Improved construction project management using multi objective optimization with genetic algorithm

Koshal Kishore[1], Er.Vikram Kaintura[2]

[1, 2] *Department of Civil Engineering College, Himgiri Zee University, Dehradun, Uttrakhand, India*

Abstract- Employer and Contractor agree on the type of contract they want to enter and, on the conditions, among others the risk allocation and payment terms of the contract. Owners are usually very careful when choosing the Contractor and negotiating the contract price. However, the selection of the contract type is too often done rather superficially. existing factors can be divided into two major categories: quantitative factors and qualitative factors. Currently, the AEC industry researchers have given many efforts to develop techniques that only consider quantitative factors and ignore qualitative factors such as "client priority on construction time, contractor's planning capability. the enumeration method that is usually used needs to assess and compare the performances of a great deal of scenarios, which seems to be time consuming for complicated projects with numerous scenarios. This study therefore developed an integrated method to efficiently provide contractors with plans having optimal environment–cost–time performances. Genetic multi objective are integrated through an iterative loop, which remarkably reduces the efforts on optimal scenarios searching. In the integrated method, the simulation module can model the construction equipment and materials consumption; the assessment module can evaluate multi-objective performances; and the optimisation module fast converges on optimal solutions.

Keywords- *cost, constructor, optimization, genetic*

I. INTRODUCTION

A construction contract is the commercial arrangement which governs the relationship between the Employer or Owner and the Contractor during a construction project [1]. The contract specifies what is to be built, for which price, under which payment terms, how the Client is to monitor the Contractor's performance and how contingency events are to be dealt with (Buckner-Petty, 2019; Alsaedi et.al 2019; A.M. Dale et.al 2019; Ward & Chapman, 1994). The Contractor is the firm or individual responsible for performing the works on behalf of the Employer (be it a private company or a public institution), who usually owns the completed work and compensates the Contractor for it. Contractor performance can be defined by the level and quality of projects delivered to clients. It has been a common practice however to select the least cost bidder among competing contractors to perform the job. Predicting the performance of construction firms in such a situation is indispensable in order to ensure quality and guarantee international standards. Inefficient management of construction project can result in low performance and productivity [2]. Therefore, it is important for contractors and construction firms to be familiar with the method leading to evaluate the performance of the construction project (Love & Li2000; Li et.al 2018; M. Menegaki et al. 2018; D.M Taofeeq et.al 2019)

Before starting a construction project, both Employer and Contractor agree on the type of contract they want to enter and, on the conditions, among others the risk allocation and payment terms of the contract. Owners are usually very careful when choosing the Contractor and negotiating the contract price. However, the selection of the contract type is too often done rather superficially. This can be an important mistake, as the contract allocates responsibilities, risks and rewards and impacts the Contractor's performance and thus the project outcome interms of quality, time and cost [3]. The type of contract influences extremely their future relationship, the risk allocation and the financial outcome for both of them, especially if some of the risks materialize (Russell, 2003; Karakhan et.al 2018; D. Yu et.al 2018; Taylan et.al 2018). Thence, an important question is the selection criteria which the Employer and Contractor use to choose between different contract types for international construction projects (Daniel W. Halpin et al. 2017; Brian Thorpe et al. 2017). There are many international standard forms of contracts, which can be divided mainly into lump-sum, target-cost and cost-plus contracts (Russell, 2003) (Supraptoet al.2016; Urquhart et al. 2018).

1.1 Performance of construction contractor

Poor performance such as low quality, time delays and cost overrun are not uncommon in construction project. Frimpong et al., (2003) suggested [4] that time delays and cost overruns arise primarily as a result of payment difficulties, poor contractor management, material procurement problems, poor technical ability, and escalation of material prices. On the other hand, some researchers have analysed the major causes of quality defects, one of which Love & Li (2000) described as poor workmanship. These studies also contributed to the identification of quality, time and cost as the three most important indicators to measure construction project performance. Conversely this may not ensure quality which is an indispensable measure in project delivery. Predicting the performance of the contractor is highly important for both the contractor and the owner.

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].

II. RELATED WORK

Ann Marie Dale et al. (2019) this study examined the relationship between safety program scores based on documents and contractor reported activities and project leading indicators of contractor safety climate, safety behaviors of workers and crews, and safety attitudes of coworkers from employee surveys. Hierarchical linear regression models accounted for contractor size and number of workers, nested in contractors within projects. Separate models examined the relationships between safety program scores and 1) contractor safety climate; 2) co-worker attitude scores, 3) employees' own behavior score, and 4) crew behavior scores. [9]

Mohammad Alsaedi et al. (2019) this study aimed to uncover the critical factors affecting the contractors' bidding decisions in Saudi Arabia-based construction projects. A questionnaire survey, which consisted of 31 factors, was distributed to first-, second- and third-grade contractors. In total, 67 responses were obtained. Median and relative importance index (RII) techniques were adopted for ranking the most critical factors. Based on the received responses, the top six critical factors were "size of the job", "type of the job", "company's strength in the industry", "designer/design quality", "rate of return", and "project cash flow". The least significant factors were "job start time" and "labor environment (union/non-union/cooperative)". The findings of this study show a level of agreement among all contractors about the critical factors. The findings would benefit contractors and subcontractors by increasing their understanding of the major factors affecting the bidding decision process.[10]

D.MTaofeeq et al. (2019) A total number of ninety-five (95) risk factors that are dampening and affecting contractor productivity in Malaysia construction industries were revealed by the ranking of the contractor risk attitude factors through SPSS. In the same vein, the risk factors were further classified into six (6) sub-classes depending on their nature and likelihood of occurrence. Such as (Technical risk, Logistical risk, Management risk, Social-political risk, financial risk, and Environmental risk). In order to achieve the proper response rate for this study, in total 250 questionnaires were distributed to the construction industry in Kuantan Malaysia randomly. Of the 250 questionnaires distributed, 234 questionnaires were received with an equal percentage of 93.6%. [11]

Jingru Li etal. (2018) This study revealed that the extended TPB (theory of planned behaviour) model has significantly improved the explanation power of CWR (construction waste reduction) behavior than the classic TPB model. Results showed that contractor employees' behavior-related knowledge was the most influential factor on their CWR behavior, notably greater than subjective norm, attitude, personal norm and perceived behavioral control. These findings provide useful inputs for designing effective approaches to motivate CWR behavior of contractor employees and policy making to reduce construction waste. [12]

Ali A. Karakhan et al. (2018) The present study aims to bridge this gap in safety knowledge by proposing a decision-making framework that can be used to evaluate the safety maturity of construction contractors. Development of the decision-making framework included two tasks. First, an integrative literature review to identify influential safety maturity factors and their potential indicators was performed. The result of the review revealed seven factors (safety leading indicators, safety lagging indicators, safety and supervisory personnel, system maturity and resiliency, preconstruction services, technology and innovation, and safety culture) that influence the safety maturity of construction contractors. Second, the identified factors, and their indicators, were integrated into a formal multicriteria decision-making method, referred to as Choosing by Advantages, to evaluate the safety maturity of five construction contractors on a selected case study project. The proposed framework is expected to provide practical and theoretical directions on how to evaluate contractor safety maturity using relevant evaluation factors and sound decision-making methods. [13]

Dengke Yu et al. (2018) The study involves three aspects. First, three stages of KM research in construction were distinguished in terms of the time distribution of 217 target publications. Major topics in the stages were extracted for understanding the changes of research emphasis from evolutionary perspective. Second, the past works were summed up in a three-dimensional research framework in terms of management organization, managerial methodology and approach, and managerial objective. Finally, potential research orientations in the future were predicted to expand the existing research framework. [14]

Maria Menegakiet al. (2018) This paper, through a review of recent literature, focuses on the factors, barriers and motivations that influence the generation and management of CDW. Based on the analysis, two indicators are calculated for selected countries using the latest available data and an explanatory model is developed with a view to enabling identification of the factors affecting CDW generation. Most importantly, a concept map is created involving thirty-six different nodes that represents existing knowledge with respect to the components of the CDW5system, and the positive or negative relationships between them. [15]

S. Urquhart et al. (2018) Limited research has been conducted on the internal tendering procedures (ITP) of construction contractors because of the commercially sensitive and confidential nature of the subject matter. This limitation explains the reluctance of contractors to undergo interviews.

Existing research (outside bid/no-bid and margin decision factor identification and subsequent decision modelling development) only begins to provide insights into key tendering stages, particularly around risk assessments and corporate review processes. [16]

Sadi Assaf et al. (2018) The purpose of this paper is to investigate the major causes of DDDs in a fast-expanding economy, where errors can translate to an adverse impact on the economy. This paper aims to identify and assess the causes of DDDs for large construction projects from the consultants' perspective. [17]

Osman Taylon et al. (2017) This study aims to integrate the contractor selection approaches for the formulation of decision problems using fuzzy and crisp data. Fuzzy AHP approach was employed for determining the criteria weights, and fuzzy TOPSIS method was used to find out the performance of contractors. Fuzzy extension of AHP enables the pair-wise comparison of criteria using synthetic global scores based on the data of a single expert. However, in this study, we used the data of multiple DMs and averaged the aggregated findings in the pair-wise comparison table; hence, seven contractors were evaluated based on the Big Data. [18]

D. Alleman et.al (2017) This study focuses on the use of qualifications-based selection (QBS) and best-value (BV) procurement approaches, how and why agencies use each approach, and their associated opportunities and obstacles. Data for this study were obtained from a majority of federally funded CM-GC projects completed between 2004 and 2015. It was found that the use of BV procurement versus QBS procurement had no statistically significant difference in project characteristics or in performance of the projects in the data set. The choice of BV or QBS procurement coincided with an agency's CM-GC stage of organizational development and influences of nonagency stakeholders on the CM-GC process. [19]

Seyit Ali Erdoganet al. (2017) The term and content of construction project management are outlined in this article. The main problems of construction management were identified and possibilities to solve them are discussed. The model for decision making in construction management by using multi-criteria methods was created and applied to real case study. AHP method and "Expert Choice" computer program was employed for calculations. [20]

Mohammad Suprapto et al. (2016) hypothesized the effects on project performance are mediated by owner–contractor collaboration, measured in terms of relational attitudes (relational norms and senior management commitment) and teamworking quality (inter-team collaborative processes). Using PLS-SEM, the analysts analysed a sample of 113 capital projects. The results suggest that through better relational attitudes and teamworking quality, projects with a partnering/alliance contract are likely to perform better than those with lump-sum and reimbursable contracts. [21]

Sharfuddin Ahmed Khan et.al (2016) Using a real case study of a multi-million dollars project, the results of ulti-million construction contractor selection) model is compared to the results analytical hierarchy process (AHP) in two scenarios; using the same main evaluation criteria, and then adding more sub-criteria. The AHP model was built by using the lessons learned from the project after its completion, the evaluation criteria and their weights were adjusted. Sensitivity analysis of both scenarios, before and after completion of project shows the robustness of contractor selection. [22]

III. THE PROPOSED METHOD

3.1 Proposed Methodology

The model in this thesis is based on Genetic Algorithm. It consists basically of an initial population that evolves through a number of iterations. The outcome solution is called Chromosome and is represented by set of integer values called Genes. The initial population is generated randomly, then the fitness is calculated for all possible solutions and the following operators are performed:

- Selection,
- Crossover
- Mutation Operator.

The chromosome of this model is the number of days to be shifted for each non-critical activity, the critical path may change after each iteration, but the total duration of the project remains the same if the user wants it to meet the deadline, or he might extend the deadline if the user wants

The quality of individuals (feasible solutions) is evaluated and ranked using a fitness function to minimize the total cost of resources

Criteria to select the resources:

As mentioned before, the direct cost of any activity is divided into three categories:

1- Materials cost
2- 2- Human resources cost
3- Equipment cost
The model can work up to 9 resources, three resources for each category or as the user's preference. The user should choose the resources with greatest difference in cost between the available pool cost and the extra resource cost or the resources which its pool is not that big and he will need to get more resources from outside.

Model's Constraints There are two types of constraints in this model:

1- Hard Constraints: They are the constraints that cannot be broken. In this model there are three hard constraints which they are the deadlines for each project
2- 2- Soft Constraints: They are the constraints that can be broken, but a certain penalty is added. In this model they are the extra resources needed.

Human Resources Equipment Resources Material Resources 34 near optimum solution that all the resources needed are within the pool limit, then an additional cost will be added depending on which resource is exceeding the pool limit and its associated cost. The model will automatically select the resource with the least additional cost instead of the resource with the higher cost to minimize the cost as much as possible.

4.2 Model's Variables

The variable in this model is the number of days to be shifted for each activity. These variables will be added to the start date, so that the activity will be shifted by the number written in the variable cells.

Model's assumptions and limitations:

This model has few assumptions that the user has to take into consideration:

• The number of resources needed is constant throughout the activity period.

• The model can accommodate only one predecessor with Finish-to-Start Relationship, unless the user entered the start date manually.

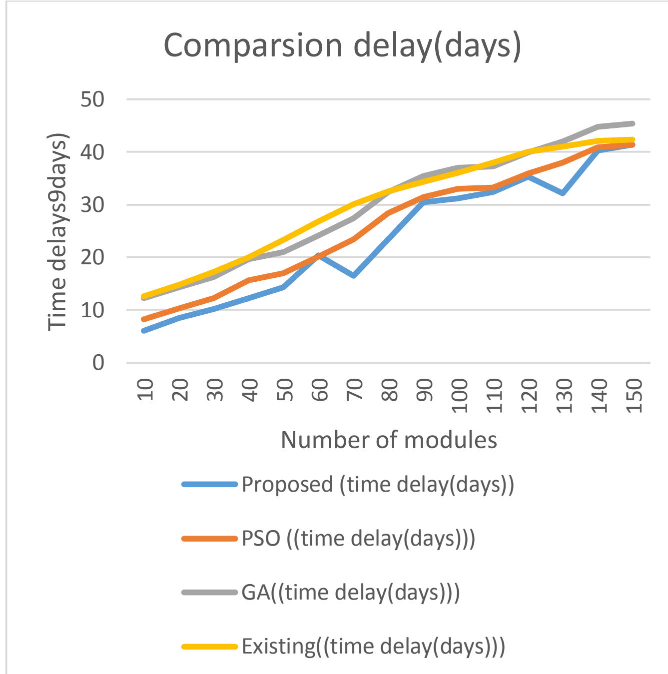
• There is no limitation to the extra resources needed, but the model can be adjusted to limit the number of extra resources.

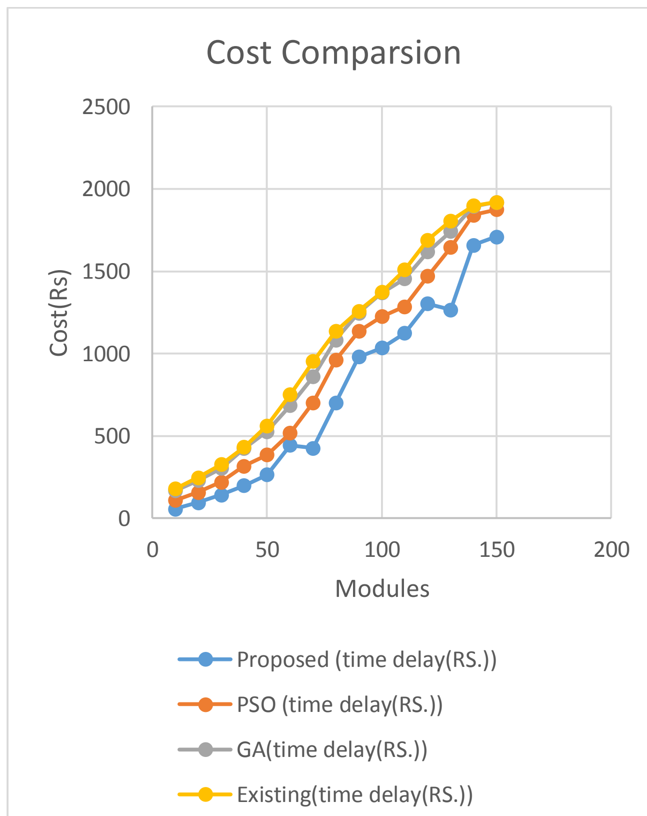
• The model minimizes the direct cost only, because the indirect cost will not change as the duration of the projects does not change. But it can be adjusted to minimize the direct and indirect cost if the user wants to extend the time of any project.

IV. RESULT ANALYSIS

4.1 Result Analysis

Like the analytic hierarchy process, decision makers utilize ANP to solve multicriteria decision problems. The AHP uses a one-way top-down hierarchal process for its components such as goals, criteria, and alternatives [50]. The ANP which is a generalized version of AHP uses a network for some problems when their components have interdependencies between them. The flow in the ANP's network is open and allows any component to interact with another regardless of their levels, which is not possible in AHP [51].





Liang and Wey [52] proposed an ANP model to optimally select government projects by accounting for the limitation of resources along with uncertainties and socioeconomic factors.

In order to test the model's effectiveness, seven projects in a nation-wide highway improvement project were used as an example. In the example, construction costs were determined by probability distributions and seven criteria were used to evaluate the projects. Moreover, since the model involves the use of multiple criteria, ANP was combined with MCS to make the selection of projects based on the solutions achieved by solving the multi-objective problems. ANP ranking was used to rank each project based on its value of priority among other projects. A cost-benefit approach was used to optimize the selection of projects based on the existing budget plan and the allocation of remaining budget to fund a project in full. The four objectives within these two problems were minimization of cost (Eq. (17)) and the number of project managers (Eq. (18)), and the maximization of project ranking (Eq. (19)) and the number of completed projects

IV. CONCLUSION

Making an environmentally friendly construction plan that simultaneously considers performances in multiple metrics is extremely difficult for the construction contractor. Many industry practitioners assume that other product performances will certainly suffer from the environmentally friendly strategy. This study proposes an innovative method that employs simulation, assessment, and optimization integration to perform efficient environment–cost–time multi-objective optimization, which may constitute a practical method for reducing environmental impacts with limited compromises on project cost and time performances. According to the case study, the obtained solutions not only reduce construction related GWP impacts, but also could receive the same or even better cost and time performances. This method provides construction plans that enables contractors to take trade-offs on interested objectives and help dispel the misgivings for further environmentally friendly applications. contractor can make their final decisions based on their preferences and project characteristics. In addition to the decision-making ability on construction planning, proposed method is also a credible tool that shows the ability and responsibility of a contractor company. This method could be used for contractors to show that construction is conducted in an energy-efficient, cost-, and time-effective manner. In addition to the construction, the integration of simulation, assessment, and multi-objective optimization could be implemented in other fields. This integration will be especially valuable for industries where several industrial objectives, many feasible options, and complex activity interactions need to be considered

V. REFERENCES

[1]. Ward, S. & Chapman, C., 1994. Choosing contractor payment terms. *International Journal of Project Management,* 12(4), pp. 216-221.

[2]. Li, H. and Love, P.E., 2000. Genetic search for solving construction site-level unequal-area facility layout problems. *Automation in construction*, *9*(2), pp.217-226.

[3]. Russell, S.H., 2003. Contract Types: An Exposition of Cost-Price Relationships in a New Paradigm. *The Journal of Cost Analysis & Management*, *5*(1), pp.43-58.

[4]. Frimpong, Y., Oluwoye, J. and Crawford, L., 2003. Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study. *International Journal of project management*, *21*(5), pp.321-326.

[5]. N, B, Ganaway, (2006) Construction Business Management: A Guide to Contracting for Business Success. *London:Butterworth-Heinemann*, 2006, pp. 213-216.

[6]. A, Salter, and R, Torbett, "Innovation and performance in engineering design," *Journalof Construction Management and Economics*, 2003, 21, pp. 573–580.

[7]. Georgy, M.E., Chang, L.M. and Zhang, L., 2005. Prediction of engineering performance: a neurofuzzy approach. *Journal of Construction Engineering and Management*, *131*(5), pp.548-557

[8]. Retrieved from www.ques10.com in May 2015.

[9]. Dale, A.M., Buckner-Petty, S. and Evanoff, B., 2019. P. 1.08 Connecting contractor safety management programs and worker perceived safety climate in commercial construction projects.

[10]. Alsaedi, M., Assaf, S., Hassanain, M.A. and Abdallah, A., 2019. Factors Affecting Contractors' Bidding Decisions for Construction Projects in Saudi Arabia. *Buildings*, *9*(2), p.33.

[11]. Taofeeq, D.M., Adeleke, A.Q. and Hassan, A.K., 2019. Factors Affecting Contractors risk attitude from Malaysia construction industry perspective. *Social Science and Humanities Journal*, pp.1281-1298.

[12]. Li, J., Zuo, J., Cai, H. and Zillante, G., 2018. Construction waste reduction behavior of contractor employees: An extended theory of planned behavior model approach. *Journal of cleaner production*, *172*, pp.1399-1408.

[13]. Karakhan, A.A., Rajendran, S., Gambatese, J. and Nnaji, C., 2018. Measuring and evaluating safety maturity of construction contractors: multicriteria decision-making approach. *Journal of Construction Engineering and Management*, *144*(7), p.04018054.

[14]. Yu, D. and Yang, J., 2018. Knowledge management research in the construction industry: a review. *Journal of the Knowledge Economy*, *9*(3), pp.782-803.

[15]. Taylan, O., Kabli, M.R., Porcel, C. and Herrera-Viedma, E., 2018. Contractor selection for construction projects using consensus tools and big data. *International Journal of Fuzzy Systems*, *20*(4), pp.1267-1281.

[16]. Urquhart, S. and Whyte, A., 2018. Rethinking the tendering frameworks of construction contractors in the context of a soft systems methodology approach. *Frontiers of Engineering Management*, *5*(3), pp.369-380.

[17]. Menegaki, M. and Damigos, D., 2018. A review on current situation and challenges of construction and demolition waste management. *Current Opinion in Green and Sustainable Chemistry*, *13*, pp.8-15.

[18]. Assaf, S., Hassanain, M.A. and Abdallah, A., 2018. Review and assessment of the causes of deficiencies in design documents for large construction projects. *International Journal of Building Pathology and Adaptation*, *36*(3), pp.300-317.

[19]. Alleman, D., Antoine, A., Gransberg, D.D. and Molenaar, K.R., 2017. Comparison of qualifications-based selection and best-value procurement for construction manager–general contractor highway construction. *Transportation Research Record*, *2630*(1), pp.59-67.

[20]. Erdogan, S.A., Šaparauskas, J. and Turskis, Z., 2017. Decision making in construction management: AHP and expert choice approach. *Procedia engineering*, *172*, pp.270-276.

[21]. Suprapto, M., Bakker, H.L., Mooi, H.G. and Hertogh, M.J., 2016. How do contract types and incentives matter to project performance? *International Journal of Project Management*, *34*(6), pp.1071-1087.

[22]. Khan, S.A. and Hosany, Y.I.A., 2016. Multi-million construction contractor selection: a comparative study. *International Journal of Intelligent Enterprise*, *3*(2), pp.93-119.