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Received: 22 June 2021  
Accepted: 12 February 2022

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## CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

# AHP based multi criteria decision analysis of success factors to enhance decision making in infrastructure construction projects

Solomon Belay<sup>1\*</sup>, James Goedert<sup>2</sup>, Asregedew Woldesenbet<sup>2</sup> and Saeed Rokooei<sup>3</sup>

**Abstract:** The study presents analytical data-based multi-criteria approach of critical success factors of infrastructure construction projects analyzed in the Ethiopian construction industry. This multi-criteria technique helps to improve the decision capabilities and ultimate performance of construction processes in various low-income countries of the East African region. The aim of this paper is to establish a logical relationship and interdependencies of success-related factors for enhancing decision making for various project teams and identify priorities while taking into account all known construction organizational constraints. A structured hierarchical matrix was developed based on a pre-identified success-related factors, and initially evaluated by experienced professionals as part of a content validation of the survey. Different professionals working in various construction organizations in Ethiopia were invited to participate in the questionnaire survey. All the required data analysis, including sensitivity performance, was conducted through Expert Choice© 11. Further, Kendall's coefficient of concordance was conducted to examine and compare multiple expert responses. Based on the findings, the top success-related factors that affect decision making in construction projects are Adequate Goals/Objectives, Consultant's Competency, Prior Experience of Consulting Firms, Consulting Firm's Willingness and Cooperation, and Financial Standing of Contractor. The results are based on their global priority weights in the hierarchical model. The findings highlighted that there is disagreement between the major stakeholders involved in the construction process.

### ABOUT THE AUTHOR

Solomon Melaku Belay is an assistant professor of Construction Engineering and Management at the Faculty of Civil and Water Resource Engineering, Bahir Dar Institute of Technology. His research interest focuses on Critical Success Factors, Analytic Hierarchy Process, Building Information Modeling, Structural Equation Modeling, and Safety and Health in Construction Projects.

### PUBLIC INTEREST STATEMENT

This study investigated the potential factors that affect the successful delivery of infrastructure projects in the Ethiopian construction industry. To achieve this objective, a dynamic multi-criteria decision analysis tool, Analytic Hierarchy process, was employed to analyze the perspective of various experts in a pair-wise comparison basis. The findings reveal that setting the required goal of the project during the inception stage of projects is the most important factor determining the success of infrastructure projects. Moreover, the experience and competency of consulting firms and financial status of the contractor are also detrimental in the successful delivery of infrastructure projects across the Ethiopian construction sector.

The contribution of the study is introducing a bench-marking multi-criteria decision analysis technique to enhance decision making in the Ethiopian infrastructure sector.

**Subjects: Engineering Management; Engineering Project Management; Civil, Environmental and Geotechnical Engineering**

**Keywords: Decision support system; critical success factors; project management; AHP**

## 1. Introduction

The infrastructure construction sector takes a significant portion of the gross domestic product of each country, and its successful completion can result in long-term economic and social development of lives in general (Sarvari et al., 2021). In Ethiopia for instance, the construction industry took more than half of the country's budget every year, for the past decade. Most of this budget is allocated for the construction of critical infrastructures including: road, rail way, buildings, water, and energy sectors (Sinesilassie et al., 2018).

A recent article published by (Belay et al., 2021) illustrated that the construction industry generates an immense employment opportunity to newly graduate engineers, enhances the livelihood of citizen through infrastructure development, and also directly contributes to the development of the overall national economy of the country in multiple instances. Further, the rapid growth of the industrial sector due to the second growth and transformation plan, also known as GTP II, has been a contributing factor to the huge infrastructure demand and expansion across various regions in the country.

This created a big construction market involving multiple construction companies including international organizations participating in international competitive bids. However, prior studies reveal that although infrastructure construction has been booming in the country, local construction firms lack competitiveness, constrained resources, and limited capacity to undertake major projects (Gebrehiwet & Luo, 2017). These challenges limit many organizations to perform the required job efficiently and ultimately fail to meet project objectives, including sustainability, schedule, budget, and quality. Furthermore, despite recent studies investigated critical success factors in organization, project, and industry levels in various regions, very few studies examined the project-based success-related factors, particularly for infrastructure construction sector in low-income economies, such as the East African region countries. Hence, this study aims to analyze and prioritize critical success factors using a multi-criteria decision technique, to help construction business CEOs and top management team in various decision-making stages along the project lifecycle.

The findings of this study are believed to be a benchmark for such topic in Ethiopia and will be helpful to construction firms, experts, educators, policymakers, and other key stakeholders to improve the overall performance of construction projects in the country. Moreover, the result helps to provide analytical evidences in the development of construction standards and roadmaps in Ethiopia, and as well as the sub-Saharan African region.

## 2. Literature review

The construction business environment is very complex that involves multiple resources and requires the overall collaboration of project participants in all stages of the project life cycle (Dinesh, 2016; Lim & Mohamed, 1999; Müller & Turner, 2007). In recent years, success and performance of infrastructure construction projects are measured through multiple indicators such as cost, schedule, safety, quality, safety, sustainability, and stakeholder management (PMBOK, 2017).

The level to which these project goals are achieved control the overall success of infrastructure projects in budget-constrained environments (Kovacic & Müller, 2014; Mathar et al., 2020). In contrast, the successful completion of different infrastructure projects in low- and middle-income countries is greatly affected by various risk factors including project teams, and financial and technical of different stakeholders. (Davis, 2014; Liu et al., 2018; Locatelli et al., 2014; Yong & Mustaffa, 2013a).

### **2.1. Critical success factors in infrastructure projects**

Construction projects are complex in nature and require the collaborative effort of each construction team across the project life cycle. Successful completion of these infrastructure construction projects could be a detrimental factor to ensure client satisfaction and profit to construction organizations. Ensuring success in the competitive business environment is dependent upon a combination of multiple factors, including the internal project-related factors, external factors directly and indirectly affecting construction projects, and the key stakeholders involving in those projects.

Prior studies highlighted that success factors different from industry to industry, and even project to project; taking to account the difference in construction policies and regulations, contract agreements, projects budget, and other critical factors. These studies suggested exploring success-related factors in country-wide aspects.

For instance, Kog and Loh (2012) identified 10 critical success factors from a total of pre-identified success-related factors in Singapore. The pre-identified factors were initially grouped under four categories, namely, project characteristics, contractual arrangements, project participants, and interactive processes. Tabish and Jha (2011) in India summarized 36 critical factors based on public infrastructure projects. Similarly, in China, the top-ranking success-related factors in public infrastructures are the clarity of information disclosure, timely responses to public inquiries, necessary avenues and equipment, diversity in the ways of disclosing information, and results presentation (Liu et al., 2018).

A study by (Shen et al., 2017) in Thailand's public green building industry reveal that all key project teams and stakeholders are responsible for successful completion of infrastructure projects and should regularly enhance their overall technical and management capacity to make sure that affordable and sustainable products are met, thereby making green buildings more affordable and pleasing to the general public. Further, Tripathi and Jha (2017) reported success criteria in India's construction market using a multi-criteria structural equation modeling approach. The findings proved that the top management team of construction organizations play valuable role in ensuring success to infrastructures and also helps to get a better and valuable lesson to new innovations and strategies to improve performance of construction projects.

Recent studies in different parts of the world employed various methods and techniques to prioritize and rank success-related factors in infrastructure projects. These include factor analysis, regression analysis (Altarawneh et al., 2018), hypothesis testing (Marleno et al., 2018), structural equation modeling (Demirkesen & Ozorhon, 2017), analytic hierarchy process (Belay et al., 2021), and artificial neural networks (Maghsoodi & Khalilzadeh, 2018). It can be noted that multiple methods have their own merits and demerits to analyze data. However, most of the data analysis techniques are normally affected by the quality of data collection and the experience, understanding and response of experts on each question.

One of the ways to improve this challenge is by using a multi-criteria decision analysis tool, analytic hierarchy process (AHP). AHP can have many advantages over other methodologies in similar studies. These include (1) AHP allows a few inconsistencies in expert judgements during analysis (Gudienė et al., 2013), (2) it helps experts (respondents) to focus on pairwise factors

instead of considering many factors at a time (Inayat et al., 2015), and (3) it helps to make decisions that have subjective factors (Kog & Loh, 2012), when compared with other decision-making tools dealing with the subjectivity of respondents. Hence, for these and other reasons, analytic hierarchy process was adopted in the current study to best capture the empirical data from various experts in the Ethiopian construction sector.

### 3. Methodology

Initially, a systematic review of literature search was conducted on the major research databases such as Springer, Elsevier—Science Direct, Taylor and Francis, Google scholar and American Society of Civil Engineers (ASCE) from 2005 to 2021. The first time keywords, such as “Critical Success Factors in Construction Projects”, “Critical Success Factors in Infrastructure development projects”, “Developing Countries” were typed, and this process resulted in 345 relevant documents. Then after a quick scan of the abstracts, the initial list was reduced to 70 articles, conference proceedings, and graduate thesis works. Finally, using including-excluding criterion, such as language, geographical location, methods used, and relevance of analysis, a final list of 31 success-related factors were pre-selected for further scrutiny.

The next stage was to prepare AHP questionnaire matrix using the pre-identified critical success factors for content analysis as part of a pilot test. In this case, the structure matrix was sent to two experienced experts in the field, and two more professors from universities. During this process, the experts recommended to reduce the pre-selected 31 success factors in infrastructure developmental projects to 19 critical success factors.

The final list of success-related factors was grouped under six main categories for ease of analysis. These categories include: External Factors, Project-Related Factors, Project Team Management Related Factors, Owner-Related Factors, Consulting Firm-Related Factors, and Contractor-Related Factors. Table 1 presents the final list of 19 success factors including their categories.

#### 3.1. AHP model of the study

The AHP model developed for the current study consists of three successive levels, as shown in Table 2. The top level of the hierarchy (Level 0) is the goal of the model, which is “Decision Support Analysis of CSFs in Construction Projects”. The middle level of the hierarchy covers the six categories of success-related factors. Similarly, the bottom level of the hierarchical model consists of all the 19 success-related factors in construction projects.

During the questionnaire matrix design, the relative weights (eigenvectors) of both levels 2 and 3 in a pairwise comparison matrix through a nine-point scale. These nine-point scales comprised of the following distinct aspects: Decision #1 = Equal Importance; #3 = Moderate Importance of One Over Another; 5 = Strong Importance; 7 = Very Strong Importance; and the last scale, 9 = Absolute Importance of each criterion. Further, 2, 4, 6, 8 demonstrate the intermediate values between adjacent value scales (Saaty, 1990).

#### 3.2. Response analysis

Initially, 89 experts were invited to fill out the pairwise comparison matrix survey of the questionnaire. These experts were chosen using a purposive sampling technique for ease of AHP analysis. The experts have enormous experience in the Ethiopian infrastructure construction sector. The experts consist of owners, consulting firm, contractors and from the academics. From these, a total of 84 experts responded by filling the questionnaire survey.

Twenty-three percent of the respondents were from consulting organizations, 22% clients, 30% contractors, and 25% from academia. In addition, from the respondents, 15 experts had 0 to 7 years

**Table 1. Short-listed success-related factors in infrastructure projects**

<b>CSFs</b>	<b>References Used for Model Development</b>
<b>External Factors</b>	
Economy of the Country	(Gunduz & Yahya, 2018; Hwang & Lim, 2013; Kog & Loh, 2012; Long et al., 2004; Mathar et al., 2020)
Impact of Politics	(Ejaz et al., 2013; Gunduz & Yahya, 2018; Hwang & Lim, 2013; Kulatunga et al., 2009; Ramlee et al., 2016; Yang et al., 2009)
Social Factors	(Al-Ageeli & Alizobae, 2016; Ejaz et al., 2013; Maghsoodi & Khalilzadeh, 2018; Salleh, 2009b; Silva et al., 2015; Yong & Mustafa, 2013b)
<b>Project-Related Factors</b>	
Project Type	(Derrick J.Z & Mohamed F.E, 2011; Gudienė et al., 2014; Gunduz & Yahya, 2018; Hwang & Lim, 2013; Nilashi et al., 2015; Shahu et al., 2012; Yang et al., 2009)
Application of Innovative Technologies	(Belay et al., 2021)
Availability of Adequate Funding	(Derrick J.Z & Mohamed F.E, 2011; Ejaz et al., 2013; Gudienė et al., 2014; Hwang & Lim, 2013; Mathar et al., 2020; Shahu et al., 2012)
Project Size	(Al-Ageeli & Alizobae, 2016; Koops et al., 2016; Kulatunga et al., 2009; Nguyen et al., 2004; Ramlee et al., 2016; Salleh, 2009a)
<b>Project Management Team-Related Factors</b>	
Top Project Management Team Commitment	(Esmaili et al., 2016a; Hwang & Lim, 2013; Inayat et al., 2015; Saqib et al., 2008; Shahu et al., 2012; Silva et al., 2015; Tabish & Jha, 2011; Toor & Ogunlana, 2009; Yang et al., 2009)
PM Team's Past Experience	(Gudienė et al., 2013; Kog & Loh, 2012; Nilashi et al., 2015; Shahu et al., 2012; Yang et al., 2009; Yong & Mustafa, 2013b)
Communication Skill of the top management Team	(Ejaz et al., 2013; Esmaili et al., 2016b; Gunduz & Yahya, 2018; Hwang & Lim, 2013; Maghsoodi & Khalilzadeh, 2018)
<b>Owner-Related Factors</b>	
Adequate Goals/Objectives	(Mathar et al., 2020; Nguyen et al., 2004; Salleh, 2009a; Saqib et al., 2008)
Variations	(Abraham, 2004; Gudienė et al., 2013; Rachid et al., 2019; Yang et al., 2009)
<b>Contractor-Related Factors</b>	
Contractor's Previous Relevant Experience	(Al-Ageeli & Alizobae, 2016; Hwang & Lim, 2013; Ramlee et al., 2016; Silva et al., 2015)
Contractor's Technical Competency	(Gunduz & Yahya, 2018; Kog & Loh, 2012; Ramlee et al., 2016; Shahu et al., 2012; Toor & Ogunlana, 2009)
Safety, Health and Environment	(Derrick J.Z & Mohamed F.E, 2011; Ejaz et al., 2013; Esmaili et al., 2016a; Inayat et al., 2015; Yang et al., 2009)
Financial Standing of Contractor	(Low et al., 2018; Marleno et al., 2018)
<b>Consulting Firm Related-Factors</b>	
Consultant's Competency	(Hwang & Lim, 2013; Ramlee et al., 2016; Silva et al., 2015; Toor & Ogunlana, 2009)
Consulting Firm's Willingness and Cooperation	(Ramlee et al., 2016; Salleh, 2009a; Shahu et al., 2012)
Prior Experience of Consulting Firms	(Al-Ageeli & Alizobae, 2016; Inayat et al., 2015; Kog & Loh, 2012; Kulatunga et al., 2009; Mathar et al., 2020)

**Table 2. Hierarchical structure of the AHP model**

Level 0	Level 1	Level 2
Decision Support Analysis of CSFs in Construction Projects	External Factors	<ul style="list-style-type: none"> <li>Economy of the Country</li> <li>Impact of Politics</li> <li>Social Factors</li> </ul>
	Project-Related Factors	<ul style="list-style-type: none"> <li>Project Type</li> <li>Application of Innovative Technologies</li> <li>Availability of Adequate Funding</li> <li>Project Size</li> </ul>
	Project Management Team-Related Factors	<ul style="list-style-type: none"> <li>Top Project Management Team Commitment</li> <li>PM Team's Past Experience</li> <li>Communication Skill of the top management Team</li> </ul>
	Owner-Related Factors	<ul style="list-style-type: none"> <li>Adequate Goals/ Objectives</li> <li>Variations</li> </ul>
	Consulting Firm-Related Factors	<ul style="list-style-type: none"> <li>Consultant's Competency</li> <li>Consulting Firm's Willingness and Cooperation</li> <li>Prior Experience of Consulting Firms</li> </ul>
	Contractor-Related Factors	<ul style="list-style-type: none"> <li>Contractor's Previous Relevant Experience</li> <li>Contractor's Technical Competency</li> <li>Safety, Health and Environment</li> <li>Financial Standing of Contractor</li> </ul>

of prior experience, 25 of them had 8 to 10 years relevant experience. Whereas the remaining 29 and 15 experts had 11 to 15, and greater than 15 years of prior experience in the field, respectively. Each of the criteria within each category on the hierarchy was evaluated and prioritized using a pairwise comparison matrix to examine the top-ranked critical success factors in the Ethiopian construction sector.

### 3.3. AHP computation steps

AHP is a hierarchical and pairwise comparison matrix-based multi-criteria decision analysis technique that helps to solve multiple complex decision problems. When using AHP, the developed hierarchical structure is usually separated into various layers designed from level 0 to level n. The goal of the decision problem is normally placed at the top of the hierarchical model; and the other levels of the structure consists of categories, factors, alternatives, and so on. (Saaty, 1988).

As Saaty explained in his books, the various relative weight of each criterion was calculated using normalization. The priority of each factor to the criterion at the top subsequent levels above is denoted by the Eigenvector also known as the local vector as shown in Equation 1 below.

$$A_w = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & \dots & a_{ij} & \dots \\ \dots & a_{ji} = 1/a_{ij} & \dots & \dots \\ a_{n1} & \dots & \dots & 1 \end{bmatrix} \tag{1}$$

where  $a_{ij}$  is the comparison between item  $i$  and  $j$ .

**Table 3. Priority of level 2 success-related factors**

Rank	Level 2—Success-Related Factors	Global Weight
1	Adequate Goals/Objectives	0.12
2	Consultant’s Competency	0.11
3	Prior Experience of Consulting Firms	0.11
4	Consulting Firm’s Willingness and Cooperation	0.1
5	Financial Standing of Contractor	0.08
6	Availability of Adequate Funding	0.07
7	PM Team’s Past Experience	0.05
8	Top Project Management Team Commitment	0.05
9	Variations	0.05
10	Communication Skill of the top management Team	0.04

In this case, the criteria weights of each critical success factor are normalized by mathematically solving for a non-zero eigenvalue described in Equation 2.

$$\sum_{j=1}^n a_{ij} w_j = \lambda_{max} w_i \tag{2}$$

where  $w$  is the criteria weights (eigenvectors) and  $\lambda_{max}$  is the maximum eigenvalue in the model.

The Eigenvector illustrates the relative weights of each criterion under every level of the model. Then, the priority weights of each level up were aggregated using the geometric mean method. First, answers from each responder were synthesized into a single priority vector using GMM in order to get an overall computation of the priorities for each factor in the model (Equation 3 and Equation 4; Inayat et al., 2015). Where  $G$  = geometric mean of each factor in the hierarchy,  $a$  = weight provided by a respondent,  $n$  = total number of experts

$$(a_1, a_2, a_3, a_4 \dots a_n) = \left( \sum_{i=1}^n a_i \right) \tag{3}$$

$$\text{So, } G(a_1, a_2, a_3, a_4 \dots a_n) = (a_1, a_2, a_3, a_4 \dots a_n)^{1/n} \tag{4}$$

The global priority weight of each parameter is computed using the following formula (Equation 5; Gudienė et al., 2013).

$$G.W_{p,i} = W_{f,i} * W_{c,i} \tag{5}$$

where  $i$  = hierarchy level,  $W_f$  = factor local priority weightage, and  $W_c$  = category local priority weightage.



It is important to determine if experts were consistent in their responses in order for their judgements to be considered for the computation of global weights. One of the ways to measure this, as proposed by Saaty (1990), is to compute a consistency index for each expert in the study. The consistency index measures the consistency of data based on the maximum Eigenvalue, which is calculated by summing the product of each element in the Eigenvector. In order to verify that the consistency index meets the threshold value of a maximum of 10% (0.1). Saaty (1977) suggests what has been called the consistency ratio, which is determined by the ratio between the consistency index and the random consistency index (RCI) provided for each number of criteria. The matrix will be considered consistent if the resulting CR is less than 10%.

The degree of consistency of responses by each individual respondent can be calculated by using the consistency index (CI) formula (Saaty, 1977) as shown in Equation 6:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (6)$$

where  $n$  is the number of the criteria compared, and  $\lambda_{\max}$  is the maximum eigenvalue of matrix  $A_w$ .

The ratio of C.I. calculated in a particular matrix to the mean value of random index (RI) is referred to as consistency ratio (C.R.). Equation 7 shows the degree of consistency

$$C.R. = \frac{C.I.}{R.I.} \quad (7)$$

For the analysis, a common software package, Expert Choice® 11 was employed to analyze the pairwise comparison matrix collected from experts in the Ethiopian construction sector.

#### 4. Data analysis and findings

The multi-criteria decision analysis covers both the level 1 CSF categories and the level 2 success-related factors. The findings of both cases are presented in the next subsequent sections.

##### 4.1. Level 1 ranking of categories

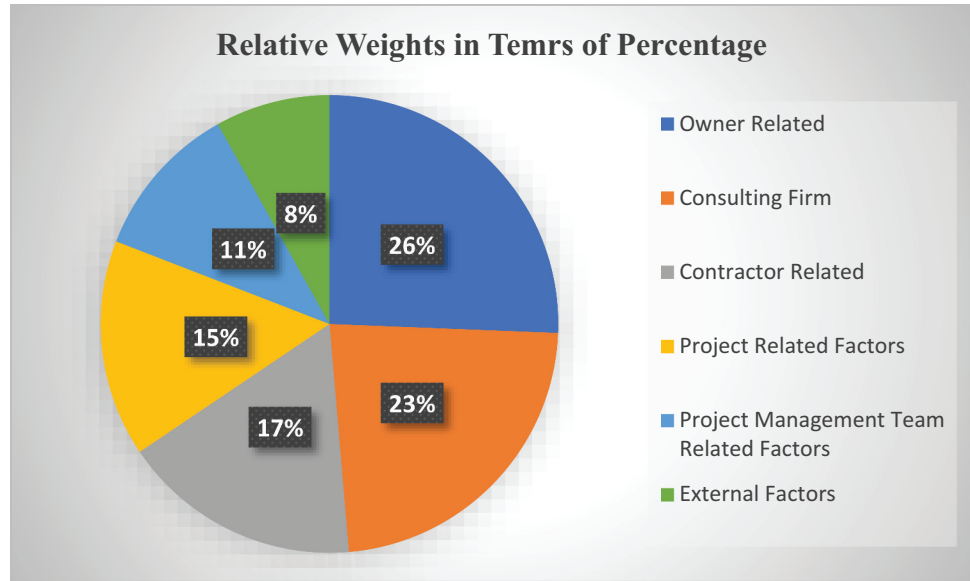
The first section of the analysis focuses on the pairwise comparison matrix computation of success categories. The overall findings of the expert choice output are illustrated in Figure 1.

As per the multi-criteria decision analysis, owner-related factors (0.26) are the most important categories that affect the successful completion of infrastructure projects in the Ethiopian construction sector. Consulting firm-related factors took the second place with a relative weight of 0.23 (23%) of the overall result. The remaining places were taken by Contractor-Related Factors (0.17), Project-Related (0.15), Project Management Team-Related Factors (0.11), and External Factors (0.08).

For the second part of the analysis, the global priority analysis of critical success factors was computed using a geometric mean method (Table 3). In this case, Adequate Goals/Objectives ranked first (weight = 0.121). Similarly, Consultant's Competency, Prior Experience of Consulting Firms, Consulting Firm's Willingness and Cooperation, Financial Standing of Contractor ranked second, third, fourth, and fifth with global priority weight values of 0.11, 0.11, 0.1, and 0.08.

In contrast, critical success factors such as Social Factors (0.02), Project Type (0.02), and Project Size (0.01) ranked at the bottom. This means that the lower level factors are not a priority that determines the overall success of infrastructure projects in the Ethiopian construction sector.

**Figure 1. AHP analysis of level 1 categories.**



**4.2. Level of agreement between stakeholder responses**

The agreement level among the expert opinion between various stakeholders was examined using Kendall’s coefficient of concordance ( $\omega$ ). Kendall’s coefficient of concordance is employed to test the null hypothesis ( $H_0$ ) that there is no agreement between the opinion of groups. ( $\omega$ ) is computed through the following formula (Belay et al., 2021):

$$\omega = \frac{12 \cdot \sum_{i=0}^k (e_i - e)^2}{n \cdot (n^2 - 1)} \tag{8}$$

where  $e_i$  = average of ranking of a responder;  $e$  = average of ranks assigned to the  $n$ th variable factor;  $k$  = judgment number;  $q$  = average of group of experts; and  $n$  = number of aspects of a problem or factor being ranked. The average of opinions of various experts’ groups is computed to examine the sum of the squares of deviations from the sum of ranks  $\sum_{i=0}^k (e_i - e)^2$ . Finally, concordance coefficient of  $\omega = 0.002$  was computed through the findings in Table 4.

The concordance coefficient significance ( $\chi^2$ ) of different groups are illustrated in the following formula (Inayat et al., 2015).

$$\chi^2 = \omega \cdot q \cdot (n - 1) \tag{9}$$

After calculation of values in Table 4, which is  $\chi^2 = 3.17$ , then the next stage is computing,  $\chi^{\alpha, df}$  that can be read from the chi-square table. The value can be obtained by taking into account a degree of freedom of  $df = n - 1 = 19$  (success factors) —  $1 = 18$ , and significance level  $\alpha = 0.05$ . The findings reveal that  $\chi^{\alpha, df} = 28.87$ . Hence, since the value  $3.17 < 28.87$ , the null hypothesis ( $H_0$ ) is not rejected, and the findings can be summarized that there is no agreement on the opinion of each expert groups (parties).

**Table 4. Correlation among different stakeholders**

Success Factors in Ethiopia	Key Construction Parties				$(e^i - e^{-i})^2$
	Owner-Related	Consulting Firm-Related	Contractor-Related	Academic	
Economy of the Country	15	9	10	15	81
Impact of Politics	10	12	12	12	36
Social Factors	17	18	16	19	900
Project Type	18	16	18	16	784
Application of Innovative Technologies	14	8	14	7	9
Availability of Adequate Funding	6	5	7	5	289
Project Size	19	19	19	17	1156
Top Project Management Team Commitment	9	10	6	11	16
PM Team's Past Experience	8	6	9	10	49
Communication Skill of the top management Team	11	14	8	9	4
Adequate Goals/ Objectives	1	3	1	1	1156
Variations	7	11	11	8	9
Contractor's Previous Relevant Experience	13	15	15	14	289
Contractor's Technical Competency	12	13	13	13	121
Safety, Health and Environment	16	17	17	18	784
Financial Standing of Contractor	5	7	4	6	324
Consultant's Competency	2	1	3	3	961
Consulting Firm's Willingness and Cooperation	4	4	2	4	676
Prior Experience of Consulting Firms	3	2	5	2	784

### **4.3. Sensitivity performance**

The third section of the AHP analysis covers the sensitivity analysis of critical success factors using Expert Choice 11. Based on the results, owner-related factors, consulting firm-related factors, and contractor-related factors showed a better performance than others.

## **5. Discussion**

The major objective of the study is to identify and prioritize success-related factors that may affect the successful completion of infrastructure construction projects particularly in low-income economies. The analytical model was developed based on infrastructure projects being constructed in Ethiopia as a case study. The questionnaire data matrix was examined using a multi-criteria analysis approach analysis, AHP. Further, the paper examined sensitivity analysis of top success factors in the hierarchical model.

The global priority weights result shows that client's adequate goals/objectives (0.121) is the most significant factor influencing infrastructure project success in the Ethiopian construction industry. Owner is the initiator and financier of construction projects. Having a clear and concise objective prior to planning helps consulting team to control and manage the detail design and documentation of infrastructure projects timely (Sobieraj & Metelski, 2021). This in turn has a direct effect on the successful delivery of infrastructures in the required time, allocated budget, and depicted quality (Belay et al., 2021).

The remaining top success factors relates with performance and competency consultant and design firms. Based on the findings, consultant's competency (0.109), prior experience of consulting firms (0.106), and consulting firm's willingness and cooperation (0.099) resulted in the second, third, and fourth priorities in the hierarchical model. Consulting/design firms are one of the key and integral stakeholders of which their involvement could come as early as the initiation and planning stages of the project life cycle. The success or failure of infrastructure projects greatly depends on the capacity and competency of consultants (Jongo et al., 2019). Hence, it is important for the consulting firms to keep their professionalism high, and compete in various big infrastructure projects in the Ethiopian construction sector.

The fifth global weight priority is concerned with the financial standing of contractor (0.080). Successful delivery of construction projects needs appropriate financial allocation and flow during the life cycle of the project (Doloi et al., 2011). Previous studies underlined the influence of financial competency of construction firms in relation to the successful infrastructure delivery (Shahu et al., 2012; Silva et al., 2015). These studies also highlighted that the contractors should enhance their overall capacity through different measures that are deemed vital for improving the competency of skilled and unskilled employees.

## **6. Conclusion**

This paper explored the potential success-related factors that may greatly affect the successful delivery of infrastructure construction projects in developing countries. The empirical analysis was based on a case study conducted in the Ethiopian construction industry using AHP-based multi-criteria decision technique. In addition, the study conducted a sensitivity analysis and Kendall's concordance analysis to examine and compare various responses collected through a structure questionnaire survey.

The AHP analysis showed that the key stakeholder affecting success of infrastructure projects is Owner. Whereas consulting firms, construction organizations, and project-related factors take up the second, third, and fourth priorities in the hierarchical structure. It is vital to pinpoint to the fact that previous studies also reported that Owner is critical in determining the successful delivery of

infrastructure projects. The second stage of the analysis focuses on prioritizing critical success factors for infrastructure projects in the context of the Ethiopian construction industry. The result reveal that the top critical factors are: clear goals/objectives, consultant's competency, prior experience of consulting firms, consulting firm's willingness and cooperation, and contractor's financial standing and status.

The contribution and nobility of this study is twofold: (1) the analysis provide a benchmarking analytical output to enhance the overall success of infrastructure construction projects in the Ethiopian construction industry, and (2) the paper comprised the expert analysis of academic institutions in the analysis and discussion of findings. This in turn will be useful to devise nationwide construction policies and strategies to improve the performance and resilience of infrastructures in developing countries. Future studies could focus on the investigation of success factors in critical infrastructures with the consideration of multiple environmental, social, and economic factors.

#### Funding

The authors didn't receive funding for this study.

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#### Disclosure statement

No potential conflict of interest was reported by the author(s).

#### Data availability statement

The data underlying the results presented in the study are available within the manuscript.

#### Citation information

Cite this article as: AHP based multi criteria decision analysis of success factors to enhance decision making in infrastructure construction projects, Solomon Belay, James Goedert, Asregedew Woldesenbet & Saeed Rokooei, *Cogent Engineering* (2022), 9: 2043996.

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