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Identifying the Factors Affecting the Use of Prefabricated Construction Systems in Turkey

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Abstract: The main aim of this research is to identify the factors that affect the use of prefabricated construction systems in Turkey. This study adopted a survey methodology to explore the reasons for less and ineffective use of prefabricated systems in Turkey. Three questionnaires were designed and distributed to design firms, prefabricated system/element manufacturers, and contractors. The surveys were distributed in person as well as via e-mail. Obtained data were analyzed statistically by using SPSS 22 software. The analysis of data is done to rank the severity of problems. The ranking was followed by a comparison of mean values within groups (design firms, manufacturers, and contractors). As a result, three critical reasons that affect the use of prefabricated construction systems were identified. Finally, solutions and recommendations were offered. This study has rendered useful insights for the prefabricated construction industry such that the findings will help the stakeholders to revive this industry in Turkey.

Keywords: *Prefabricated construction system, construction management, Turkey*

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I. INTRODUCTION

Prefabricated construction is increasingly being adopted world-wide to augment productivity and to facilitate the adverse environmental and social effects as a result of conventional activities.

Prefabrication is a manufacturing process, generally conducted at a specialized facility, in which various materials are joined to form a part of the final installation [1, 2]. The manufacturing process may be undertaken in a factory environment (factory prefabrication) or under the open sky at the site (site prefabrication) [3]. The term off-site fabrication is used when both prefabrication and pre-assembly are integrated [4]. Precast construction was made feasible with the advancement of adapted equipment for transportation and erection.

Prefabrication technology is regarded worldwide as offering significant advantages including easier and quicker erection of the building structure, lower project cost, achieving tighter control over quality, enhanced durability, less material waste, high levels of design flexibility, better sustainability, enhanced occupational health and safety, better architectural appearance, and improved standardization and modularization of reinforced concrete components compared to on-site produced components [5, 6, 7, 8, 9, 10]. In addition, many studies in the literature have acknowledged the benefits of prefabrication in buildings and support this idea [11, 12, 13].

In spite of the advantages of prefabricated construction offers, the use of precast concrete systems in Turkey is still at a low level compared to in many European countries. Many factors may influence the market share of precast concrete systems such as labor costs, climate, and the relative costs of alternative construction methods. One of the most important studies was conducted by Arditi et al. [8] and Polat [14], which identify the main reasons why precast concrete systems are not widely used

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in the United States. Researchers found out that lack of expertise in precast concrete design and contractors' unawareness of significant cost savings that may likely be achieved when using precast concrete systems were two of the main factors preventing the extensive use of these systems in the U.S. building construction market in 1995. In addition to Polat and Damci [15], conducted similar studies related to Turkey. This research was based on literature review of factors affecting the use of prefabricated systems at Turkish construction industry.

Since the construction industry is subject to rigorous and rapid changes due to its dynamic nature and its complex relations with other industries, the 12 years between 2007-2019 is a long period of time to expect the very same business environment to prevail.

The main objective of this research was to identify the factors that prevent the extensive use of prefabricated systems in Turkey with an extensive survey.

II. METHODS AND MATERIALS

To determine the factors affecting the use of prefabricated construction systems in Turkey is the main of this research. After a thorough review of extant literature, particularly in the knowledge areas, three questionnaires were composed and administered to the architects, prefabricated component manufacturers, and contractors. The surveys were applied to the participants by face to face and via e-mail.

All questions in the three questionnaires are common and each survey consists of six parts. The parts can be summarizing as; questions related to the design process, manufacturing process, storing, transportation and demographic variables, respectively. In other words, the questionnaires measure all phases of prefabricated construction. The questionnaire includes 46 criteria (10 criteria for design process, 12 criteria for manufacturing, 6 criteria storing, 7 criteria for transporting and 11 criteria for construction process) on a Likert-type scale of 1 to 5, where 1 represents "not-a-severe" and 5 represents "most severe".

After the first draft of the questionnaire, a pilot study was conducted with the aim of testing the level of ease at which respondents would be able to complete the questionnaire without any problem. The pilot study examined clarity of language, appropriateness, and logic of questions, layout of the whole questionnaire. The pilot study involved 11 designers, 13 precast concrete manufacturers and 11 contractors with an average of 10 years' experience at prefabricated construction industry in Turkey. They all commented that the logic and robustness of the 46 criteria met their expectations of a comprehensive list of criteria that affect the use of prefabricated systems. After ensuring the reliability, the questionnaires applied to 80 participants.

III. FINDINGS

The sample comprised of architects who design prefabricated components and systems, manufacturers and contractors who are currently employed in the prefabricated construction industry. Therefore, the participants' experience (in years) at construction industry is an important value for evaluating the significance of problems that are encountered during construction process. The distribution of respondents' experience is presented in Table 1. In addition to other demographic variables (gender, education) are identified in Table 1.

TABLE 1
DEMOGRAPHICS OF SURVEY RESPONDENTS

Demographic variables	Architects		Manufacturers		Contractors	
	N	%	N	%	N	%
Gender						
Female	13	40.6	0	0	10	31.25
Male	19	59.4	16	100.0	22	68.75
Education						
Two-year degree	0	0	3	18.8	0	0
Bachelor's degree	27	84.4	13	81.2	29	90.62
Master degree/PhD	5	15.6	0	0	3	9.38
Experience (in years)						
1-5 years	25	78.1	1	6.3	20	62.5
6-10 years	4	12.5	6	37.5	8	25.0
11-20 years	3	9.4	5	31.2	2	6.2
More than 20 years	0	0	4	25.0	2	6.2
Total	32	100.0	16	100.0	32	100.0

In line with the advice of many social scientists [16, 17] that a Cronbach's alpha coefficient of reliability should be calculated when using a Likert scale in a questionnaire, it was imperative for this study to determine the internal consistency of the criteria contained in the questionnaire. The aim here is to confirm whether the criteria and their associated Likert scale are actually measuring the construct they were intended to measure, which are the problems affect the use of prefabricated systems. Since Cronbach's alpha coefficient is usually between 0 and 1; as a rule of thumb, George and Mallery [18] suggest that a value of 0.7 is acceptable, while is 0.8 indicates good internal consistency. Using the SPSS (Statistical Package for Social Sciences) software tool, the overall Cronbach's alpha coefficients for this study were 0.939 for designers' questionnaire, 0.972 for manufacturers' questionnaire, and 0.939 for contractors' questionnaire, demonstrating very good reliability and internal consistency of majority of the criteria.

In order to measure respondents' perception of the level of severity of each factor that affects the use of prefabricated systems, a severity index formula was computed using Eq. 1 below. The equation was derived from similar formula computed by Spillane et al. [19].

A. *Demotivation Severity Index*

$$DS = \left(\frac{\sum_{i=1}^{N} (S_i)}{NS} \right) \times 100\% \quad (1)$$

Where S is the severity rating given by (i^{th}) respondent ranging from 1 to 5; i = 1, 2, 3 . . . N; N is the total number of respondents for that particular criterion; and S is the highest possible severity rating, which is 5.

Table 2-6 show the severity index values and ranking of factor that affect the use of prefabricated systems.

TABLE 2
RANKING OF FACTORS FOR THE DESIGN PROCESS

Design Process	Architects		Manufacturers		Contractors	
	SI	Rank	SI	Rank	SI	Rank
D1. Lack of variety at the number of structural component limit the designs.	75.6	5	65.0	8	76.3	2
D2. Performance of prefabricated structural components under the dynamic load	69.4	10	61.3	10	68.4	10
D3. Lack of variety at the number of structural component affect the creativity negatively	73.1	9	65.2	7	72.6	8
D4. Inadequate technical knowledge level about the prefabricated systems	73.2	8	76.3	1	73.2	7
D5. Inadequate information flow among the construction stakeholders (civil engineers, contractors, manufacturers, etc.) at design process	76.9	2	75.0	2	75.8	3
D6. Not consulting to manufacturers by architects for designing prefabricated structural components affect construction process negatively.	75.7	4	63.8	9	73.7	6
D7. Lack of periodical meetings among the stakeholders affect the design process negatively.	77.5	1	67.5	4	76.5	1
D8. Lack of flexibility at prefabricated structural components limits the designs	76.3	3	66.5	5	73.9	5
D9. Poor design which cares for element dimension and weight economically and number of the reputation of panel.	75.0	6	66.3	6	74.2	4
D10. The limited number of architects and civil engineers who specialize in pre-fabricated systems compared to traditional systems	73.3	7	70.0	3	71.1	9

TABLE 2
CONTINUED...

From the ranking in Table 2 it is clearly seen that "D7- Lack of periodical meetings among the stakeholders" is the most important factor for both designers and contractors for design process of prefabricated systems. Whereas, manufacturers most suffer from "D-4 Inadequate technical knowledge level about the prefabricated systems." The consensus of designers, manufacturers and contractors on the least effective factor is significant. According to all participants, "D2 Performance of all prefabricated structural components under the dynamic load" is not so much important factor that affect the use of prefabricated systems.

TABLE 3
RANKING OF FACTORS FOR THE MANUFACTURING PROCESS

Manufacturing Process	Architects		Manufacturers		Contractors	
	SI	Rank	SI	Rank	SI	Rank
M1. Absence of technical skilled trained labor	75.6	3	75.0	3	74.5	4
M2. Lack of quality control systems during the manufacturing process.	73.1	7	76.3	2	73.2	6
M3. Failures at the design process of prefabricated structural components cause incorrect manufacturing.	71.3	8	71.3	4	71.1	8
M4. Manufacturers do not make production proper to technical drawings	62.5	9	42.5	9	60.5	9
M5. Manufacturers' laborers do not have enough knowledge on reading and understanding technical drawings.	76.9	1	68.8	5	75.3	1
M6. Inadequate level of concrete vibration during the production of prefabricated components	60.0	11	37.5	11	56.3	11
M7. Production of illegitimate prefabricated components causes the extension of term delivery	75.0	4	63.8	7	74.2	5
M8. Production of illegitimate prefabricated components causes extra payments	76.3	2	57.5	8	75.1	2
M9. Corroded steel and prestressing wire are used during manufacturing process.	53.8	12	35.0	12	51.6	12
M10. Quality and dimensions of aggregate are not proper that are used at production of prefabricated components.	74.4	5	77.5	1	74.7	3
M11. Deformation failures at molds affect the manufacturing process negatively	73.3	6	66.3	6	72.6	7
M12. Not proper production to technical specifications	60.2	10	40.0	10	57.4	10

The ranking of twelve factors that are related with manufacturing process of prefabricated components is seen in Table 3. According to data in this table, "M5 - Manufacturers' laborers do not have enough knowledge of reading and understanding technical drawings" is the most important manufacturing process problem for both architects and contractors. However, for manufacturers the most important problem is "M10. Quality and dimensions of aggregate are not proper that are used at production of prefabricated components."

It is significant that architects, manufacturers and contractors have the same opinion on the least effective three factors for manufacturing process: M12 -Not proper production to technical specifications; M6 - Inadequate level of concrete vibration during the production of prefabricated components; M9- Corroded steel and prestressing wire are used during manufacturing process.

TABLE 4
RANKING OF FACTORS FOR THE STORING PROCESS

Storing Process	Architects		Manufacturers		Contractors	
	SI	Rank	SI	Rank	SI	Rank
S1. Incorrect storage of prefabricated components causes physical damage	76.9	3	67.5	1	75.8	5
S2. Inadequate protecting precautions during storage causes dimensional and functional damages on prefabricated components.	76.2	5	57.5	6	76.8	4

S3. Unsuitability storage spaces for properties and dimensions to prefabricated components causes damages.	77.1	2	61.3	5	77.0	3
S4. Not planning storage process according to work schedule causes damage on prefabricated components and economic losses	77.5	1	62.5	4	77.4	2
S5. absence of experienced employee on controlling the storage spaces and stock control causes economic losses and organizational problems.	75.6	6	63.8	3	74.2	6
S6. Not determining the proper time for prefabricated component orders causes delays	76.5	4	66.3	2	77.8	1

There is no consensus on both the most and the least severe prefabricated component storing process factor (Table 4). When the context of most severe factors analyzed, it is understood that the storage process of prefabricated components is not planned according to work schedules; incorrect storage systems and not determining the proper time for orders of prefabricated components affect storage process negatively.

The ranking of seven transporting process factors is seen in Table 5. It is noteworthy that all participants concur on the most severe factor; T7 - not following the schedule.

Distance between plant and installation places is the least effective factor that affects the use of prefabricated systems for both designers and contractors; however improper transportation method is least affect the process according to manufacturers.

TABLE 5
RANKING OF FACTORS FOR THE TRANSPORTING PROCESS

Transporting Process	Architects		Manufacturers		Contractors	
	SI	Rank	SI	Rank	SI	Rank
T1. Limitations of highway commissions affect the transportations of prefabricated components.	75.6	5	70.0	2	73.7	6
T2. Long-distance between the plant and the installation places.	74.4	7	67.5	4	73.2	7
T3. Improper physical conditions of highways causes damages prefabricated components during transportations.	76.9	3	65.0	6	75.8	3
T4. No attention to prefabricated components during transportation	74.8	6	68.8	3	74.2	5
T5. Improper vehicle for transportation	75.9	4	65.3	5	74.7	4
T6. Improper transportation method	78.1	2	63.8	7	77.9	2
T7. Not following the schedule affect transportation negatively.	79.4	1	71.2	1	78.2	1

The ranking of construction process factors is seen in Table 6. Data in this table show that lack of auditing installations within the scope of quality control plan is vital problem for constructing the prefabricated systems for architects and contractors. Lack of technical experience of employees who control the installations of prefabricated systems is the most severe problem for manufacturers during the construction process.

It is significant that not monitoring the installations periodically is the second important problem for all three groups.

Failures and deficiencies at the conjunction of prefabricated column and beam are the least important problem for architects, contractors, and manufacturers.

TABLE 6
RANKING OF FACTORS FOR THE CONSTRUCTION PROCESS

Construction Process	Architects		Manufacturers		Contractors	
	SI	Rank	SI	Rank	SI	Rank
C1. Failures at the conjunction of prefabricated column and beam	68.1	11	60.0	11	67.9	10
C2. Failures at the conjunction of prefabricated column and wall	68.8	9	66.3	5	68.6	9
C3. Failures at the conjunction of prefabricated column and column	68.2	10	62.5	9	67.6	11

C4. Failures at the conjunction of prefabricated foundation and beam	71.9	7	61.3	10	71.1	7
C5. Failures at the conjunction of prefabricated beam and beam	69.4	8	62.7	8	68.9	8
C6. Lack of technical experience of employees who control installations of the prefabricated construction system	77.5	4	73.8	1	75.8	5
C7. Not provide qualified technical skilled laborers during construction process affect the process negatively.	76.9	6	68.8	3	75.5	6
C8. Not monitoring the work schedule during installation affect the process negatively	77.1	5	67.1	4	76.8	3
C9. Not taking into consideration of movement of cranes affect the construction process negatively.	78.1	3	66.0	6	76.2	4
C10. Not auditing the installations within the scope of quality control plan affect the construction process negatively.	78.8	1	65.4	7	77.4	1
C11. Not monitoring the installations periodically affect the construction process negatively.	78.5	2	70.0	2	77.1	2

IV. CONCLUSION AND RECOMMENDATIONS

Prefabricated construction offers important advantages to designers and also contractors. Prefabricated construction systems have been used in many countries in Europe. However, the use of this system in Tukey is not much common. It is generally declared reason for this situation is lack of specialized architects, engineers and workers in prefabricated construction systems. It is not possible to say that the only reason is lack of expert employees. Therefore, the focus of this study is identifying the most significant factors causing the use of prefabricated systems at Turkish construction industry. A questionnaire survey was conducted architects, manufacturers and contractors to explore the problems that affect the use of precast concrete systems in Turkey. From the findings of this study the most important factors that affect the architects, manufacturers and contractors during design, manufacturing, storing, transporting and the construction phase.

During the five phases of prefabricated construction, architects and contractors have some opinions on the most severe three problems that affect the use of these systems. The first problem which was built consensus is "lack of periodical meetings among the stakeholders". Not only prefabricated construction type but also all types of construction periodical meetings with all stakeholders is necessary and vital for all process of construction. Otherwise, incompatible technical drawing will be produced and these productions will cause failures or changes and delays at construction process. The best precaution for problems is to prevent them at the beginning of the process. This can be provided inevitably organizing periodical meetings during all phases of construction process.

Second problem is "manufacturers' laborers do not have enough knowledge on reading and understanding technical drawings". Unfortunately, at least having two-year degree is not compulsory for the employees working for manufacturing prefabricated components. As a result, workers cannot understand the technical drawings. To understand these special technical drawings, it needs to become familiar with these documents. It can be provided by vocational training for the employees who have insufficient knowledge of reading and understanding technical drawings.

The most severe problem is "lack of auditing the installation within the scope of quality control". Quality control is significant especially for the construction phase. Otherwise random productions and installations will occur. Establishing and managing a suitable quality control system is required for prefabricated construction systems.

All participants and also all stakeholders who are participated in the prefabricated construction systems have the same opinion on the factor "Not following the schedule affect the transportation negatively." Preparing a schedule is essential for monitoring the construction phases. If the organizations do not follow the schedule or do not prepare schedule, making plans and organizations lose their meanings.

This study is of benefit to both prefabricated construction industry participants and researchers because this research categorizes and identifies the main reasons why prefabricated construction systems are not used from the perspectives of architects, manufacturers and contractors. In addition, this study shows all participants that the problems should be solved immediately in order to promote the extensive use of these systems.

Declaration of Conflicting Interests

The authors hereby make the declaration that there are no financial or non-financial conflicts in this work.

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