Improving Residential Complex Project Performance using Information and Communication Technology supported by the DEXi Method

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ABSTRACT

A complex project involves a significant level of risk, uncertainty, and complexity due to several variables, including the project's size, duration, scope, and interdependencies. The use of Information and Communication Technology (ICT) leads to increasingly better and more sustainable results in the progress of complex tasks. Specialized Information Technology (IT) software packages are available on the market to meet the specific needs of the construction industry. The main objective of this research is to identify the factors that have the greatest impact on complex projects and to explore the utilization of ICT applications to improve productivity. The first step of the research methodology is to assess the effectiveness of ICT in construction. The second step is to specify the responses of the participants in complex projects. The final step involves employing a verified computational methodology to identify the parameters that influence the effectiveness of ICT use in the construction sector. This study utilized survey data, expert comments, in-depth interviews, and exploratory research to assess the impact of management styles on ICT performance metrics. The research also drew on previous work in the construction project area to enhance its findings. According to the results of the Relative Importance Index (RII), the most significant component in the use of ICT was the technical calculation based on time. The analysis showed that improving the efficiency of subcontractors and suppliers' coordination yielded a rank value of 0.869. The special computational software called Decision Expert (DEXi) method is also used to facilitates decision making based on specific criteria. Ultimately, this study concludes that ICTs are crucial for improving the efficiency and effectiveness of sustainable project implementation in all aspects.

Keywords-RII method; complex building construction; ICT factors; DEXi method

I. INTRODUCTION

Developing a residential project is a labor-intensive, complex process that requires meticulous attention to detail. During the construction of an apartment complex, the designer has to perform several tasks to ensure comfortable living conditions, such as landscaping the surrounding area and placing benches, pedestrian walkways, sports fields, playgrounds, and roads for vehicles. Free apartment plans should be provided so that the buyer can independently arrange the interior of the apartment. Ground or underground parking is essential, as is the presence of social infrastructure and a high level of security. The complex must have video surveillance, fire alarm and extinguishing equipment, and be located in a secured area with access control. Residential complexes are classified into different classes, including economy, comfort, and business, based on the technology used to construct the residential buildings, the variety and caliber of materials used, design elements, services offered, and the subtleties of improving the local area. IT encompasses a wide range of tools and systems that can collect, organize, transmit, and manipulate data. In the context of the construction industry, this term refers to the use of ICT in many aspects of a project, including planning, execution, administration, and management. ICT can overcome the barriers of time and space to facilitate the links between project managers. It also improves productivity by automating processes, improving communication, and enabling efficient management of resources. It facilitates connections to the markets and enables efficient cross-border transactions. In addition, ICT provides access to vast amounts of information and educational resources that help project managers, designers, workers, and engineers improve their knowledge and skills. Furthermore, it enables collaboration between individuals and organizations regardless of their geographic location, fostering teamwork and innovation. Several variables influence the adoption of ICT [1]. Although there is a consensus that ICT gives companies a competitive advantage, several aspects should be considered. For instance, "distraction" refers to how ICT can affect job performance and project quality. Overuse of ICT as a substitute for face-to-face contact is distracting [2]. ICT can also create "noise" that hampers communication and complicates the planning and management of construction projects [3].

Many authors have described how the construction sector, especially Small and Medium-sized Enterprises (SMEs), has rapidly adopted ICT over the past two decades. The data show minor changes in site management and construction, but most ICT solutions support the processes. For example, 90% of the ICT spending is allocated to technical staff at headquarters, while 10% is allocated to the field [4]. The use of ICT not only at the project level, but also at the level of the construction organization and its strategy can provide a competitive advantage [5]. Authors in [6] reviewed Industrial Revolution (IR) 4.0 practices and the main problems that delay their implementation in construction industry. They conclude that with IR 4.0 the construction sector can catch up with industries, such as manufacturing and automotive, in productivity. Authors in [7] proposed a method that allows the decision maker to evaluate different candidates and select the best candidate as a project manager for large construction projects using the Analytic Hierarchy Process (AHP), approximate weights of the criteria, and a fuzzy technique. Authors in [8] proposed a new approach to construction project success calculation, which depends on different co-dependent success criteria based on the multi-criteria decision method Technique for Order Preference by Similarity to Ideal (M-TOPSIS) as the most appropriate method. Authors in [9] proposed an approach to assess the risks of schedule delays in the various life cycles of construction projects, which can serve as a management tool to proactively prevent schedule delays and mitigate their risks. Authors in [10] introduced a model to select the best mode to perform each project activity in terms of time, cost, and quality, enabling a more efficient scheduling of construction projects. Authors in [11] indicated that an effective factor in project management is the accountability strategies for each stakeholder group. It promotes coordination and assists authorities in decision making.

II. EFFECTIVE FACTORS

Changes in the project scope and expected deliverables can delay project execution. Every time the project scope changes during execution, the original plan must be revised, including the construction schedule, construction methods, procurement strategy, quality assurance procedures, and more. Project completion will take longer, cost more, and require more resources [12-15]. Establishing the primary success factor with the client during project planning and key performance indicators using the milestone technique is important to accurately assess project success. Sponsor approval must always be obtained, and any adjustments should be discussed early to avoid problems. Setting a scope helps to prioritize deliverables if the project changes dramatically during construction [16]. The project's complexity, which is mainly determined by its size, often causes huge delays and costs. Dams, skyscrapers, roads, and nuclear power plants take longer to be built than workshops, homes, and non-profit organizations [17, 18]. The scope of construction projects includes predictable deliverables, but the initial scope specifications may not be met due to cost inflation and construction delays [19]. The client's key success factors must be identified early in the project planning process, and key performance indicators that determine project success should be established. Changes should be approved by the sponsor and incorporated quickly to avoid disagreements. To focus on the expected deliverables, the scope for drastic project changes during construction must be frozen [20]. The aim of this research is to identify, with the use of ICT, the key factors in complex construction projects in order to improve the current construction methods. The problem is to determine whether the current methods are sufficient for the construction of complex buildings. In order to achieve this, it is essential to study the complex factors of construction, to evaluate their effectiveness, and to create a model for decision makers that analyzes the significance of the different impacts of ICT.

III. INFORMATION AND COMMUNICATIONS TECHNOLOGY FACTORS

In this study, the factors and sub-factors were selected from previous studies [21-24]. ICT was applied to these parameters in order to determine their effect. Costing and budgeting, project cost control, financial management, cost calculation techniques, scheduling project processes, quality control, and project security were the main factors:

- Costing and budgeting using ICT (F1): It shows the approximate total amount of funds required to complete a construction project from start to finish, including all related costs and expenses incurred along the construction process.
- Project cost control using ICT (F2): This involves monitoring how project expenditures deviate from initial projections as work progresses, and developing remedial solutions as needed.
- Financial management using ICT (F3): The financial management of construction refers specifically to the management of the economic activity of a construction company. Its objective is to ensure the profitability of operations, and thus the financial health and durability of the business.
- Technical calculation utilizing ICT/cost (F4): To calculate the total cost, it is necessary to take into account numerous variables, including labor, materials, machinery, overhead, and other project-related expenses.
- Technical calculation of ICT/time (F5): It is the process of planning and carrying out a strategy for the amount of time needed for project-related work tasks.

- Technical calculation of ICT/quality (F6): It is the extent to which a construction process results in a product that meets the needs and desires of its users. There are several ways to assess construction quality, including safety, time, and cost.
- Technical calculation of ICT/security (F7): It includes surveillance systems, access control measures, and trained security personnel.

Table I displays the sub-factors of the proposed factors.

TABLE I. THE SELECTED SUB-FACTORS

Symbol	Factor	Symbol	Factor	Symbol	Factor
Project costing and budgeting using ICT		F2-16	ICT knowledge	**Technical calculation of ICT/time**	
F1-1	economic situation	F2-17	ICT invested funds	F5-1	enhancing works
F1-2	construction costs	F2-18	preparation work	F5-2	enhancing control
F1-3	supply and demand	F2-19	ICT concepts	F5-3	enhancing procurement
F1-4	ICT applications	F2-20	ICT construction time	F5-4	enhancing processes
F1-5	government response	F2-21	ICT reliable education	F5-5	enhancing management
F1-6	workers education	F2-22	ICT experience	F5-6	enhancing suppliers
F1-7	reduction of recovery	F2-23	ICT database	F5-7	enhancing planning
F1-8	reduction of conflicts	F2-24	ICT materials	F5-8	enhancing security
F1-9	resistance to change	F2-25	ICT suppliers	F5-9	enhancing resources
F1-10	construction duration	F2-26	ICT requires	F5-10	enhancing facilities
F1-11	academic education	F2-27	ICT programs	**Technical calculation of ICT/quality**	
F1-12	training the engineers	F2-28	ICT laws	F6-1	increasing quality
F1-13	available databases	**Financial management using ICT**		F6-2	increasing budget
F1-14	cost of the equipment	F3-1	ICT improvement	F6-3	increasing invoice
F1-15	providing suppliers	F3-2	ICT based on budgeting	F6-4	increasing monitoring
F1-16	complex requirements	F3-3	ICT based on purchasing	F6-5	increasing finance
F1-17	available programs	F3-4	ICT based on monitoring	F6-6	increasing suppliers
F1-18	applicable laws	F3-5	ICT based on financial	F6-7	increasing scheduling
Project cost control using ICT		F3-6	ICT information	F6-8	increasing security
F2-1	technical account	F3-7	ICT based on scheduling	F6-9	increasing resources
F2-2	budgeting	F3-8	ICT based on security	F6-10	increasing communications
F2-3	purchasing/ invoicing	F3-9	ICT based on resources	**Technical calculation of ICT/security**	
F2-4	cost control	F3-10	ICT communications	F7-1	developing works
F2-5	financial management	**Technical calculation using ICT/cost**		F7-2	developing budgets
F2-6	subcontractor	F4-1	improving costs	F7-3	developing the invoice
F2-7	scheduling /planning	F4-2	improving budgets	F7-4	developing methods
F2-8	website management	F4-3	improving invoicing	F7-5	developing management
F2-9	resource management	F4-4	improving monitoring	F7-6	developing activities
F2-10	facilities	F4-5	improving management	F7-7	developing planning
F2-11	success of investment	F4-6	improving database	F7-8	developing security
F2-12	ICT costs	F4-7	improving scheduling	F7-9	developing resources
F2-13	ICT demand	F4-8	improving security	F7-10	developing control
F2-14	ICT construction risks	F4-9	improving resources		
F2-15	ICT support	F4-10	improving communications		

IV. METHODS AND PROCEDURE

The RII methodology was deployed to rank the importance of the factors and distinguish those that have a significant impact from those that do not. As a final step in evaluating their effectiveness in complex construction projects, the top-ranked criteria proposed by the seven groups were collected and inserted into the DEXi software package. The adopted methodology is depicted in Figure 1.

Fig. 1. The proposed methodology.

A. *Relative Importance Index*

This study employed the RII method to determine the impact of the effective factors on survey responses. The ability to provide an accurate numerical representation for each effective factor facilitated this process. The RII was calculated using [25-28]:

$$\text{RII} = \frac{\sum P_i \times U_i}{n \times N} \qquad (1)$$

where P_i is the respondent's rating of the effective factors, U_i is the number of respondents that place identical weighting/rating on the factor, n is the highest attainable score for each factor, and N is the sample size of the people who responded to the survey.

B. Questionnaire Details

The development of the project questionnaire included the introduction of the initial premises, followed by the survey and interviews. The factors considered entail the company size and level, job title, experience, and years of working on projects. The study involved participants from several engineering disciplines and the classification of the respondents was as follows: project managers were 24% of the total respondents, site engineers were 31%, planning engineers were 21%, and finally consulting engineers were 24% of the total respondents. The project managers were the main source of the financial and schedule information. Among the selected respondents, 25% had more than 15 years of experience, 60% had between 5 and 10 years, and 15% had less than 5 years. Most of the respondents have sufficient understanding of the construction industry to classify the factors that have a significant impact on project costs.

C. DEXi Decision Modeling Software

The DEXi software package facilitates decision making with its numerous practical features. The objective is to collectively evaluate the potential outcomes and construct qualitative decision models with multiple attributes. This strategy can facilitate the resolution of complex decision situations, where the decision maker is faced with multiple choices and needs to select one to meet their goals. A multi-attribute model is a hierarchical structure that results when a decision problem is divided into smaller, more manageable subproblems. The DEXi model creation process is significantly influenced by qualitative (discrete) features. DEXi is highly efficient at sorting and categorizing decision analysis due to its limited number of specified categories. The steps for applying the DEXi method are:

1) Structure Development

In the first step, the researcher develops the structure of a multi-attribute model for the evaluation of the effective factors. Each main group includes sub-coefficients that represent the factors that obtained the highest effect in previous tests. The most relevant attributes are identified and organized into a hierarchical structure.

2) Scaling

Scales that are not ordered can either grow or shrink; they are not limited to a single state. Without sorting the data, it is not possible to say for sure what the relationship is between two sets of data. The numbers on a scale that is set up in a certain order are arranged in a more useful way, that is, they are in accordance with the value they add to the range of options. As the scale goes up, the values are in the "bad" to "good" range. As it goes down, the values are in the "good" to "bad" range. In this case, "bad" is a value that the decision maker feels is always bad for the choices.

3) Utility Function

A special utility function in DEXi is responsible for translating every possible permutation of the lower-level attribute values into matching values. This is due to the possibility that each row represents an if-then rule related to the category.

4) Evaluation of the Options

Multi-attribute models make it easier to evaluate choices based on many different factors. In this step of the evaluation process, each case or factor is evaluated on the basis of what has been prepared in the scale and the sum of the possibilities that have been organized in the vertices of the function. The evaluation in the form of good, acceptable, and bad is entered manually by the researcher.

5) Preparation of EvaluationCcharts

The evaluation charts are the specific and detailed requirements to achieve each of the categories. The chart is only for the applicant's factor subjects. The shapes obtained through this program represent a true picture of what it could be or produce the strongest influencing factor among an enormous group of factors. This method is distinguished by finding or filtering the best factors and presenting them graphically or in a prominent form. After a series of procedures is carried out, using methods for calculating the influence of the factors and the program for filtering the factors and finding the most influential one, a true picture of the course of events in projects can be presented to decision-makers.

V. RESULTS AND DISCUSSION

Developing countries face a major challenge in effectively managing the factors associated with project delivery. The proposed business strategy aims to optimize financial gains while creating a positive impact on society, the environment, and the government. The primary goal of effective factor management is to achieve a balanced strategy that mitigates negative impacts while promoting positive ones. This study focuses on specific hazards that could impede or halt construction activities in Iraq and on reducing the likelihood of supply chain disruptions caused by events, such as natural disasters or labor disputes. By utilizing this tool, users can improve their understanding of the patterns, anomalies, reliability, comparability of datasets, and potential threats. Figure 2 illustrates the ranking results of the ICT factors in complex projects.

The DEXi method is followed to evaluate and rank the results based on a set of criteria. The variables can be ranked based on criteria, such as technology implementation, presence of factor content, or other important characteristics. To effectively optimize the variables, a thorough understanding of the factor rankings is essential. Fundamentally, it is unrealistic to expect a compliance program's factor ranking methodology to account for every single characteristic. The DEXI program provides an alternative perspective, but there may be additional factors to consider. Figure 3 illustrates the overall correlations between the factors.

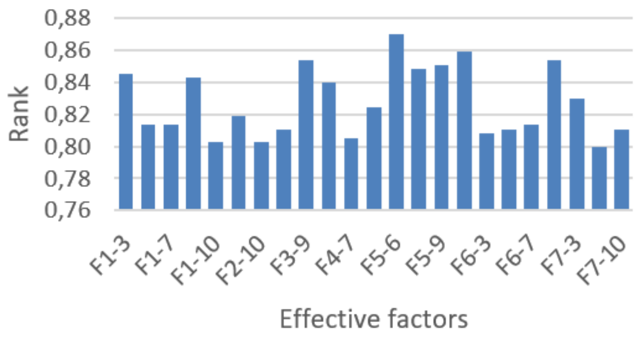

Fig. 2. Ranking results of ICT factors in complex projects.

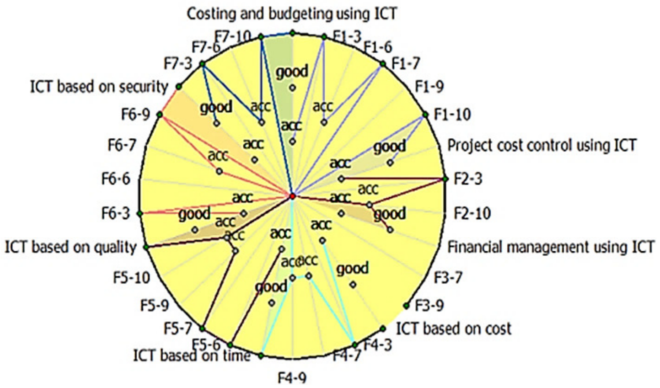

Fig. 3. The overall correlations between the factors.

Deploying new or complex systems typically requires competitive discussions. This helps procurement and vendors identify system needs. Data storage, delivery, and retrieval are faster with digital technology. Managers can use this technology to better manage operations, set goals, and make decisions. ICT enhancements have improved employee collaboration and information sharing for digital resource management. ERP systems, collaborative technologies, and automation of repetitive tasks reduce labor costs, increase efficiency, and save operating expenses. ICT closely connects customers and businesses, strengthening relationships and streamlining transactions. Improved connectivity makes products easier to use. The economic use of ICT has reduced poverty. Modern ICT scheduling software facilitates planning and scheduling, reduces dependence on physical documents and time, tracks project performance, and optimizes resource allocation. Integrating strategy and technology improves productivity, time, cost, and resource management. Sharing successes and failures helps organizations minimize project delays, especially on complex and large-scale construction projects. Construction data collection and project outcomes can benefit from ICT. Evolutionary algorithms optimize project resource allocation, path discovery, and time in advanced scheduling software. A quality management system ensures the authenticity and reliability of a company's products and enhances its reputation. Maintaining quality and meeting industry, regulatory, and customer needs requires proactive measures. ICT security protocols can prevent unauthorized access, modification, deletion, or disclosure of personal data. Strong ICT security includes monitoring and restricting access to sensitive data. Access restriction, monitoring, and encrypted data transmission are effective ICT security measures. DEXI adds project-related factors to the existing methodology, depending on the results.

VI. CONCLUSION

The aim of this paper is to analyze the factors that contribute to the effective implementation of complex construction projects and the following conclusions emerged from the analysis:

A. Relative Importance Index (RII) Method

- In costing and budgeting using Information and Communication Technology (ICT), the reduction of resistance to change in complex project elements (F1-9) was found to have a rank value of 0.8427.
- In the project cost control using ICT, the response of purchasing and invoicing (F2-3) was found to have a rank value of 0.819.
- In the financial management using ICT, the ICT considered as a factor in managing resources (F3-9) was found to have a rank value of 0.853.
- In the technical calculation using ICT based on cost, the improvement of procurement and invoicing (F4-3) was found to have a rank value of 0.840.
- In the technical calculation using ICT based on time, the improvement of the time of subcontractors and suppliers' arrangements (F5-6) was found to have a rank value of 0.869.
- In the technical calculation using ICT based on quality, the increase in the quality of managing resources (F6-9) was found to have a rank value of 0.853.
- In the technical calculation using ICT based on security, the development of the technical calculation of the invoice (F7-3) was found to have a rank value of 0.829.

Using ICT, these factors are the most effective in complex construction projects.

B. Decision Expert (DEXi) Method

- The most effective factor in scheduling using ICT was subcontractors' information that improves project time (F5-6). This factor was verified in [29].
- In the management by ICT and Quality Management (QM), the effective factors were F3-9 and F6-9. These factors represent the effect of resource management, which was verified in [30].
- Other selected effective factors were F1-3, F2-3, F4-3, and F7-3 due to the controlling process of purchasing and project security. These results were verified in [31].

The resulting factors show that the (DEXi) method provides specific effective and more realistic factors.

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