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Determining the main criteria and presenting a mathematical model in the evaluation of new construction technologies

R. Ahmadi

Department of Structural Engineering and Technical Building - Road, Housing and Urban Development Research Center

ABSTRACT: Evaluating new construction technologies based on quantitative analysis before applying the technology in the construction industry can minimize the risk of using a technology. The research method in this article is experimental-theoretical. The experimental part includes the review of the information on 45 types of implemented technologies, their field impressions, and pathology, and in the theoretical part, the author designs 330 quantitative evaluation questions and receives the opinions of prestigious universities of the country regarding the proposed questions and finally presents the mathematical model of the evaluation criteria. The questions are designed to meet the two goals of safety and competition. The mathematical model presented for the first time by the author is presented in this article under the title of the triangle of evaluation criteria of new construction technologies. The length of the sides of this triangle is equal to the score obtained from each of the questions related to the quality, cost, and speed of construction for each technology, which are the three main criteria for the quantitative evaluation of a technology. The evaluation triangle shows that if the length of the quality side becomes zero in the evaluation of a technology, it is a deterrent and ban on the use of that technology. Presenting the normalized triangle model for evaluation criteria was aimed at achieving a competitive goal. The length of each of the sides of this triangle can be between zero and 0.5 (except zero and 0.5), provided that the sum of the sides does not exceed one. In this model, if the length of one of the sides approaches zero, the result will be a skinny triangle. which indicates the high risk of that technology in relation to that criterion.

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1- Introduction

In developed countries, the history of industrialization and the use of modern construction technologies began in the 18th century with the beginning of the Industrial Revolution and has grown significantly in the 19th century. Today, due to the culture, environment, and geographical extent of the countries, we see the use of modern technologies. We are an innovative construction company in high-rise construction projects and quick-build one- and two-story buildings. In developing countries, due to the ever-increasing growth of the urban population, the need for mass housing in the form of short- and medium-rise buildings is felt. For example, in most Asian countries, South America, and Africa, mass housing is mainly provided with 2-15-story buildings, and to achieve this goal, they consider the use of new construction technologies in an industrial production manner. While developed countries mainly use They prefer high-rise buildings. Although the type of housing needed in developed and developing countries is different, but both of them use the solution of using modern construction technologies in the industrial production method and are almost the same in terms of the main and effective indicators and have minor differences.

The basic challenge in using construction technology is the feasibility of using the technology before construction and operation. Nowadays, evaluation is done only for existing buildings and on a case-by-case basis. This type of evaluation does not help construction industry workers in the feasibility stage of mass housing supply projects. Many researchers have tried to use the experiences of the developed technologies for future projects. In 2021, Edward et al. [1] studied an important industrialization project with printing technology in the Czech Republic in order to minimize project costs in terms of construction and service life, for this purpose, the indicators And the parameters of the factors affecting the project costs have been determined, which include the equivalent costs related to investment stagnation, operational costs, repair and maintenance, renovation in the future and recycling. They have tried to check the impact of the above cost indicators on the economy of the project, they have done their analysis based on the assumption of linear relationships and finally, they have concluded: the analysis of energy consumption during operation, the implementation mechanism of printed building technology and updating Costs in different stages of construction and engineering costs have a significant

*Corresponding author's email: r.ahmadi@bhrc.ac.ir

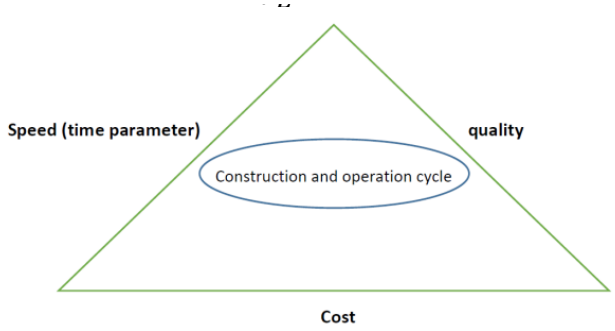

Fig. 1. Similar model of new construction technology evaluation criteria

impact on the economic evaluation of this building. The main criticism of this research is the use of technology that does not have a known structural structure, and its structural behavior against lateral loads has many uncertainties. In 2021, Petri et al. [2] examined the impact of transportation on a house construction system in terms of the system's ability to move volume, its effect on the service radius of the factory, and the impact on the total cost of the building. This research has omitted to deal with the effects of transportation in terms of quality and construction engineering. In 2020, Mona et al. [3] examined the door element of architectural components under the industrialization system of a building and tried to optimize the product in terms of production speed and production volume by linear modeling in the factory production line. The researchers [4] to [9] have also done case-by-case research on construction projects built with industrial production methods, mainly on implementation methods in a specific project or from the point of view of the application of technology in the architecture of a specific building.

2- Research pattern: experimental-theoretical

The experimental part of the research included the investigation of 45 types of technologies, including the complete building system and subsystems. This part includes collecting and organizing the information of each technology, field impressions of the performance of the implemented new technologies, determining the strengths and weaknesses of the technology, pathology, and analysis. It is information whose results are used in the theoretical part. In the theoretical part, firstly, three main criteria of quality, cost, and speed (time) of construction definition and quantitative evaluation questions have been designed for each criterion, so that the quality criterion is 100 questions, the construction cost criterion is 150 questions, and the construction speed criterion is 80 questions and the answers to the questions are all optional. In addition to being placed in one of the above three criteria, the questions are also categorized into one of the two target groups of safety and competitive evaluation. Questions do not have a single value in terms of their effectiveness in evaluating technology, so the weighting factor for each question is intended according to the importance of the question and its impact. For example, when the question related to the ability to use a technology in seismic areas of a country is raised, it will have a different importance and impact than the question related to the permitted methods of structural analysis in that technology. Therefore, the weighting factor of each question will be different. In order to take advantage of the collective wisdom, the questions and answer options as well as the suggested weight coefficients for each question have been made available to academics and experts in the construction industry, and their valuable opinions have been received and applied as much as possible. Finally, the model Mathematics based on the results is presented by the author for the first time.

3- Results and Discussion

The indicators that make up the sides of quality, cost minimization, and speed of the triangle of the main evaluation criteria with engineering content were explained in the previous section, now the most important question of the research is raised and is: how to consider (if necessary, convert) these three main criteria into criteria How can it be expressed with mathematical and engineering sciences? ??? In this part, first, a mathematical model is presented to express the effect of each criterion, as well as the type of relationship and dependence of these three criteria. In this model, according to figure number (1), a triangle with the sides of the three main quality evaluation criteria, cost minimization and speed is used, which was presented by the author for the first time, and we call it the triangle of new construction technology evaluation criteria. In this article, two characteristics related to the sides of the triangle have been used for this model, which according to figure number (1) are:

1-3- The sides of the triangle are non-zero evaluation criteria.

$$AB\,,BC\,,CA\ >0 \tag{1}$$

2-3- The total length of two sides is greater than one side

$$AB+BC>CA\text{،}\ BC+CA>AB\ \text{،}CA+AB>BC\ \ (2) \tag{2}$$

3-3- The ratio of one side to the sum of the sides of the triangle

$$\lambda = {AB}/{L}\ ,\lambda = {BC}/{L}\ ,\lambda = {CA}/{L}\quad L=AB+BC+CA \tag{3}$$

4- Conclusion

The present article is a part of a comprehensive research in the field of "evaluation of new construction technologies" by the author, which will be presented in several articles. This article shows that with reliable quantitative tools and the mathematical model provided by the author, it is possible to evaluate new construction technologies in two sectors: safety and competitiveness. The obvious point is the deterrence function if the safety goal is not met, which deprives the technology of its usability. Also, the performance of the competitive target compared to other technologies and obtaining a small score will be the factor of success or failure of a technology. Based on the study, the following results have been obtained:

1- The triangle model of evaluation criteria for new technologies was presented in the three sides of quality, cost minimization, and speed, which expresses the user and engineering indicators of a technology.

2- The evaluation indices were presented in the form of general and specific indices and the grouping of specific indices in the main safety group (with structural and fire subgroups) and the main operation group (with architectural, energy, and acoustic subgroups) was determined.

3- The side related to the quality of the new technology in the evaluation criterion triangle consists of two safety and competitive parts, the lack of safety (structure and fire) in technology causes the length of the quantity side to be zero in the quantitative evaluation and the triangle loses its definition. and this means preventing and prohibiting the use of new technology in the construction industry.

4- The normalized evaluation triangle is used to make the risk parameter for evaluation criteria with competitive goals, in which: First, the length of each of the three sides of quantity, cost, and speed is determined by the risk parameter of that criterion, whose value is between zero and 5 0.0 is placed (except for zero and 0.5). Second: the total length of the sides of this triangle is 1.0.

5- According to the normalized triangle model, the closer the risk parameter for one side of this triangle is to zero, it creates a thin triangle and makes the use of technology risky

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