
[38] Anholcer M, Hinc T, Kawa A. Losses in transportation – importance. In Kawa A, Maryniak A, editors. SMART Supply Network. Cham: Springer; 2019. p. 111–128.
[39] Buzzettoa RR, Baulia MR, de Carvalhoa MM. The key aspects of procurement in project management: investigating the effects of selection criteria, supplier integration, and dynamics of acquisitions. Production. 2020;30(7):e20190112.
[40] Xu S, Luo H. The information-related time loss on construction sites: a case study on two sites. Int J Adv Robotic Syst. 2014 Aug 22;11(8):128.
[41] Organization for Economic Co-Operation and Development. Guidance note compliance risk management: managing and improving tax compliance; 2004.
[42] Chaudhary MT, Piracha A. Natural disasters – origins, impacts, management. Encyclopedia. 2021;1(4):1101–1131.
[43] Zou PX, Guomin Z, Jiayuan W. Understanding the key risks in construction projects in China. Int J Project Manag. 2007;25:601–14.
[44] Bassiony MS, Abd El-Karim A, El Nawawy OAM, Abdel-Alim AM. Identification and assessment of risk factors acting construction projects. HBRC J. 2017;13(2):203–216.
[45] Slameto. The application of fishbone diagram analysis to improve school quality. Dinamika Ilmu. 2016;16(1):59–74.
[46] Enesi Y, Salawu OOA, Ajayi AI, Afolalu SA, Samson O. Pareto analysis of product quality failures and cost effects in bottling machines – a lean thinking solution for the alcohol industry. Int J Mech Eng Technol (IJMET). 2018;9(11):2380–8.
[47] Serrat O. The five whys technique. ADB Asian Development Bank; 2009.