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RESEARCH ARTICLE

Selecting the appropriate project delivery method for real estate projects using fuzzy AHP

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Abstract

The real estate industry holds a remarkably significant share in the Turkish economy. Due to the nature of the dynamic characteristics of the real estate industry, project achievement is not an easy task. Choosing the appropriate Project Delivery Method (PDM) is significantly crucial, considering that it provides various benefits, including economic contribution and time-saving. This study aims to determine the main factors affecting PDM selection with the most suitable analysis method for real estate projects in Turkey. The PDM types used in the real estate sector and the factors affecting the appropriate PDM selection process are identified based on literature review and interviews with professionals related to the Turkish real estate industry. The model generated is utilized as a tool in choosing the appropriate PDM in real estate projects by using Fuzzy Analytical Hierarchy Process (AHP). In terms of the theoretical contribution to the literature, this study identifies five main factors categorized as i) time-related issues, ii) cost, funding and cash flow related issues, iii) scope related issues, iv) owner organization, risk, and relationship related issues, and vi) project characteristic issues with 13 sub-factors. In addition to the theoretical contribution, a hierarchical model and a Fuzzy AHP based approach to select the appropriate PDM for the real estate projects in Turkey are provided as a practical contribution.

Keywords

Project delivery methods, Real estate projects, Fuzzy analytical hierarchy process, Multiple-criteria decision analysis.

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1. Introduction

The construction industry holds a significant share in the economies of countries, including Turkey. According to the Association of Real Estate and Real Estate Investment (GYODER)'s report [1], the construction industry contributed approximately 5.5% to GDP in Turkey in 2019. The real estate sector, which includes several sub-sectors such as residential, commercial, and industrial, plays a substantial role in this industry. As a consequence of the increasing population and the inter-regional migration, the demand for sheltering and other needs for real estate has been growing [2]. In addition to the increase in population, urban transformation and renovation also cause the augmentation in demand for real estate [3]. Therefore, the real estate industry is one of the fastest-growing industries in the world, and it has a remarkable locomotive effect on the national economies, especially in developing countries.

However, due to the nature of the dynamic characteristics of the real estate industry, project

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achievement is not a simple task. At that point, proper project management is an essential factor for project success, including completion with the planned schedule, costs, and quality. Moreover, the selection of the appropriate PDM is an indispensable part of the project management issue because PDM determines the roles and responsibilities for each party who take part in a construction project; therefore, it presents a roadmap covering all the steps in order, from design to actual construction [4]. Under a suitable PDM contributing to avert the problems regarding cost, time, and quality, the project becomes much more durable in case of any contingency. Thus, when we consider the complex characteristics of real estate projects, PDM selection becomes crucial to enhance project performance. Especially for the Turkish real estate industry, which is highly fragile in being affected by economic and political factors, PDMs gain more importance in terms of being a driver of project efficiency. Accordingly, determining factors affecting the selection of the most appropriate PDM is vital for the construction project cycle. Yet to the best knowledge of authors, an article in the literature that examines PDM types and selection criteria specifically for the Turkish real estate industry is unavailable. Also, because the existing studies focus on the specific project types and countries, adapting their findings for Turkish industries might be misleading. As a consequence, this study aims to present a model to select the most appropriate project delivery method by considering the factors affecting the selection and the most common PDMs used in the Turkish real estate industry.

2. Literature review

2.1. Project Delivery Method (PDM)

In construction management literature, there are several types and definitions of project delivery methods. El-Sayegh [5] describes PDM as the owner's approach to organizing the project team to handle the whole process of design and construction. Mahdi and Alreshaid [6], on the other hand, consider PDM as a means to ensure that delivery risk and performance in the design and construction processes, which are typically under the responsibility of the owner, are assigned to other parties. Moreover, Carpenter and Bausman [7] explain PDM as a process for determining the details of contractual liabilities regarding the design and construction phases of a project. In a nutshell, PDM explains the way different parties in a project collaborate to realize the owner's expectations. In the literature, various PDMs are applied to different types of projects to meet their specific project requirements. Among them, the most common and the fundamental ones are Design-Bid-Build, Design-Build, and Construction Management at Risk and Agency.

Design-Bid-Build (DBB) is a traditional type of PDM in which the contract is separated into two phases by the owner as design and construction [8]. In DBB, the total cost of construction is the last consideration of the constructor election [7]. Even though its nature allows low initial investment for the owner, DBB prevents the minimization of the project duration since it has three linear phases (design, bid, build). DBB requires the finalization of one task before moving to another. Thus, in general, it is known as the longest delivery method. Moreover, because of the lack of connection among the parties, the change order process is difficult, and this might be a threat to project efficiency.

Design-Build (DB) method refers to a process including only one contract between the owner of the project and one party, which holds the responsibility for both design and construction. Here, the party might fulfill the whole responsibility of design and construction or subcontract it [9]. This method reduces the overall completion time by keeping constructability alive during the design process and provides convenience for the implementation of change orders to the project. Al Khalil [10] underlines that DB is more suitable for projects with a well-defined scope, a standard and repetitive design, and a tight schedule. Due to the project parties' structure, DB ensures lower costs through the possibility of direct procurement from vendors. As distinct from DBB, this approach tends to eliminate the complexity and the confusion in the relationship of the parties by providing design and construction via a single entity [10].

On the other hand, Construction Management at Risk (CMR) is a type of PDM that first requires identifying a designer and then selecting a construction manager (CM) separately. CMR entails two contracts: one between the owner and the designer, and one between the owner and the CM [11]. Also, during the construction stage, the CM has the liability of the construction works for a high price [12]. Shortly, including the CM in the early stages, CMR increases the collaborative feature of projects and differentiates from other types of PDM [13]. Accordingly, CMR reduces the need for modifications because of the dialogue maintained between the two main parties (designer and CM) within the project. However, CMR still requires more time than DB.

Lastly, Construction Management at Agency (CMA) method includes a construction manager whom the owner of the project selects for monitoring the whole project [14]. Therefore, the use of this method, generally in the case of multiple prime contractors, brings upon the CM several responsibilities. Some examples can be preparing various contracts for the completion of different tasks within the project and realizing those contracts throughout all the phases. This enables a fast-track schedule, which ensures time and cost efficiency [6]. Eventually, when we take into account these different PDM types and their features, selecting the most suitable method for a specific project is critical with regards to its achievement. At that point, the identification and the categorization of the key factors affecting the PDM selection are quite critical [15].

2.2. *Previous studies on the factors affecting the suitable PDM Selection*

Because of its great importance in the construction industry, the study of factors that influence the decision-making process for an appropriate PDM selection is a major area of interest in the literature [10]. Many researchers (e.g., [6, 5, 16, 17]) have investigated the factors affecting the PDM selection in various projects. Mahdi and Alreshaid [6] aimed to compare four different kinds of PDMs (i.e., DBB, DB, CMR, and CMA), with particular sorts of projects and owners. Thirty fundamental factors identified by literature review and questionnaires were classified into seven groups. A multi-criteria decision-making methodology following the analytical hierarchy process was applied in order to support the concerned parties in choosing suitable PDM for their construction projects. El- Sayegh [5] examined three main delivery methods, DBB, DB, and CM, which are available in the United Arab Emirates. Through the literature review, a comprehensive list of 21 factors divided into 8 groups (i.e., cost, quality, scope, project characteristics, owner organization, time, cash flow, risk, and relationship) was identified. Among all, owner organization and quality were found to be the most significant factors.

Chen et al. [16] conducted a study on the selection of PDMs in the Chinese construction industry, benefiting from data envelopment analysis. The researchers examined PDM applications and selection procedures in China. The study aims to investigate the factors affecting the PDM selection and to suggest an effective method for the decision-makers. The data were collected using the survey technique. From the top Chinese companies, 92 project managers participated in the study. Multivariate Statistical Analysis was utilized for analysis, and a model was constructed to provide suitable project delivery selection. Both the literature and the Likert scale questionnaire were used to acquire the main indicators. Firstly, the study determines project objectives and assesses their relative importance for each PDM type. The authors list the project objectives under Cost, Schedule, Safety, Quality, Contract/business, and Other categories. Besides, 20 factors that affect the PDM selection are identified and evaluated under five categories: Schedule, Cost, Owners and contractors, Project, and External environment. Additionally, the study presented the importance of the factors for each PDM type and made a comparison between the PDMs.

Focusing on how to reasonably choose a suitable PDM to achieve successful project management, Liu et al. [17] elaborated on the contractor's fundamental characteristics, which contribute to the efforts for a successful project in the context of various PDMs. The study consists of two data collection processes, including a literature review and actual completed projects. Through the literature review, the authors listed 12 contractor characteristic factors and conducted a questionnaire based on these factors. Then, they selected 73 successful projects using different kinds of PDMs in China and evaluated the key 12 factors by utilizing rough set theory. The results revealed four significant factors for a successful project in the context of various PDMs. These are contractor's coordination, communication, demonstrated capacity for financial management, previous experience in similar projects, and design capability. Similar to the aforementioned studies, Mostafavi & Karamouz [18] conducted a study about choosing suitable PDM using the Fuzzy AHP and analyzing the risks. For the selection factors, the researchers benefited from the study of Oyetunji & Anderson [4] that included 20 key factors related to the PDM selection. These factors were mainly about cost, time, risk, regulatory, project features, and owner features. The study ensures choosing the most suitable PDM through the proposed Fuzzy Multi-Attribute decision-making model.

In each of the previous studies, the main factors affecting the selection of PDM and PDM used in the project vary according to the project type and the country where the research is applied. Liu and the colleagues [19] investigate the Chinese construction projects, considering only the owner characteristics for the selection of the PDM. On the other hand, Swarup et al. [20] focus on green office buildings in the United States and prefer to use schedule, cost, quality, and owner's perception as the most influential factors. The differences between the findings of several previous studies mainly originate from including different kinds of perspectives. In other words, the number of factors and their categorization is not identical, as the authors examine different types of projects in different countries. To sum up, there are various studies on project delivery methods and the factors affecting the selection of PDM. However, aside from Swarup et al. [20], not much of the studies specifically focus on the real estate industry. Moreover, as the scopes and findings of the existing studies mainly rely on the characteristics of the country and project types in question, the results cannot be directly adapted for the Turkish real estate industry. To the best knowledge of authors, a study does not exist in the literature that explores the PDM selection, the factors influencing the PDM selection, and the success of the project, specifically for the Turkish real estate industry. When we consider the locomotive role of the real estate industry in the Turkish economy, it is crucial to identify the main factors affecting the suitable PDM selection for the success of real estate projects in Turkey.

3. Research methodology

This study was conducted to develop a framework to select the most appropriate PDM for real estate projects in Turkey. Accordingly, factors affecting the PDM selection were identified through an extensive literature review. After listing key variables, the study generates a PDM selection model implementing the Fuzzy AHP decision-making approach. The following sections explain the theoretical background of the Fuzzy AHP approach and the model construction processes. The main framework of this study is presented in Fig. 1.

3.1. Identification of the key factors affecting the PDM selection in Real Estate Projects

Following an extensive literature review, we examined the studies focusing on the PDMs and the factors affecting the selection of them. The literature review for factor selection includes papers published after 2000, which were published in well-recognized, peer-reviewed journals and conferences. The keywords used during the literature review can be listed as follows; "construction" "construction industry", "real estate", "real estate industry", "project delivery",

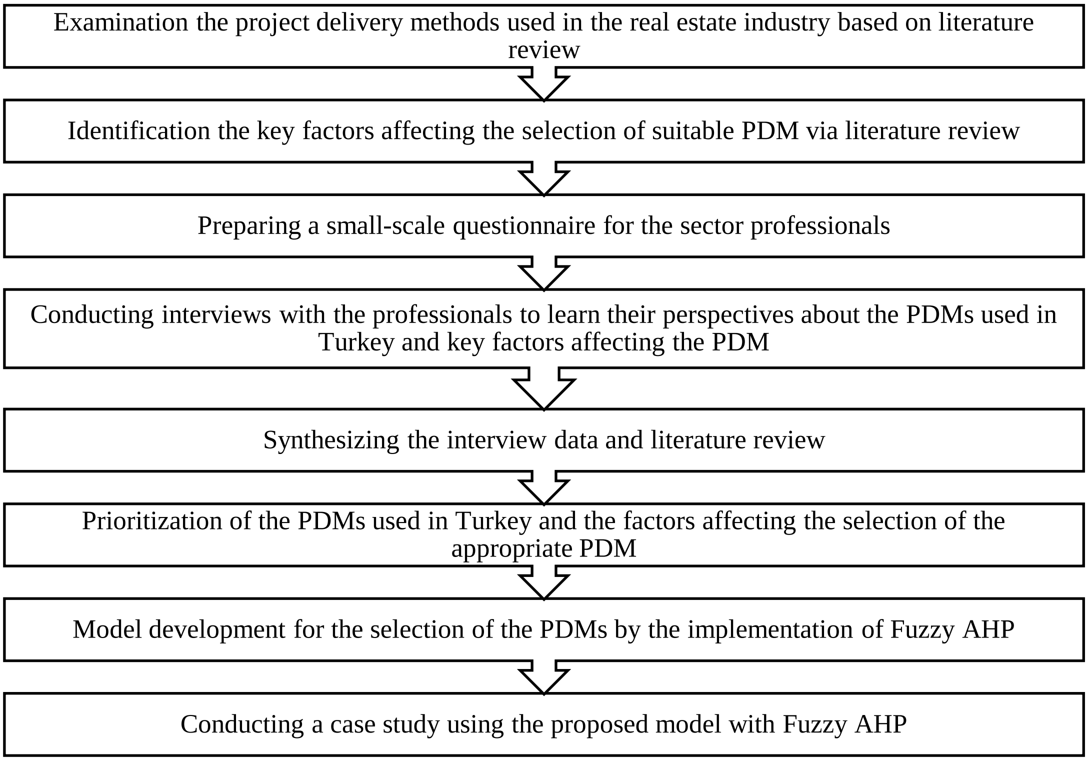

Fig. 1. Main framework of research

"project management", and "multi-criteria decision making". As a result of this examination, we selected the most relevant 14 manuscripts [5, 6, 8, 10, 11, 14, 15, 16, 17, 18, 19, 20, 21, 22].

Evaluating these 14 papers, we observed a high number of recurring factors. In other words, some of the factors listed in the studies have very close meanings. Thus, we combined and collected them under the same title. Then, we conducted the questionnaire with ten sector professionals to determine the factors affecting the PDM selection and the PDM types used in the Turkish real estate sectors.

To acquire data specific to the real estate industry, interviews with professionals, including questionnaires, is one of the most common methods. The professionals who have sufficient experience in the Turkish real estate industry are considered as eligible to provide the required data for this study. Accordingly, a questionnaire consisting of two main parts was prepared. In the first part of the questionnaire, we aimed to collect data about the demographic characteristic of the participants, such as their area of expertise, their work experience, and their organization type as the stakeholder. The second part of the questionnaire includes questions on PDMs and determining factors related to their selection, which were determined based on an extensive literature review. The experts were determined based on selection criteria. Therefore, they have at least five years of experience in the Turkish real estate sector and have completed at least one real estate project in Turkey from beginning to end. Moreover, each expert was elaborately informed about the scope of the study. Then, the abovementioned questionnaire is distributed to the professionals during the interview. Ten professionals from five different companies voluntarily participated in this study. They work for various stakeholders including, owner, contractor, designer, and consultants in the real estate industry, and have different areas of expertise (Table 1).

Table 1. Demographic information of interviewers.

Area of Expertise in Real Estate Projects				
Project Manager	Contract Manager	Planning & Cost Control Manager	Designer Engineer	Site Engineer
3	2	2	2	1
Years of Experience in Real Estate Projects				
5-10 years	10-20 years	>20 years		
3	4	3		
Involved Organization				
Owner	Contractor	Designer/Engineer	Consultant	
4	3	2	1	

Therefore, the final form of the factor list was created by synthesizing the data collected through interviews with the results of the literature review. Table 2 and Table 3 show the PDMs used in the real estate industry projects and the final key factors and, respectively. In the tables, the codes from P1 to P10 represent the references of the professionals. By combining the data acquired from the literature review and interview-based questionnaires with sector professionals, the hierarchal model is created as in Fig. 2.

3.2. Fuzzy theory and fuzzy AHP

AHP refers to a multi-criteria decision-making method, which was first introduced by Thomas L. Saaty in the 1970s [23]. The AHP is an important tool that was designed to help to provide solutions to unorganized problems on several decision-making instances, which can be either simple individual problems or complicated business investment issues [10]. According to Saaty [24], the AHP focuses on the measurement of numerous intangibles that do not have any existent scale to bring them together with the tangibles that are inherently measurable. This way, the situations requiring the evaluation phase of the tangible and the intangible factors considered in the same pool might be achieved by using the AHP. Moreover, this method helps to organize the factors with its hierarchy structure, breaking the decision-making case down [25]. In this hierarchical system, AHP compares an element to the subsequent higher level, which is the main logic of the method [26]. By courtesy of its helpful decision-making features, the AHP method is also a highly preferred approach among the studies focusing on the PDM selection (e.g., [6, 10, 27]).

However, the classical AHP method also has been criticized for its inadequacy in addressing uncertainty [28]. In other words, it cannot reflect the actual human thinking process, which is based on inaccuracy and unreliability. To overcome these shortcomings, the Fuzzy AHP method, which integrates the AHP and the fuzzy set theory, is proposed. Here, the word "fuzzy" means vagueness, namely ambiguity. It originates from the lack of a boundary of a piece [29]. Particularly in complex situations, taking the appropriate decision is quite difficult due to the uncertainty in the judgment of decision-makers. Since the multi-criteria decision-making methods utilize professionals' opinions, the data is based on experience rather than scientific facts. Thus, the fuzzy theory is commonly used in decision-making related studies [30]. The theory of the fuzzy set developed by Zadeh [31] was oriented to the rationality of uncertainty resulting from imprecision to cope with the vagueness of human thought. A fuzzy set enables the development of a conceptual framework, which is similar to the framework utilized for ordinary sets. However, it is seen as a more generalized version and can be applied within various scopes, especially in pattern classification and information processing [29]. Moreover, the most crucial aspect of the fuzzy set theory is known as its ability to provide vague data [32].

Table 2. The references for the Project Delivery Methods used in the real estate industry

PDM Name	References Based on the Literature Review	References Based on Expert Opinion
Design - Bid - Build (DBB)	[5, 6, 8, 10, 11, 14, 15, 16, 17, 18, 19, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
Design - Build (DB)	[5, 6, 8, 10, 11, 14, 15, 16, 17, 18, 19, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
Construction Management at Risk	[5, 6, 11, 14, 15, 16, 18, 20]	
Construction Management at Agency	[5, 6, 10, 16, 18]	P1, P3, P6, P7, P9, P10

Table 3. The feferences for the key factors related to the selection of the Project Delivery Method

Factors	Sub-Factors	References Based on the Literature Review	References Based on the Questionnaires
Time Related Issues (X1)	Normal Schedule (Y1)	[5, 6, 8, 10, 11, 14, 15, 18, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
	Fast Track Schedule (Y2)	[5, 6, 8, 10, 11, 18]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
Cost, Funding and Cash Flow Related Issues (X2)	Cost Growth Tolerance (Y3)	[5, 6, 8, 10, 14, 15, 16, 18, 20]	P2, P4, P6, P7, P8, P9, P10
	Facilitate Early Cost Estimates (Y4)	[5, 6, 8, 10, 11, 15, 16, 18]	P1, P2, P3, P4, P5, P6, P7, P8, P10
Scope Related Issues (X3)	Well Defined Scope (Y5)	[5, 6, 10, 15, 18, 19, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
	Vague Scope (Y6)	[5, 10, 15, 18, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
Owner Organization, Risk and Relationships Related Issues (X4)	Owner’s Willingness to Be Involved (Y7)	[5, 6, 10, 15, 18, 19, 20]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
	Owners Available Human Resources (Y8)	[10, 15, 18, 19]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
	Risk Allocation (Y9)	[5, 6, 15, 18, 19]	P1, P2, P3, P4, P5, P6, P7, P8, P9
	Minimized Number of Contracted Parties (Y10)	[5, 6, 10, 16, 18]	P1, P2, P5, P8, P9, P10
	Level of Compatibility and Communication Among Project Team Members (Y11)	[5, 6, 11, 16, 17, 18, 19, 20, 21]	P1, P2, P3, P4, P5, P6, P7, P8, P10
Project Characteristics Related Issues (X5)	Standard Project (Y12)	[5, 6, 10, 15, 17, 18, 19]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
	Complex Project (Y13)	[5, 6, 10, 15, 22]	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10

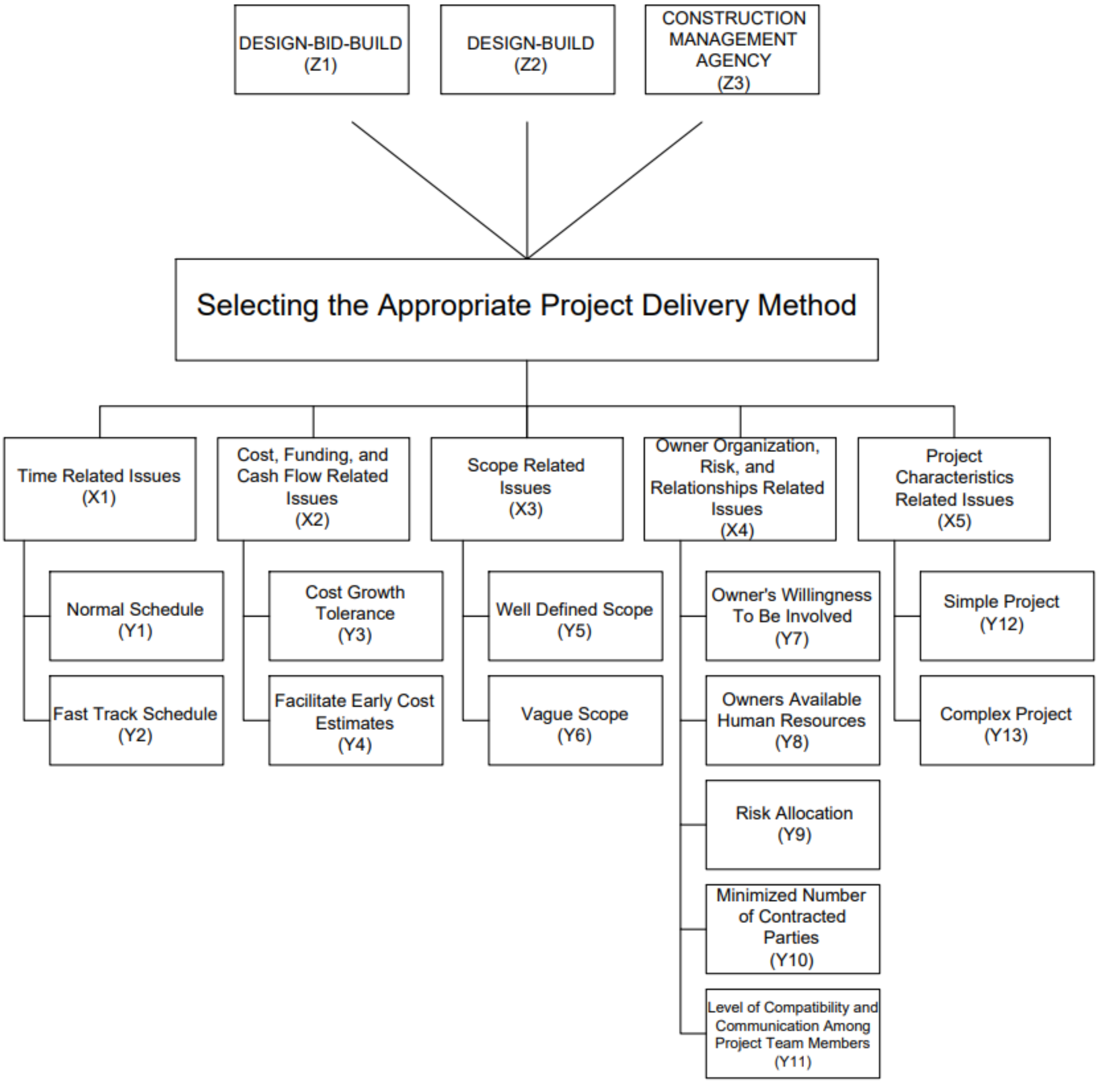

Fig. 2. The scheme of hierarchy.

Regarding the Fuzzy AHP, Van Laarhoven & Pedrycz [33] presented the first study, which applied the fuzzy logic principle to the AHP in which triangular fuzzy numbers were used for pairwise comparisons' modeling. From that time, many researchers (e.g., [34, 35, 36, 37]) conducted studies about this approach and recommended various Fuzzy AHP methods. The main aim of the Fuzzy AHP, unlike the AHP, is to mitigate the high uncertainty level in the judgments for multi-criteria decision-making. Because of these reasons, we prefer to use the Fuzzy AHP approach for this study. According to Chang [35], the mathematical theory and the algorithm of the Fuzzy AHP method consistent with Zadeh's fuzzy set theory are shown below.

Triangular fuzzy numbers (TFNs)

Definition 1: Firstly, Let F(R) to be a representation of all fuzzy sets, and R is the set of real numbers. Here, $M \in F(R)$ is a fuzzy number if $x_0 \in R$, $\mu_M(x_0) = 1$. Also, for any $\propto \in [0,1]$, $A_\propto = \left[x, \mu_{A_\propto}(x) \geq a\right]$ is a closed interval.

Definition 2: A triangular fuzzy number (TFN) has linear representations, which are represented as l (lower), u (upper), and m (modest) value. A fuzzy number M on R can be a TFN if its membership function ($\mu_M(x): R \rightarrow [0,1]$) defined as:

$$\mu_M(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l,m], \\ \frac{x}{m-u} - \frac{u}{m-u}, & x \in [m,u], \\ 0, & otherwise, \end{cases} \quad (1)$$

where; $\{x \in R \mid l < x < u\}$; $l \le m \le u$. Also, when $l = m = u$, it is a non-fuzzy number by convention.

Fuzzy synthetic extent analysis

Let $X = x_1, x_2, x_3, \dots, x_m$ be an object set, and $G = g_1, g_2, g_3, \dots, g_n$ be a goal set. According to this method, each object is taken, and extent analysis for each goal is performed, respectively. Therefore, m extent analysis values for each object can be obtained with the following signs:

$$M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, \; i = 1, 2, 3, \dots, n \quad (2)$$

where M_{gi}^j (j= $1, 2, 3, \dots, m$) all are Triangular Fuzzy Numbers.

Definition 3: The value of the fuzzy synthetic extent with respect to the i[th] object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \quad (3)$$

Definition 4: The possibility degree (V) of $M_1 \ge M_2$ is defined as:

$$V(M_1 \ge M_2) = \sup_{x \ge y} [\min(\mu_{M_1}(x), \mu_{M_2}(y))]. \quad (4)$$

where sup represents supremum. When a pair (x, y) exists such that x ≥ y and $\mu_{M1}(x) = \mu_{M2}(y)$, then we have $V(M_1 \ge M_2) = 1$.

Since M_l and M_2 are convex fuzzy numbers we have that

$$V(M_1 \ge M_2) = 1 \; iff \; m_1 \ge m_2 \quad (5)$$

$$\begin{aligned} V(M_2 \ge M_1) &= hgt(M_1 \cap M_2) \\ &= \mu_{M_1}(d), \end{aligned} \quad (6)$$

where hgt is the ordinate of the highest intersection point D between $\mu_{M1}(x)$, and $\mu_{M_2}(y)$,which is represented by d in Eq. (6) (see Fig. 3)

When $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ the ordinate of D is given by Eq. (7):

$$V(M_2 \ge M_1) = hgt(M_1 \cap M_2)$$
$$= \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}. \quad (7)$$

To compare M_1 and M_2, both of $V(M_1 \ge M_2)$ and $V(M_2 \ge M_1)$ are needed.

Definition 5: The possibility degree for a convex fuzzy number to be greater than k convex fuzzy numbers M_i $(i = 1, 2, \dots, k)$ can be defined by:

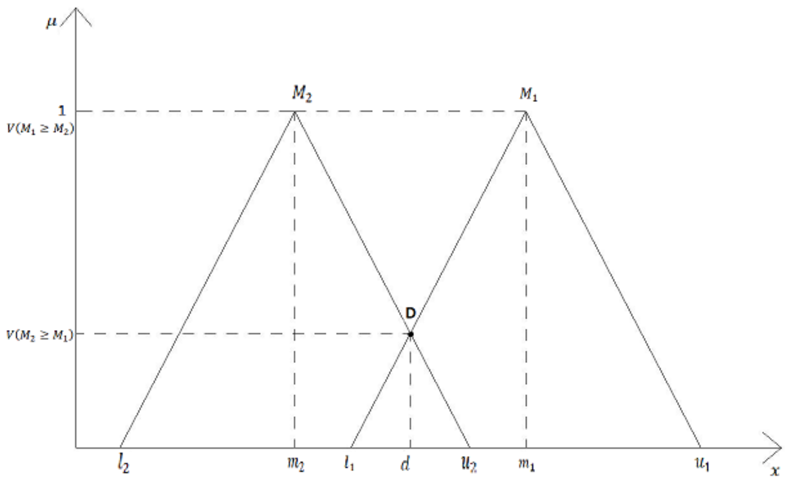

Fig. 3. Intersection between M1 and M2

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \ and \ (M \geq M_2 \ and \ \dots \ and \ (M \geq M_k)] = \min V \ (M \geq M_i), \quad (8)$$

$i = 1, 2, 3, \dots, k.$

Assume that:

$$d'(A_i) = minV(S_i \geq S_k). \quad (9)$$

For $k = 1, 2, \dots, n; k \neq i$. Then the weight vector is given by:

$$W' = (d'(A_1), d'^{(A_2)}, \dots, d'(A_n))^T \quad (10)$$

where $A_i (i = 1, 2, \dots, n)$ are n elements.

After normalization, the normalized weight vectors are as follow:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (11)$$

where W is a non-fuzzy number.

4. Case study

Considering the scope of this study, a real estate project which was developed in Istanbul, Turkey, was chosen as the case study to test the proposed model. The construction of the case study project started in Istanbul by a Turkish contractor, which has more than 30 years of experience in real estate development projects. According to the agreement signed between the parties regarding the construction works, the completion period of the project, consisting of 600 units, was determined as 24 months. Based on the information provided by the professionals who worked in this project, there was not any schedule delay during the construction period. Besides its on-time completion, the project did not have any cost overrun, it was completed slightly below the estimated budget.

For the case study, the professionals with more than ten years of experience who participated in all phases of the project were selected. Accordingly, we formed a focus group consisting of five professionals. We initially informed the focus group about the scope of the study, the model hierarchy, and how they should answer the questions in the questionnaire. During the data collection process for the case study, the hierarchical scheme (Fig. 3) is provided to the respondents to visualize the items in their decision-making process precisely. In other words, the respondents can explicitly embody all the factors via this hierarchy scheme. They filled the pairwise comparison sheets for Fuzzy AHP analysis by utilizing the visual guide of hierarchy. As Saaty [38] proposes, we used a nine-point scoring system for pairwise comparison. Here, point 1 indicates an equal preference of one variable to another one, while point 9 stands for an extreme preference. In the first step, five main factors on the top level of the hierarchy are compared among themselves by again using a nine-point Likert scale. Then, the 13 sub-factors are scored with pairwise comparison one by one. Finally, pairwise comparisons of the 3 PDMs are conducted with respect to each sub-factor. According to the answers, the most suitable PDM is recognized and compared with the actual PDM used during the project.

After getting all the data from the experts for the decision process based on the pairwise comparison, any tool created based on Excel, Matlab, etc. can be used regarding the Fuzzy AHP logic and analysis. In this study, we preferred to use a web-based Fuzzy AHP tool, which is Decision Era-Fuzzy AHP. As it is represented in Fig. 4, we defined the hierarchy in the web-based tool.

Firstly, all the factors in the hierarchy are labeled in the online tool. Then, based on the pairwise comparison data obtained from the focus group members, the template in the web-based tool is filled in order to complete the evaluation phase. Using the algorithm, including the Fuzzy AHP logic, the most appropriate decision is acquired for the selection of a suitable PDM. After the implementation of the case study data, the final weights of the main and the sub-factors are determined, as shown in Table 4 and Table 5.

By combining all analysis results, the preference weights for 3 PDMs are visually stated in Table 5. In this case study, A1, A2, and A3 refer to Design-Bid-Build (DBB), Design-Build (DB), and Construction Management Agency (CMA), respectively. Table 6 shows the final crisp weights and associated prioritization of each PDM alternative.

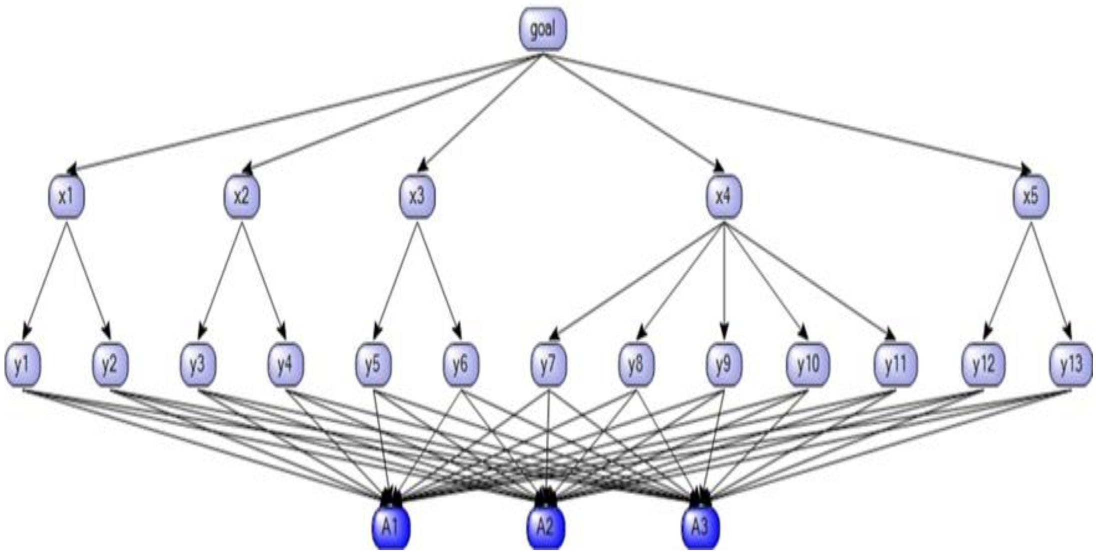

Fig. 4. Hierarchy structure

Table 4. Matrix of the final weights (main factors) with respect to the decision (goal).

Component	Final fuzzy weight	Final Crisp weight
X1	(0.222,0.299,0.417)	0.309
X2	(0.333,0.468,0.617)	0.472
X3	(0.067,0.102,0.138)	0.102
X4	(0.057,0.074,0.111)	0.079
X5	(0.048,0.057,0.095)	0.064

Table 5. Matrix of the final weights (sub factors) with respect to the decision (goal).

Component	Final fuzzy weight	Final Crisp weight
Y1	(0.038,0.059,0.109)	0.066
Y2	(0.141,0.24,0.406)	0.257
Y3	(0.035,0.061,0.107)	0.066
Y4	(0.224,0.407,0.688)	0.431
Y5	(0.045,0.089,0.153)	0.094
Y6	(0.007,0.013,0.024)	0.014
Y7	(0.004,0.006,0.011)	0.007
Y8	(0.003,0.005,0.01)	0.006
Y9	(0.004,0.005,0.01)	0.006
Y10	(0.016,0.026,0.053)	0.03
Y11	(0.017,0.032,0.058)	0.035
Y12	(0.034,0.049,0.1)	0.058
Y13	(0.005,0.008,0.016)	0.009

Table 6. Matrix of the final weights (alternative PDMs) with respect to the decision (goal).

Component	Final fuzzy weight of Alternatives	Final Crisp weight of alternatives	Prioritization based on Crisp weight
A1	(0.077,0.161,0.397)	0.199	3
A2	(0.089,0.192,0.432)	0.226	2
A3	(0.281,0.646,1.415)	0.747	1

As Table 6 indicates, the most appropriate PDM is selected as Design-Bid-Build by using the proposed model.

At the end of the data collection with pairwise comparison, the model proposes the Design-Bid-Build method as the PDM. The project professionals who participated in the case study also confirm the same PDM. Due to the fact that the PDM that is suggested by the model and the one used in reality is the same, we can conclude that the model developed in this study presents reliable results to determine the appropriate PDM to be used in the real estate projects.

5. Conclusion

The real estate industry is one of the fastest-growing industries in Turkey. With having more than 200 sectorial interactions, nearly 2 million employees, and %15 of the economic impact of the construction industry, the real estate industry is the locomotive of the Turkish economy [39]. In other words, its contribution to the country's economy is remarkably high. Despite the unstable conditions in the Turkish economy regarding political, social, and economic risks, the geopolitical position of Turkey fosters and increases the demand of the real estate industry for not only domestic but also for foreigner investors. Thus, considering the adverse effect of the economic and political issues, the projects should be managed more professionally by foreseeing the contingencies to prevent both time and cost overruns. At this point, PDMs come into prominence to overcome the possible problems. Liu et al. [19] argue that for a construction project to meet project objectives successfully, the most suitable PDM must be selected using scientific methods. In this manner, this paper focuses on the selection of the appropriate PDM by considering the factors affecting the selection and the most common PDMs used in the Turkish real estate industry.

Firstly, we determined the factors that have an impact on the selection of the PDM in the real estate industry. The factors were selected through a detailed literature review and the interviews with the sector professionals who have different kinds of roles in the real estate projects such as the project managers, the contract managers, the designers, the site engineers, the owners, and the contractors. The 14 selected studies focus on different countries and different types of PDM, with a large number of factors influencing PDM selection (e.g. [14, 11, 16, 9]). For example, Konchar & Sandivo [14] compared PDM types for construction projects in the United States. They examined CM at risk, DB, and DBB in terms of cost, schedule, and quality. The findings revealed that DB is the most successful PDM type for US construction projects. Similarly, Ibbs et al. [8] evaluated DB and DBB from time, cost, and productivity perspectives. Most of the data used in the study are collected from the projects in the United States. However, these studies, which focus on a developed country, consider only three main categories and neglect some critical issues, such as project complexity and risk allocation. On the other hand, Chen et al. [16] highlighted the importance of risk allocation in PDM selection, considering the improving economy of China. They evaluated 20 key factors affecting the PDM selection under five categories, which are schedule, cost, owners and contractors, project, and external environment. Considering the complex and risky environment of construction projects, especially in developing countries, examining the key factors related to a project and risk is also quite important for the Turkish real estate industry. Therefore, we aimed to consider or eliminate the factors and PDM types mentioned in the selected 14 studies depending on their relevancy to the real estate industry in Turkey. As a result, the final list consists of 5 main factors categorized as i) Time-related issues, ii) Cost, funding, and cash flow related issues, iii) Scope related issues, iv) Owner organization, risk and relationship related issues and v) Project characteristic issues, with 13 sub-factors. Besides, the main PDMs used in the Turkish real estate industry are found as DBB, DB, and CM at Agency. Afterward, the proposed model is implemented by conducting a case study. The model result shows that DBB is the most appropriate PDM for the real estate project examined in the case study. When the result of the case study and realized PDM selection are compared, it is seen that the model is consistent and can be utilized to determine the proper PDMs for the real estate projects in Turkey.

The proposed model was created through a detailed literature review and supported by interviews with the professionals from the real estate industry. Unlike many studies in the literate (e.g., [16]), this study includes expert opinions rather than focusing solely on studies in the literature. Therefore, this study contributes to the literature by revealing the factors that specifically affect the choice of PDM in the Turkish real estate sector. Moreover, the study evaluates the most commonly used PDMs, and select the most suitable one for the Turkish real estate projects by utilizing Fuzzy AHP. Considering its detailed evaluation phases with the sector professionals, this study may help the decision-makers by including different viewpoints such as those of the contractors, the owners, the designers, and the consultants. Especially, not only in Turkey but also in other developing countries, the professionals who are responsible for the selection of the most appropriate PDM can utilize this study and manage the project more appropriately.

On the other hand, this research has some limitations as well. Initially, the number of interviews with sector professionals can be increased. We interviewed as much as possible with representatives of different project stakeholders. However, if more participants are provided from each stakeholder group, their different perspectives can be statistically compared. Another limitation of this study is that only a single case study is conducted. More case studies can be conducted to augment the reliability of the proposed model. This way, the data about consistency can be achieved in order to analyze the results deriving from this proposed model. For future studies, as the number of interviews increases, the collected data also increases and fosters the reliability of the model. In other models, statistically, the broadened sample size helps to obtain more realistic results. Moreover, the number of future case studies may enable testing the validity of the proposed model. Last but not the least, some methods such as sensitivity analysis can be performed to test the model's stability. By focusing on these two limitations, further case studies can be conducted to reinforce the reliability of the model.

To sum up, considering the gap in the literature, this research provides valuable theoretical contributions to the literature by showing the factors affecting the selection of the PDM and the suitable PDMs for the Turkish real estate industry. Moreover, this research also provides practical contributions. It assists the decision-makers to select the most appropriate PDM with the Fuzzy AHP model enabling the proper execution process of the project from the beginning to the end. In light of this study, the users might make some changes and modify the proposed model to address the needs of their projects.

Ethics Committee Permission

The authors acquired ethics committee permission for surveys implemented in this paper from the Science and Engineering Fields Human Subjects Ethics Committee of Boğaziçi University (No. 84391427-050.01.04-E.17947).

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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