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Relationship between Management Challenges and Construction Project Sizes Using Fuzzy AHP

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Abstract –Residential building projects can be as simple as a single-story house or as complex as skyscrapers. How hard it is to manage these projects depends on how big they are. What aspects of projects get more challenging as they get bigger is still unknown. Thus, this paper delves into this subject and tries to identify these challenging factors in the emirate of Sharjah in the United Arab Emirates. To accomplish this goal, factors found in the literature were ranked by experts using the fuzzy-analytical hierarchal process (F-AHP). The identified factors were grouped into three categories. According to the F-AHP, technical challenges were the most challenging part of managing a large project. Interpersonal and operational factors came in second and third, respectively. First on the list of sub-factors was quality management, then the use of technologies. Surprisingly, the cost was ranked last. These results will help make it easier for decision-makers to match projects with project managers.

Keywords**:** Construction projects, Multi-criteria decision making, Project-project manager assignment, Fuzzy-Analytical hierarchical process

1. Introduction

Construction projects can vary greatly in terms of their size, scope, and level of difficulty. Moreover, construction projects are associated with high risks [11,25,26]. As a result, it is important to classify construction projects based on their complexity, which can help stakeholders better understand the nature of the projects and identify the necessary resources and strategies to guarantee their successful completion. Classifying residential construction projects based on complexity involves assessing various factors, such as the project's size, technical requirements, coordination degree, and potential risks involved. Understanding project complexity is an essential first step to assign project managers (PMs) to construction projects.

The objective of this research is to develop a methodology to assess the difficulty of managing construction projects based on their sizes. To fulfill this objective, the following two research questions are to be answered:

RQ1: What factors make large construction projects harder to manage than small projects?

RQ2: How to rank factors answered in Q1 based on their difficulty to handle?

Researchers who studied the PM-project fit problem have considered multi-criteria decision analysis (MCDA) techniques [10]. Thus, to answer the above two questions, we also adopt a multi-criteria approach to analyze these factors. Toward this end, we use fuzzy analytical hierarchical process (F-AHP) to rank the factors discussed in the literature and identified by practitioners.

This research stems from the requirement of a regulatory authority in the emirate of Sharjah in the United Arab Emirates (UAE) that authorizes PMs to construction projects in the public and private sectors. Residential construction projects in Sharjah range between one floor villas to high-rise buildings, and it is needed to understand the factors that might make the construction of large project harder than small ones. Negative consequences of a failed construction project are not limited to the project's sponsor and contractor only, but also the suburb and city where the projects are located. Thus, this research is unique since it adopts a regulatory stakeholder's perspective, neither the sponsor or the contractor as in previous studies [14].

2. Literature review

Based on the previous literature, the factors affecting the management difficulty of complex projects can be divided into three clusters: technical, operational, and interpersonal. Technology, quality, risk and safety are within the technical cluster, while planning, time and cost management are considered as operational factors. Interpersonal factors include leadership, supply chain, stakeholder, and communication management.

2.1. Technical Factors

Technology generally refers to the integration of tools, applications, software, and machinery used during different construction stages. Many megaprojects experience several complexities, such as unclear schedules and deliverables, which makes it challenging to comply with technology standards. Technology is indispensable in complex projects due to its direct impact on project success and environmental sustainability [2,12].

Quality management is increasingly challenging in large projects due to the elevated risks, complex interfaces, and the multitude of deliverables, impacting project success [5,9].

Risk management is about assessing and implementing processes to minimize the impact of risk during construction. [4] report that construction projects face more risks than projects in other industries due to uncertainties from varying construction practices, working conditions, mixed cultures, and political conditions.

Safety refers to protecting personnel from physical injury and health refers to protecting peoples' minds and bodies from sickness resulting from processes and materials at the workplace. Construction projects feature numerous health risks, which become more significant as projects grow due to the increased volume of construction activities [15].

2.2. Operational Factors

Planning involves formulating and implementing a development plan. Variations in the construction project's variables, such as size and operating place, can alter the preparation process and the requisite management [7]. Thus, large projects are susceptible to poor planning, especially when the management does not evolve adequately with the scope of work. [7] argues that poor planning ultimately results in delays that complicates projects.

Time management plays a vital role by observing that time allocation influences project performance directly [16]. Time allocation and management are associated with significant complications in large projects. [13] states that most managers in large projects fail to adequately manage time and deliver in time irrespective of the nature of penalties imposed for late completion and the type of contract.

Cost management is an important part of projects. Poor cost management can be negligible in small projects, but its effects can be highly detrimental in megaprojects as large projects are highly susceptible to multiple possible causes of cost overruns, according to [11]. [6] argue that the primary managerial sources of cost overruns are inefficient contract administration, regular change of subcontractors, poor knowledge of subcontractors, improper contract negotiation, acquisition of low-quality materials, and delays in materials delivery.

2.3. Interpersonal Factors

Stakeholder engagement was found to have the biggest impact on the delivery of large projects [3]. This significance originates from the numerous stakeholders involved, including clients, consultants, designers, safety officers, supervisors, administrators, material suppliers, machinery and plant operators, contractors, project managers, and construction workers. As a project grows, managers struggle to maintain effective communication between stakeholders in a responsive and transparent engagement [3].

leadership is the most impactful trait in construction projects and directly affects the measurement and assessment of quality, change management, knowledge updates, collaboration, employee remuneration, the specification of quality objectives, and cultural excellence [17]. Managing these factors is highly complex in megaprojects, necessitating effective leadership to enable project success.

Supply chain management (SCM) controls the supply flow through all construction stages. Large projects are more susceptible to SCM issues mainly due to the underlying goal, environmental, organizational, technological, task, and information complexities [18]. Supply chain integration and coordination involve the governance of supplier networks

Communication in construction refers to exchanging information through all construction phases. As projects grow, a point is reached beyond which one manager cannot control the entire project. [8] describe this point as losing the "helicopter perspective," linking it with more problematic communication.

TABLE I. KPIs Classifications and References.

criteria	Factors (sub-criteria)	References
Technical	Technology	[2,12]
	Quality management	[5,9]
	Risk, Safety and Health	[4,15]
Operational	Planning	[7]
	Time	[13,16]
	Cost	[6,12]
Interpersonal	Stakeholder management	[3]
	Leadership	[17]
	Supply chain	[18]
	Communication	[8]

3.Methodology

Fuzzy Analytical Hierarchy Process (F-AHP) is a popular technique in solving a multi-criteria decision-making problem including criteria and sub-criteria, and it helps to measure, order, rank, and evaluate decision choices through the use of pairwise comparisons [1]. In this paper the interpersonal, operational and technical variables are considered the criteria while the factors under these variables are considered the sub-criteria.

i. Development of the Project Complexity Structure – the first step involves the identification of the technical, interpersonal and operational factors, which contribute to project complexity. A systematic review was carried out to identify the factors by reading academic literature and papers. Input from professionals was used to identify relevant factors. These factors were then divided into technical, interpersonal and operational criteria.

ii. Obtaining expert judgment – after the identification of the technical, interpersonal and operational factors, a survey was conducted for rating pairwise comparisons between the criteria and between sub-criteria. The survey targeted experts in the construction industry in different roles such as project managers, project engineers, chief engineers, and functional managers. A nine-point fuzzy scale, (equally important [1], weakly important [3], strongly important [5], very strongly important [7], and extremely important [9]) is used in the rating of the pairwise comparisons for criteria and sub-criteria of project complexity.

iii. Convert judgment into fuzzy numbers – since the inputs of the experts are subjective, uncertain, and linguistic, the nine-point scale input is converted into three triangular fuzzy numbers (l, m, and u) using a delta fuzzification factor ($\Delta = 1$). For all sub-criteria judged as one, the fuzzy numbers become (1,1,1). For sub-criteria judged from 2 to8, the fuzzy numbers become $(x-\Delta, x, x+\Delta)$. For sub-criteria judged as 9, the fuzzy numbers become (8,9,9). For sub-criteria judged as 1/x, the fuzzy numbers become $(1/(x+\Delta), x, 1/(x-\Delta))$. Finally, for sub-criteria judged as 1/9, the fuzzy numbers become (1/9, 1/9, 1/8).

iv. Aggregation of the judgments – the judgments of the experts are combined using the geometric mean formula shown in equation (i):

$$Geometric\ mean\ (r_i) = \left(\prod_{k=1}^{k} d_{ij}\right)^{\frac{1}{k}} \quad (1)$$

In this equation, d_{ij} is the fuzzy number, k is the number of experts, and $i\ and\ j$ are a set of two criteria. As such, $d_{ij} = (d_{ijk}, d_{ijk}, d_{ijk})$, which represents the triangular fuzzy numbers for a given kth expert.

v. Calculation of the fuzzy weights – the fuzzy weights of each criterion and sub-criteria are calculated as follows:

$$fuzzy\ weights\ (W_i) = \frac{1}{n}\sum_{j=1}^{n} \frac{z_{ij}}{\sum_{k=1}^{n} z_{kj}} \quad (2)$$

vi. Calculation of De-Fuzzification weights by calculation the Center of Area of each criterion and sub-criteria as follows:

$$center\ of\ Area(COA)\ (W_i) = \frac{(l + m + n)}{3} \quad (3)$$

vii. Calculating the normalized weights by dividing the De-Fuzzification weights by the sum of COA. In this stage the sum total of normalized weights is 1.

4.Results

Five projects manager working on residential construction projects in the Emirate of Sharjah have evaluated the importance of Technical, Operational &Interpersonal factors. In the final steps of the methodology, the weights were de-fuzzified and normalized, and the results were ranked.

Table II below shows the results of the first level of the hierarchy. Were a comparison between the three criteria shows that technical criteria obtained a massive gap in weight compared the operational and interpersonal criteria.

TABLE II. Normalized Weights And Ranking Of Criteria.

	Normalized weights	Rank
Technical	0.492	1
Operational	0.197	3
Interpersonal	0.310	2

Tables III-V, represent the comparison of factors within their own criteria.

TABLE III. Normalized Weights And Ranking Of Technical factors.

	Normalized weights	Rank
Technology	0.308	2
Quality management	0.599	1
Risk, Safety and Health	0.093	3

TABLE IV. Normalized Weights And Ranking Of operational factors.

	Normalized weights	Rank
Planning	0.757	1
Time	0.173	2
Cost	0.069	3

TABLE V. Normalized Weights And Ranking Of Interpersonal factors.

	Normalized weights	Rank
Stakeholder management	0.057	4
Leadership	0.404	2
Supply chain	0.097	3
Communication	0.442	1

Table VI, compare the sub-criteria of all three criteria groups. Where it is visible that expert have agreed that Quality management makes big projects harder to manage than small projects. Also, according to experts Technology, Planning &Communication play a significant role compared to the remaining factors.

TABLE VI. Normalized Weights And Ranking Of All factors.

	Normalized weights	Rank
Technology	0.151	2
Quality management	0.295	1
Risk, Safety and Health	0.046	6
Planning	0.149	3
Time	0.034	7
Cost	0.014	10
Stakeholder management	0.018	9
Leadership	0.125	5
Supply chain	0.030	8
Communication	0.137	4

4. Conclusion

This study aims to determine the What factors make large residential construction projects harder to manage than small residential projects in the Emirate of Sharjah by identifying and classifying factors that have a high significant role in the matter. Factors were identified through literature review& expert's opinions and classified into Technical, operational and interpersonal. A Survey was sent to five expert and the five responses were obtained then analysed using F-AHP method. Based on the judgement of experts, the factors were ranked based on their level of impact.

It is clear that the experts have agreed that quality management, technology, planning and communication has a higher impact on making large residential construction projects harder to manage than small residential projects in the Emirate of Sharjah.

This study can be repeated for other Emirates and the overall studies can be compared and analyzed to find what are the similar and different factors between the seven Emirates of the United Arab Emirates. Understanding the impact of the factors might help in developing a frame work to increase the skills of project managers and identify a way to assign them to large residential construction projects.

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