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IDENTIFICATION OF DISPUTE CAUSES IN OFF-SITE CONSTRUCTION PROJECTS

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Merve Pelinsu YILDIRAN

Signature

Dedicated to my family

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS **vi**
LIST OF FIGURES **vii**
LIST OF TABLES **viii**
ABSTRACT **ix**
ÖZET **xi**
1 INTRODUCTION **1**
1.1 Background of The Search 1
1.2 The Purpose of The Study 3
1.3 The Methodology of The Study 6
1.4 The Limitation of The Study 7
2 OFF-SITE CONSTRUCTION **8**
2.1 The Definition of Off-Site Construction 8
2.2 The History of Off-Site Construction 9
3 DISPUTES IN OFF-SITE CONSTRUCTION **12**
3.1 Disputes in Construction Industry 12
3.2 Disputes in Off-Site Construction Industry 14
3.3 Literature Review Results For Disputes 16
4 METHODOLOGY AND FINDINGS **28**
4.1 Focus Group Discussion Technique Sub Title 28
4.2 FMEA Approach 34
4.3 Pythagorean Fuzzy AHP Integrated Fuzzy TOPSIS Hybrid Approach 35
4.3.1 Pythagorean Fuzzy AHP 36
4.3.2 Fuzzy TOPSIS 41
4.3.3 Sensivity Analysis 49
5 DISCUSSION **53**
6 CONCLUSION **60**
REFERENCES **63**
A QUESTIONNAIRE **72**
PUBLICATIONS FROM THE THESIS **79**

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
FGD	Focus Group Discussion
FMEA	Failure Mode and Effects Analysis
MCDM	Multi-Criteria Decision Making
OSC	Off-Site Construction
TOPSIS	Technique

LIST OF FIGURES

Figure 1.1 Research flowchart for the determination of dispute causes for off-site construction projects 7

Figure 4.1 Expert prequalification assessment procedure for FGD session and interviews (for questionnaires) 30

Figure 4.2 Sensitivity analysis for contractual dispute causes 50

Figure 4.3 Sensitivity analysis for financial dispute causes 51

Figure 4.4 Sensitivity analysis for technical dispute causes 51

Figure 4.5 Sensitivity analysis for managerial dispute causes 52

Figure 4.6 Sensitivity analysis for external dispute causes 52

LIST OF TABLES

Table 1.1 The novelty of the proposed study 5

Table 3.1 The dispute causes obtained from the literature review 17

Table 4.1 Expert profile (FGD session). 30

Table 4.2 Dispute causes for off-site construction projects 31

Table 4.3 The linguistic terms for Pythagorean fuzzy AHP [39] 377

Table 4.4 Expert profile 38

Table 4.5 Consistency Index analysis results for pair-wise comparison matrix ... 38

Table 4.6 Pythagorean fuzzy AHP analysis results for the calculation of weights of O, S, and D criteria 40

Table 4.7 Linguistic scale 41

Table 4.8 FTOPSIS analysis results for the analysis of importance level of factor groups 43

Table 4.9 FTOPSIS analysis results for the analysis of importance level of contractual dispute causes 43

Table 4.10 FTOPSIS analysis results for the analysis of importance level of financial dispute causes 45

Table 4.11 FTOPSIS analysis results for the analysis of importance level of technical dispute causes 46

Table 4.12 FTOPSIS analysis results for the analysis of importance level of managerial dispute causes 47

Table 4.13 FTOPSIS analysis results for the analysis of the importance level of external dispute causes 49

ABSTRACT

Identification of Dispute Causes in Off-Site Construction Projects

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Master of Science Thesis

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In recent years, the challenges faced by the construction industry have necessitated innovative methods due to the current period and the sources of raw materials. These challenges include low productivity, increased waste, unsafe working conditions, contributions to environmental pollution, failure to meet desired time and quality standards, and unpredictable cost increases. The increasing complexity of projects further exacerbates the difficulty in addressing these issues. Therefore, off-site construction has been developed as one of the methods to solve these problems. However, the lack of knowledge and standardization related to this innovative method causes industry professionals to be prejudiced against its implementation. This further complicates the adaptation process of this method. Disputes pave the way for the negative impact of industry problems on project success and are also one of the barriers to the industry's adaptation to off-site construction projects.

A review of the literature reveals that there are only three studies examining the causes of disputes in off-site construction projects. These studies used litigation

cases as data. However, disputes can be resolved before reaching the litigation process; therefore, these studies may not provide accurate information. It is essential to examine disputes within the scope of off-site construction projects, as they are one of the most critical factors for the success of a project. Hence, this study aims to identify the causes of disputes in off-site construction projects under five categories: contractual, financial, technical, managerial, and external, and determine the importance levels of these disputes.

The study employs methodologies such as Focus Group Discussion (FGD), Pythagorean fuzzy Analytical Hierarchy Process (AHP), and fuzzy Techniques for Order Performance by Similarity to Ideal Solution (TOPSIS). According to the analysis results, in the contractual factors group, C11 (Increase in contract value due to revision in scope of work) and C21 (Illegal and improper work suspension) are the most significant dispute causes. In the financial factors group, F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)) are the most important. In the technical factors group, T9 (Late completion, delivery, and installation of components) and T13 (Cost and time overruns) are critical. In the managerial factors group, M13 (Poor planning and management of the project) and M7 (Lack of information exchange) are significant, while in the external factors group, E3 (Economic factors such as changes in currency) and E18 (Credit tightening) are prominent. Additionally, when a ranking covering all categories within these five groups is made, contractual factors emerged as the most significant group, while F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)) stood out as the most important dispute causes for off-site construction projects. Subsequently, a sensitivity analysis was conducted to test the reliability of the analysis results. The findings indicate that the study's results are sufficient and satisfactory.

Keywords: Off-site construction, dispute causes.

ÖZET

Saha Dışı İnşaat Projelerinde Uyuşmazlık Nedenlerinin Belirlenmesi

Merve Pelinsu YILDIRAN

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Son yıllarda inşaat sektörünün yaşadığı sorunlar, yaşanılan dönem ve hammadde kaynakları açısından yenilikçi metotlara ihtiyaç duyulmasına neden olmaktadır. Bu sorunlara düşük verimlilik, atık artışı, güvenli olmayan çalışma ortamları, çevre kirliliğine katkı, istenilen zaman ve kalitede üretim yapılamaması, tahmin edilemeyen maliyet artışları örnek olarak gösterilebilir. Projelerin gittikçe karmaşıklaşması da bu sorunları çözmeyi zorlaştırmaktadır. Bu nedenle saha dışı inşaat, bu sorunlara çözüm olan metotlardan biri olarak geliştirilmiştir. Ancak, bu yenilikçi yöntemle ilgili bilgi ve standartlaşma eksikliği, sektör profesyonellerinin bu yöntemi uygulama konusunda önyargılı olmalarına neden olmaktadır. Bu da bu yöntemin adaptasyon sürecini daha da zorlaştırmaktadır. Anlaşmazlıklar ise sektörde yaşanan problemlerin proje başarısını olumsuz yönde etkilemesinin yolunu açmaktadır. Aynı zamanda sektörün saha dışı inşaat projelerine olan adaptasyonunun önündeki engellerden biridir.

Literatüre bakıldığında, saha dışı inşaat projelerindeki anlaşmazlık nedenlerini irdeleyen yalnızca üç çalışma olduğu görülmektedir. Bu çalışmalar veri olarak dava vakalarını kullanmışlardır. Ancak, anlaşmazlıklar dava sürecine gelmeden de

çözülebilmektedir; bu nedenle bu çalışmalar doğru bilgiye ulaşma açısından yeterli olmayabilir. Bir projenin başarısı için en önemli etmenlerden biri olan anlaşmazlıkların saha dışı inşaat projeleri kapsamında incelenmesi gerekmektedir. Dolayısıyla, bu çalışma, saha dışı inşaat projelerindeki anlaşmazlık nedenlerini sözleşmesel, finansal, teknik, yönetimsel ve dışsal olmak üzere beş kategori altında tespit ederek anlaşmazlıkların önem derecelerini belirlemeyi amaç edinmiştir.

Çalışmada metodoloji olarak FGD (Focus Group Discussion) tekniği, Pisagor bulanık AHP (Analytical Hierarchy Process) ve bulanık TOPSIS (Techniques for Order Performance by Similarity to Ideal Solution) kullanılmıştır. Analiz bulgularına göre sözleşmesel faktörler grubunda C11 (İş kapsamındaki revizyon nedeniyle sözleşme bedelindeki artış) ve C21 (Yasadışı ve uygunsuz iş durdurma), finansal faktörler grubunda F14 (Ek işler için yedek para bulunmaması) ve F3 (Ödemelerde gecikme(işveren kaynaklı)), teknik faktörler grubunda T9 (Bileşenlerin geç tamamlanması, teslimi ve montajı) ve T13 (Maliyet ve zaman aşımları), yönetimsel faktörler grubunda M13 (Projenin kötü planlanması ve yönetimi) ve M7 (Bilgi alışverişinin eksikliği), ve dışsal faktörler grubunda ise E3 (Ekonomik faktörler (para birimindeki değişim vb.)) ve E18 (Kredi sıkılaştırması) en önemli anlaşmazlık nedenleridir. Ayrıca, bu beş grubun içinde bütün kategorileri kapsayan bir sıralama yapıldığında da faktör gruplarından sözleşmesel olan en önemli grup iken faktörlerden F14 (Ek işler için yedek para bulunmaması) ve F3 (Ödemelerde gecikme(işveren kaynaklı) saha dışı inşaat projeleri için en önemli anlaşmazlık nedenleri olarak öne çıkmıştır. Ardından, analiz sonuçlarının güvenilirliğini test etmek amacıyla Duyarlılık Analizi yapılmıştır. Bulgular, çalışmanın sonuçlarının yeterli ve tatmin edici olduğunu göstermiştir.

Anahtar Kelimeler: Saha dışı inşaat, anlaşmazlık nedenleri.

1
INTRODUCTION

1.1 Background of The Search

In the construction sector, which has only improved its productivity by 1% over the past 20 years, issues such as cost overruns, project delays, and failure to achieve the desired quality are prevalent [1]. Despite being considered one of the most inefficient sectors globally, project owners in the construction industry demand the completion of projects in the shortest possible time, at lower costs, and with the highest quality. Current traditional construction methods and global conditions face challenges in meeting these demands. Additionally, over the years, problems such as low productivity, inefficiency, inadequate quality, trust issues, and lack of sustainability have become chronic in traditional construction methods. When considering productivity issues, the sector's fragmentation, disputes, lack of standardization, and resistance to digitalization must be addressed. Furthermore, the increase in labor costs due to a decline in skilled labor in recent years has made it difficult to utilize the workforce effectively. This problem, which also affects productivity, needs to be addressed.

As a solution to these issues within the sector, various construction methods have been developed. However, the construction industry is notoriously resistant to adopting new technologies and methods. One such innovative approach is the off-site construction (OSC) method [1]. In the OSC method, components of a structure, which can be partial or entire, are manufactured in factory conditions away from the construction site. These components are then transported under specific conditions to the project location, where they are assembled or installed [2]. Since the components in the OSC method are produced off-site, they are manufactured under more controlled conditions with a greater emphasis on quality standards. Additionally, the OSC method is considered more sustainable compared to traditional construction. It offers a safer environment for workers, reduces greenhouse gas emissions, requires less stringent on-site supervision, and generates

significantly less waste, presenting the idea of a green and modern construction industry [3] [4]. Furthermore, OSC is a construction method with higher added value compared to traditional construction. This is attributed to its incorporation of informatization, automation, process technologies, and other value-adding services [5]. Consequently, it allows for better monitoring [5].

Despite all these positive attributes, the OSC method is utilized at a very low level in the construction industry. Statistical studies based in Australia and the USA have shown that its contribution to the construction sector is only around 3%. In other words, although the OSC method has a positive impact on the construction sector, it either has not been sufficiently developed or its adoption still requires significant attention [4] [6]. In contrast to its low usage in the USA and Australia, China has mandated the use of OSC components to cover 30% of building components due to the positive contributions of OSC to the construction sector.

The construction industry requires the harmonious integration of diverse but interdependent components such as equipment, materials, and labor. However, these components are often provided by different stakeholders, leading to conflicts of interest among them. Consequently, disputes have become inevitable in the construction industry [7].

After COVID-19, the construction industry has been striving to contribute to the development of countries and to accelerate progress [8]. However, challenges related to inflation and supply chains are hindering this development and leading to disputes among stakeholders in the construction sector. Additionally, shortages of raw materials, declining stocks, political conflicts worldwide, and increasing energy prices are further exacerbating disputes. On the other hand, it has been reported in the Arcadis report that over the years, the resolution time for disputes is increasing and the number of disputes is at its highest levels. The longer it takes to resolve disputes, the more damage it can cause to companies. Consequently, companies may lose potential business opportunities, costs may increase, and tensions among stakeholders may reach an unsustainable level [7].

There are fundamental success criteria for the construction industry. One of the most prioritized criteria among these is the completion of a project within the specified time frame, estimated cost, and desired quality. Disputes, on the other

hand, are one of the major obstacles to the success of a project. As mentioned earlier, the increase in disputes has become inevitable [9]. It is stated that the increase in project complexity and differences in opinions among stakeholders lead to conflicts [9]. If these conflicts are not managed, it becomes inevitable for them to escalate into disputes. Resolving disputes is a time-consuming and costly process. Therefore, gaining knowledge about the causes of conflicts before they escalate into disputes is often used as an important method in conflict resolution [9]. The authors have noted that in the literature, disputes are generally addressed explicitly or synonymously with the terms conflict and claims. Disputes, however, are defined as disagreements among stakeholders that result in industrial actions. Conflicts can be addressed through conflict resolution processes before they turn into disputes. If they do become disputes, they are resolved through either litigation or alternative dispute resolution methods [9].

1.2 The Purpose of The Study

Considering its position in the construction sector, the adoption of OSC can be hindered by knowledge gaps, lack of regulations, and high initial costs [3]. As previously mentioned, OSC production takes place in a controlled environment away from the site. This necessitates multiple stakeholders to be involved in activities such as information sharing, transportation, and assembly. Nevertheless, the manufacturing procedures and assembly of OSC are challenging due to lengthy lead times, intricate protocols, and necessary permits [4]. On the other hand, risks, disputes, and conflict causes in OSC are different processes compared to traditional construction. As an illustration, the risks associated with OSC, such as joint design standards, quality control procedures for joints, component storage, and security measures, differ from those of conventional construction projects [3]. In addition to these factors, challenges such as delayed and non-sequential deliveries, fabrication mistakes, and disparities in fabrication rates between on-site erection operations, which have the potential to lead to disputes in OSC, differ from those encountered in conventional construction projects [2].

Construction contract templates created for on-site construction projects are adapted for use in off-site construction. However, in off-site construction projects, issues such as codes, risk insurance, product delivery, scheduling, and storage of

construction materials on the site are different from on-site construction projects. Additionally, different approaches are required to facilitate off-site construction practices compared to on-site projects. Tezel and Koskela [4] devised managerial recommendations to address the knowledge gap and facilitate the implementation of off-site construction in highway projects. Based on the authors' findings, further exploration is warranted regarding the requirement for an OSC system catalog demonstrating the usability of OSC components collectively; identification of crucial activities for schedule management; comprehension of component repeatability; tolerances and interfaces between on-site and off-site components; constructability; explicit OSC specifications; the need for collaboration among various contractors on-site; lifting planning; establishment of manufacturing facilities; quality control; and approval processes. Considering all these reasons, it can be seen that the primary causes of disputes and the significance level of dispute reasons in off-site construction projects may differ from those in on-site construction projects. Thus, effective prevention of disputes in off-site construction necessitates a thorough understanding of the underlying conditions, risks, and causal factors specific to these projects.

It is observed that there are relatively few studies focusing on identifying disputes in off-site construction projects. Nabi and El-adaway [10] identified causes of disputes in modular construction by analyzing litigation cases. In a separate study, Nabi and El-adaway [11] examined dispute causes in modular construction projects using national case studies. Chan et al. [12] explored contractual disputes in modular and off-site construction projects through litigation case analysis. However, the authors noted that "not all sources identified in the literature are present in litigation cases" [12]. Additionally, OSC serves as an umbrella term encompassing pre-fabrication, industrialized construction, modular construction, and prebuilt construction [13]. In light of this information, these studies may be misleading in identifying the reasons for disputes in off-site construction. This is due to the term "off-site construction" encompassing modular construction and the source of these studies being litigation cases. The reasons for disputes in off-site construction can be resolved before reaching the litigation process. Therefore, this study aimed to identify the reasons for disputes in off-site construction projects and prioritize these reasons by utilizing the knowledge and experience of professionals

in the construction industry. In the study, the reasons for off-site disputes were categorized into five categories: contractual, financial, technical, managerial, and external factors. The methodology involved a literature review to identify dispute causes, the Focus Group Discussion (FGD) technique to refine OSC dispute causes, and a hybrid approach combining Pythagorean fuzzy AHP and fuzzy TOPSIS to determine the priority order of OSC dispute causes.

For effective prevention and management of contractual, financial, technical, operational, and external dispute causes in OSC projects, comprehending both its theoretical and practical contributions is essential. This study theoretically contributes to facilitating the smooth adoption and implementation of OSC. Furthermore, it addresses the existing knowledge gap in OSC methodology. The findings of this study will enhance the understanding and knowledge related to OSC. The practical contribution of the study lies in the results serving as a checklist to prevent disputes in the addressed five categories, filling in the gaps in contract templates, and assisting in selecting dispute resolution methods.

Table 1.1 The novelty of the proposed study

	Chan et al. [12]	Nabi and El-adaway [11]	Nabi and El-adaway [10]	The novelty of the proposed study
Identification of dispute causes (source)	Literature review + litigation cases	Literature review + litigation cases	Litigation cases	Literature review + Focus Group Discussion
Availability of dispute causes from on-site construction projects	Yes	Yes	No	Yes
Data collection source	Litigation cases	Litigation cases	Litigation cases	Questionnaire
Construction method	Off-site construction and modular construction	Modular construction	Modular construction	Off-site construction
The number of identified dispute causes	62	28	40	132
Focus	Contractual disputes	Mixed (without categorization)	Mixed (without categorization)	Contractual, financial, technical, managerial and external disputes

Table 1.2 The novelty of the proposed study (continued…)

	Chan et al. [10]	Nabi and El-adaway [9]	Nabi and El-adaway [8]	The novelty of the proposed study
Methodology	Fishbone method	SNA method	SNA method	Pythagorean Fuzzy AHP integrated Fuzzy TOPSIS

1.3 The Methodology of The Study

In this study, multiple research methods were employed to conduct effective and innovative research. Initially, a comprehensive literature review was carried out to establish a solid foundation for the research, and a data set was created. The dispute causes obtained from the literature was selected from both national and international studies. Based on the information obtained from the literature, off-site construction was categorized into five groups: contractual, financial, technical, managerial, and external, and the research continued accordingly.

Subsequently, the Focus Group Discussion (FGD) method was used to evaluate the data set by leveraging the experiences of professionals in the industry. Professionals from Türkiye were asked if there were any additional dispute causes, they wanted to include while assessing the reasons for disputes. This approach grounded the research more firmly in both literature and industry insights.

To reach the final conclusion of the study, the appropriate Multi-Criteria Decision-Making (MCDM) methods were selected and applied. Therefore, to identify the causes of disputes in off-site construction projects and as an innovative approach, the Pythagorean Fuzzy AHP integrated Fuzzy TOPSIS hybrid approach was applied to conclude the study. The classical AHP is used to determine the importance levels of criteria. However, since the method requires precise and definite data, Pythagorean Fuzzy AHP was employed to make the method more flexible and sensitive to uncertainties [14]. Additionally, as dispute causes are considered risks that impact the success of construction projects, the FMEA approach was used as a risk assessment tool. The data for the research was obtained from 17 experts. The study evaluated the FMEA criteria and the groups of dispute causes in matrices to determine their importance rankings. Moreover, the dispute

causes grouped under “contractual disputes,” “financial disputes,” “technical disputes,” “managerial disputes,” and “external disputes” were evaluated based on the “O,” “S,” and “D” criteria using the Fuzzy TOPSIS method to determine their importance rankings. Thus, the study achieved its objectives by using a broad data set and different methods. Research flowchart can be seen in Figure 1.1

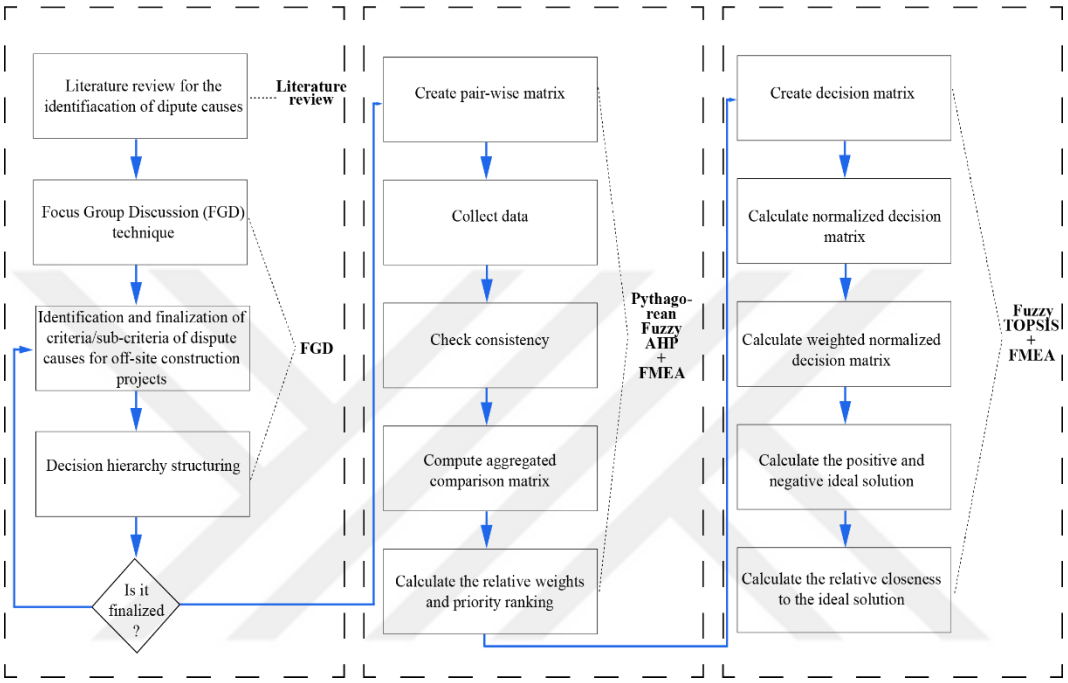

Figure 1.1 Research flowchart for the determination of dispute causes for off-site construction projects

1.4 The Limitation of The Study

In the study, data was collected from Turkey (a developing country), which holds significant economic importance and where the construction sector makes substantial contributions to the national GDP. An increase in construction practices, incorporating both traditional and innovative methods, has been observed in the country. The rise in the use of off-site construction is associated with the economic crisis, earthquakes, and population growth due to migration. The study's results should focus on the differences between developed and developing countries. Another limitation is that the study does not take into account the differences in stakeholder perspectives.

2
OFF-SITE CONSTRUCTION

2.1 The Definition of Off-Site Construction

In recent years, there has been a significant depletion of natural resources and raw material sources, leading to increased environmental problems. Sectors with high energy consumption particularly contribute to this rise in issues. For instance, globally, the construction sector consumes 40% of total energy production, 12-16% of water resources, 32% of renewable and non-renewable resources, 25% of all timber, and 40% of all raw materials; it generates 30-40% of solid wastes and emits 35-40% of CO2 emissions into the atmosphere [15]. Rapid migration from rural to urban areas results in inadequate building stock in cities, perpetuating the need for large-scale housing construction projects in urban areas. Consequently, the environmental impacts of building stock due to rapid urbanization could further escalate. Moreover, the labor-intensive nature of traditional construction impedes rapid responses to increasing housing demands [15].

Components of buildings are manufactured in a controlled environment away from the construction site, and then these prefabricated components are transported to the project site for assembly. This method is referred to as "off-site construction." Prefabricated buildings, modular construction, and precast construction are all included within the scope of off-site construction.

The method by which building components are prefabricated is defined as prefabrication, and the degree to which these components are used in a structure reflects the extent to which the off-site construction technique is adopted. In this process, building elements are pre-fabricated in the factory and then transported to the construction site for assembly. This allows the construction process to be largely controlled and pre-planned.

Components of the structure produced by this method are beams, columns, slabs, stairs, panel elements, and full-volume modules. These elements are fundamental

building blocks of the structure, prefabricated in advance using prefabrication construction methods and later used for assembly [16].

Off-site construction is divided into two main categories: volumetric and non-volumetric off-site construction. The method of prefabricating columns, beams, slabs, and wall panels is termed as non-volumetric off-site construction, whereas the modular production of buildings or components is referred to as volumetric off-site construction.

Prefabrication, industrialized construction, modular construction, or pre-built construction terms can be used interchangeably with off-site construction. While there are subtle differences among these terms as noted by Jang et al. [13], some researchers [16] use them interchangeably.

2.2 The History of Off-Site Construction

The earliest examples of off-site construction date back to 1624, when components were transported from the United Kingdom to America. The off-site construction method has been documented to enhance quality, increase structural reliability, improve productivity, shorten construction time, and reduce labor and material waste compared to traditional on-site construction methods [6]. Moreover, off-site construction contributes significantly to the sustainability of buildings due to providing numerous environmental and social benefits. The controlled environment in which components are manufactured ensures healthier and safer working conditions compared to traditional construction. According to studies on the advantages of off-site construction, it results in a 34% reduction in embodied carbon, a 74% reduction in construction waste, up to 58% cost savings, and a 30% reduction in labor requirements [15].

Despite these various advantages of off-site construction, its use is still very limited. Off-site construction accounts for only 3% of the construction industry in Australia. In the US, it accounted for between 2-3% of new single-family homes and less than 1% of new multi-family homes in the period 2000-2014 [6]. For the construction industry, which is highly biased towards new technologies, it is difficult to increase the use of a relatively new method such as off-site construction. It is assumed that this bias is also caused by a lack of knowledge. For this reason, there has been an

increase in research on off-site construction in recent years in order to increase knowledge about this method, which has many contributions to the environment and sustainability. therefore, this thesis aims to contribute to the body of knowledge by investigating the causes of disputes in off-site construction.

When examining research on off-site construction activities in Türkiye, it is observed that studies mainly focus on the prefabrication production method under the umbrella of off-site construction. A 2020 study indicated that the use of prefabrication in Türkiye first appeared in 1955 with the production of concrete poles and began to be used in industrial buildings starting in 1965 [17]. Additionally, the level of development of countries, the needs of the time, and socio-economic conditions were noted to influence the use of prefabrication. In Türkiye, prefabricated building systems are predominantly used in industrial structures, resulting in the share of concrete prefabrication in industrial buildings reaching up to 85%. There are significant concerns regarding the use of prefabrication products in residential buildings in Türkiye, largely due to the country's location in an earthquake zone. However, studies have demonstrated that well-designed systems can be durable. As of today, the concrete prefabrication industry in Türkiye has the capacity to produce structures of various heights, transportation infrastructure elements, and environmental landscaping components [17]. While prefabricated systems constitute 25% of the construction sector in the European Union, their share is only 8% in Türkiye [17].

Despite its many advantages of prefabrication, a study aimed to uncover the reasons why prefabricated systems are used much less in Türkiye compared to European countries conducted surveys with three main groups: architects, manufacturers, and contractors. According to the study's results, architects identified the lack of periodical meetings among stakeholders, absence of technically skilled trained laborers, improper transportation methods, and failure to take into consideration the movement of cranes on the construction site as the most significant barriers to the use of prefabricated construction systems. Meanwhile, manufacturers pointed out inadequate flow of information among the stakeholders, inadequate quality and dimensions of the aggregate, failure to adhere to the schedule, and lack of technical experience among employees who control the installations of prefabricated components as key factors. Lastly, contractors saw insufficient flow of information

among the construction stakeholders, absence of technically skilled trained laborers, improper transportation methods, and failure to audit the installations within the scope of the quality control plan as the most important obstacles to the use of prefabricated construction systems [18]. Additionally, the study mentioned that the biggest reason for the limited use of prefabricated construction systems in Türkiye is the lack of specialized architects, engineers, and workers in this field [18].

In China, where off-site construction projects are more prevalent, an emergency hospital was completed using modular construction methods in just 10 days during the pandemic [19]. The collaboration among the teams working on the Huoshenshan Hospital and the remarkably short construction phase are notable aspects of this project. Additionally, it is mentioned that the government provided necessary financial support and oversaw the safety, quality, and schedule of the project to ensure its timely completion [19]. Meanwhile, there is also a higher concentration of off-site construction projects in Europe. In the UK, modular construction has been increasingly utilized to address the growing housing shortage [20]. Similarly, in Germany, a company specializing in prefabricated homes reportedly increased its turnover by 20% in 2020, with expectations of even greater growth in subsequent years [21]. The reason countries like Japan, China, Singapore, Hong Kong, and the UK have maintained certain levels of off-site construction is due to government support [22]. Moreover, the rising demand for affordable housing has also contributed to the growing interest in this construction method. Considering all of this, it can be seen that an increase in the use of off-site construction methods in Türkiye would have a positive impact on the sector dynamics.

3
DISPUTES IN OFF-SITE CONSTRUCTION

3.1 Disputes in Construction Industry

Construction projects involve significant expenditures, specific materials, and equipment, integrating various fields of expertise. The primary objective of every successful project is to complete it within the scheduled time, estimated cost, and desired quality. The construction sector encompasses stakeholders with diverse expertise in different domains, each having their own demands, interests, and objectives. When these factors converge, conflicts become inevitable.

While exploring the definition of dispute, terms such as conflict and claim are encountered. Although these terms have different meanings, they are sometimes used interchangeably. Conflict can be defined as a distinct separation or disagreement between two or more beliefs, ideas, or interests [23]. In the construction sector, conflict refers to the contradiction of interests, values, or actions among different parties, leading to conflicts when one party perceives its position to be threatened. Unlike conflicts, which can be resolved without the need for a prolonged resolution process like disputes, disputes refer to extended disagreements over unresolved claims or enduring unresolved or destructive conflicts [24]. If left unresolved, conflicts can escalate into disputes, directly impacting project success and necessitating the involvement of a third party when resolution cannot be reached between the two parties. Additionally, resolving disputes can be a lengthy process in itself, potentially placing the project in a financially challenging situation.

In addition, for a dispute to arise, there must be conflicts among participants and one party must make a claim that the other party does not accept. There is no definitive rule that claims will create negativity. When a satisfactory agreement is reached on a claim, necessary adjustments are made in the contract and the issue is resolved before it escalates. However, if parties fail to reach a satisfactory compromise, the claim is addressed through negotiation, mediation, arbitration, or

litigation, which can turn into a dispute adversely affecting the construction project and participant relationships. Resolving claims satisfactorily is a common practice in the construction sector yet disputes frequently arise [23].

As can be understood from the definition of dispute, resolving problems at the conflict and claim stage would be more advantageous for the project process. Otherwise, dispute resolution is a process that takes time, affects costs, causes delays in project timelines, leads to irreversible issues among stakeholders, and results in decreases in both project quality and workforce morale.

There are numerous studies on this subject that significantly impact project success. Research has been conducted on the causes of disputes, resolution processes, and management styles in construction projects. There are many studies in the construction sector that examine the reasons for disputes and the project characteristics that lead to their occurrence. In 2021, Tanrıverdi et al. suggested that existing studies are insufficient in understanding how dispute causes combine to form disputes and examined the reasons for disputes and their relationships using a Causal Mapping approach. The study was conducted based on information gathered from Turkish experts. In the research, the causes of disputes were categorized into three groups: process, project, and people-based, further subdivided into subgroups. According to the analysis results of the study, "delays by contractor" and "errors in concept design and planning" were identified as the highest-ranking dispute causes [25]. In another study examining the causes of disputes and their interrelationships, judicial judgments were collected. The research utilized 65 legal cases, categorizing the reasons for disputes under 8 main factors. According to the study's findings, there is a strong correlation between poor performance-related issues and payment-related problems as causes of disputes [26].

In a study conducted in 2020 in the United Arab Emirates, researchers aimed to evaluate the causes of disputes and the effectiveness of resolution methods in what is acknowledged as one of the most dynamic construction sectors globally. The study involved sending surveys to 150 construction professionals to gather information. According to the study's findings, the five most significant causes of disputes in the United Arab Emirates were variations initiated by the owner, obtaining permits/approvals from municipal and other governmental authorities, changes in materials and approvals during the construction phase, delays caused by

the owner's slow decision-making process, and the limited time available during the design phase [27]. The study also concluded that negotiation is an effective method for resolving these disputes.

In another study focused on Sri Lanka, a country purported to host many foreign investors and mega government projects, researchers examined the causes of disputes in the Sri Lankan construction sector, factors influencing the selection of dispute resolution methods, and identified the most effective alternative dispute resolution method. The study aimed to determine these aspects comprehensively. According to the study's findings, the most significant cause of disputes in Sri Lanka's construction sector was identified as 'failure to administer the contract' [28]. Regarding the selection of alternative dispute resolution methods, the study revealed that the most critical factor influencing this choice was the settlement time [28].

In a study conducted in 2016 to examine the causes of disputes in the Turkish construction sector, focusing on public sector projects, several key findings were highlighted. The analysis categorized disputes into 7 main categories: unit prices, delays and extension of time, contractual matters, variations, contract documents, payments, and other disputes [24]. Under each category, specific causes of disputes were identified and examined. Project implementers believed that by considering these causes of disputes, they could effectively prevent disputes from arising.

3.2 Disputes in Off-Site Construction Industry

As mentioned earlier, off-site construction projects are considered a relatively new method in the construction sector. The lack of information about this method also leads to biases within the industry. Therefore, evaluating disputes directly affecting project success within the scope of off-site construction and increasing knowledge levels is expected to break down practitioners' prejudices toward this method. Hence, studies investigating the causes of disputes in off-site construction projects were primarily reviewed in the literature. However, it is observed that there are relatively few studies on this topic in the literature.

Chan et al. [12] conducted a study focusing on dispute causes in off-site construction projects, considering contract-based factors. The authors conducted a

detailed literature review without distinguishing between on-site and off-site construction contracts. Following this study, they categorized and weighted dispute causes by examining Canadian Supreme Court cases related to this topic over the past 20 years. As a result of this research, similarities and differences between real cases and the literature were identified. Subsequently, based on insights from both cases and literature, they categorized contract-based disputes into five categories: language, contract, design, stakeholders, and external factors. Thus, the authors identified 14 new dispute causes specific to off-site projects that were previously absent in the literature, such as uncertain payment terms, procedures, certification, ambiguous conditions for site changes, and poorly defined general provisions.

Nabi and El-adaway [10] conducted an analysis of disputes in modular construction projects by examining court cases identified through Case Law Google Scholar. They scrutinized thirty-nine dispute cases (legal cases) for this purpose. From their analysis, they identified forty dispute causes. Additionally, the authors employed Social Network Analysis (SNA) to uncover both the most prevalent dispute causes and the network of these causes. "Payment delays and defaults," "lack of collaboration among various project segments," "project completion delays," and "poor communication among project participants" were identified as the most common dispute causes resulting from their study.

Subsequently, in another study, Nabi and El-adaway [11] aimed to determine dispute causes in modular construction projects. In this research, they combined case study and social network analysis methods. Considering both traditional and modular construction projects, the authors investigated 28 common dispute causes. They then analyzed dispute causes from publicly available sources. Their case study findings helped uncover the dispute causes, revealing that "delays in work progress," "communication deficiencies," and "lack of team spirit" are fundamental dispute causes in modular construction.

Research in the literature on the causes of disputes in off-site construction projects has primarily focused on court cases. However, disputes can often be resolved without reaching the litigation stage. Therefore, to conduct a comprehensive investigation for this thesis, dispute causes from both traditional and off-site construction projects in the literature were examined and categorized into five main

factor groups. These factor groups were identified as contractual, financial, technical, managerial, and external.

3.3 Literature Review Results For Disputes

Off-site construction, which is still in its infancy in the construction industry, is much newer compared to on-site construction. As a result, it has not yet been fully embraced by industry professionals. However, this method is believed to bring a new perspective to the industry. Off-site construction, which is carried out in a safer environment compared to traditional construction, is seen to increase efficiency and contribute to sustainability in an industry where raw material shortages are prominent. It also provides a safer environment for workers. Nevertheless, considering that this method is new, the available information is quite limited. Additionally, the standardization efforts on policies and guidelines for this method are not yet at the level of traditional construction. As Jang et al. [13] noted, the flexibility offered by off-site construction can lead to specific risks in projects. For example, any issues in transporting the components to the site can cause disruptions in the work process, additional labor, and increased costs. Therefore, to mitigate the negative impacts arising from this flexibility, project management practices need to be managed and executed differently from traditional construction projects.

Hosseini et al. [6] argued that the reason for the underdeveloped, small, immature, and slow nature of the off-site construction sector, compared to traditional construction, is the lack of knowledge. The high level of knowledge deficiency in off-site projects is also evident in the research on the causes of disputes. As seen in the literature review on this topic, there are only three studies. Chan [12] aimed to identify contractual dispute causes specific to modular and off-site construction projects. Nabi and El-adaway [10] identified the causes of disputes for modular construction using case law. In these studies, case law was used as the data source. However, relying solely on case law may not be sufficient to resolve and identify dispute causes, as some disputes need to be resolved before entering a lengthy and exhausting litigation process. Considering all these factors, this study included a survey method to gather data by obtaining the views and opinions of professionals in the construction industry. It was believed that this method could uncover all potential dispute causes. In this study, the dispute causes obtained from the

literature review were categorized and examined under five categories: financial, contractual, technical, managerial, and external causes. The details of the study are presented in Table 3.1.

Table 3.1 The dispute causes obtained from the literature review

Dispute Causes	References
Contractual Dispute Causes	
Risk allocation	[9] [10] [11] [28] [29] [30] [31]
Ambiguities in bidding	[9] [10] [25] [32] [33]
Changes of scope	[9] [10] [11] [26] [27] [29] [30] [31] [34]
Poor contract documentation	[12] [26] [32] [33]
Misrepresentation of contract documents	[12]
Noncompliance to contracts terms	[11] [32] [33]
Ambiguities in contracts	[9] [10] [11] [12] [24] [25] [26] [27] [29] [30] [31] [33] [34]
Poor defined general provisions	[12]
Mismatch contract type	[11] [12] [29]
Linguistic challanges	[12]
Ambiguities in contract clauses	[12] [25] [27] [28] [32] [34]
Increase in contract value due to revision in scope of work	[34]
Excessive contractual variations	[12]
Failure to examine contract conditions at the time of tender	[30] [31]
Errors and omissions of contract terms	[24] [28] [30] [31]
Legal text layout	[12]
Problems of terminology	[12] [27]
Ineffective contract management & administration	[12] [28] [29]
Unclear method to reduce the delay damages	[31]
Unclear definition and types of defects	[31]
Complexity in contract provisions	[9] [10] [11] [12] [24] [27] [28] [29] [31] [32]
Unlawfull and improper stop work	[11] [12] [34]
Opportunistic behaviour of project parties	[11] [28] [34]
Breach of warranty claims	[11] [12] [26]
Non-practical conditions	[12]
Redundant information	[12]
Financial Dispute Causes	
Disagreement on payment method caused by variation of quantities	[24] [31]
Financial failure or inadequacy of contractor	[9] [10] [11] [27] [29] [30] [31] [33] [34]
Payment delays (owner based)	[9] [10] [11] [24] [27] [29] [30] [31] [32] [33] [34]
Adamant non payment	[26]
Disagreement of the compensation amount	[31]
Deductions	[26]
Delays in compensation	[26]
Denial of compensation	[26]

Table 3.1 The dispute causes obtained from the literature review (continued…)

Dispute Causes	**References**
Insufficient financial planning	[25]
Loss to the client	[35]
Non releasing of deposits	[26]
Payment delays (contractor based such as delays in submitting progress payment claims, errors and insufficiency in submitted documents)	[11]
Inadequate or delayed project funding	[11]
Non-availability of spare money for additional work	[33]
The low-profit margin	[36]
Too much inference from client	[32]
Unfair compensation	[26]
Untimely contractual payment	[34]
Insufficient coverage of design liability insurance	[12]
Technical Dispute Causes	
Lack of experience	[12] [24] [25] [27] [28] [32] [33]
Unavailability of materials	[33]
Material testing technique	[25]
Material/modules double-handling	[12]
Lack of quality management	[9] [10] [12] [25] [26] [27] [28] [29] [30] [31] [32]
Interfacing defects	[11] [12]
Poor risk management	[12] [28] [32]
Project uncertainty (insufficient details etc.)	[9] [10] [11] [12] [25] [27] [28] [29] [30] [31] [32] [33] [34]
Complexity of project	[12] [25] [32]
Late completion, delivery and installation of modules	[11]
Availability/Incompletion of information	[9] [10] [25] [29] [30] [34]
Project revisions	[11] [12] [24]
Lack of advanced technology	[32]
Cost and time overruns	[9] [10] [11] [24] [26] [30] [32] [34]
Unlikely industry readiness	[12]
Need for systematic design of fault-tolerant systems	[12]
Difference in construction technique	[25]
Noncompliance to the design requirements	[33] [34]
Inadequate knowledge in governing regulations	[12]
Slowness of the contractor's decision-making process	[11]
Time limitation in the design phase	[27]
Technical inadequacy of the contractor	[9] [10] [27] [29] [30] [33]
Delivering defective modules	[11]
Design libraries and automation	[12]
Design limitations (shipment method)	[12]
Design standardization	[12]
Late notification of technical changes	[32]

Table 3.1 The dispute causes obtained from the literature review (continued…)

Dispute Causes	**References**
Site conditions	[9] [10] [11] [12] [25] [27] [29] [30] [32]
Changes incorporated apart from contractual agreements (inc. design)	[9] [10] [11] [24] [25] [26] [27]
Delayed design information or drawings	[11] [12]
Managerial Dispute Causes	
Poor management skills	[27] [32] [34]
Request for acceleration of works	[9] [10] [11] [30] [31] [32]
Delays in approvals	[11] [12] [26] [31] [33]
Unrealistic expectations	[9] [10] [12] [25] [29] [30] [31] [32] [34]
Lack of professionalism	[11] [29]
Dispute resolution methods	[11] [12] [25] [32]
Lack of information exchange	[11] [32]
Unfamilarity with local conditions	[25]
Cultural differences	[12] [27] [32]
Lack of communication	[9] [10] [11] [27] [28] [29] [30] [32] [34]
Lack of collaboration	[9] [10] [11] [28] [30] [32] [34]
Poor negotiation skills	[28] [32] [34]
Poor coordinattion of construction activity	[28] [32]
Poor planning and managing of the project	[12] [27] [28] [29] [32] [33] [34]
Coordination intensity (Lack of involvement of inputs from all groups)	[12] [25] [32]
Late giving of possesion	[9] [10] [25] [26] [30] [31]
Time extensions	[9] [10] [11] [24] [30] [31] [32] [33] [34]
Unsatisfiable salary	[34]
Human behaviour related	[9] [10] [27] [28] [30] [32] [34]
Lack of construction ethics	[32]
Poor progress measurements by the contractor	[32]
Slowness of the owner's decision-making process	[11] [27] [33]
Needs effective supply chain management	[12] [31]
The ability to manage the customers' expectations/the process	[36]
Unclear instructions or fails to issue instructions in time by architects and engineers	[34]
Variations initiated by the owner	[9] [10] [11] [27] [30] [34]
Diversity of working style among parties	[34]
Labor union related issues	[11]
Lack of progress report and meeting	[32]
Not following project specifications	[9] [10] [11] [27] [30] [33] [34]
External Dispute Causes	
Government processes bureaucracy/approvals	[11] [25] [27] [32]
Disasters	[10] [25] [28] [31] [32]
Economic factors (change in currency etc.)	[9] [10] [29] [30] [31] [33]
Political interest	[36]

Table 3.1 The dispute causes obtained from the literature review (continued…)

Dispute Causes	References
Changes in laws and regulations	[31]
Country security problems, language barriers, different cultural traditions, and religious backgrounds	[31]
Impact on locality in terms of noise, traffic, and pollution/contamination	[27]
Tower crane lifting limit	[12]
Transportation insurance coverage	[12]
Unfamiliarity with project geographical condition	[31]
Taxation issue	[31]
Weather	[9] [10] [25] [27] [28] [30] [31] [32] [34]
State of sector	[10] [28] [30] [33] [34]
Building code for offsite construction	[9] [11] [12] [25] [27] [28] [31]
The legal system incompatible with the dispute resolution procedures in the contract	[31]
Lack of legal awareness	[30] [34]
The complexity of the expressions in the law	[10] [12] [29]
Contradiction among legal provisions	[12]
Lack of awareness about the legal aid effect	[36]
Transport restrictions	[12] [33]
Credit tightening	[31]
Increase interest rates for compensation	[26]
Inferences with utility lines	[25]

To describe the dispute causes listed in five categories in Table 3.5, starting with contractual dispute causes, "Risk allocation" refers to how the risks associated with the work are distributed between the parties. "Ambiguities in bidding" highlights uncertainties during the bidding process. "Changes of scope" refers to the disputes that may arise from changes in the contract scope. "Poor contract documentation" refers to the inadequate or incomplete documentation of contracts. "Misrepresentation of contract documents" refers to disputes arising from the presentation of contract documents to the parties. "Noncompliance to contract terms" is defined as a dispute arising from the parties' failure to adhere to contract terms. "Ambiguities in contracts" refers to unclear or ambiguous terms within a contract. "Poorly defined general provisions" indicates that the general provisions of a contract are not clearly defined. "Mismatch of contract type" occurs when the contract type does not match the nature of the work, leading to disputes. "Linguistic challenges" refers to difficulties in understanding and translating the language used

in the contract. "Ambiguities in contract clauses" refers to disputes caused by the selection of incorrect wording in contract clauses. "Increase in contract value due to revision in scope of work" refers to the change in contract value resulting from scope changes, a common occurrence in construction projects [37]. "Excessive contractual variations" refers to a large number of or extensive changes made in a contract. "Failure to examine contract conditions at the time of tender" refers to disputes arising from the inability to fully understand contract conditions during the bidding phase. "Errors and omissions of contract terms" discribes mistakes and omissions in the terms of a contract. "Legal text layout" indicates that contracts should be structured according to the format appropriate for legal texts [38]. "Problems of terminology" refers to disputes caused by incorrect definition of terms related to the work. "Ineffective contract management & administration" refers to an inadequate or ineffective approach in the management and administration of contracts. "Unclear method to reduce the delay damages" refers to the situation where methods used to mitigate delay damages are not clearly or effectively defined. "Unclear definition and types of defects" refers to a situation where defects (such as errors in construction projects or products) are not clearly defined or categorized. "Complexity in contract provisions" refers to the difficulty in understanding, applying, or interpreting contract provisions. "Unlawful and improper stop work" refers to the cessation of work in a manner that violates contract terms. "Opportunistic behavior of project parties" discribes the parties' exploitation of contract terms to maximize their own interests. "Breach of warranty claims" refers to a situation where a product or service fails to meet the standards, performance, or specifications outlined under the warranty. "Non-practical conditions" refers to conditions that are difficult to implement or fulfill or are not suitable for real-world circumstances. "Redundant information" refers to information that is repetitive, excessive, or unnecessary in a specific context or document.

One of the causes of financial disputes “Disagreement on payment method caused by variation of quantities” refers to conflicts arising from changes in the quantities specified in projects or contracts, leading to disputes over payment methods. “Financial failure or inadequacy of contractor” describes a situation where a contractor experiences financial failure or inadequacies. “Payment delays (owner

based)" defines lateness as the failure to make payments on time due to the employer. "Adamant non-payment" indicates a party's firm and unyielding refusal to make a payment. "Disagreement of the compensation amount" involves disputes regarding the amount and scope of compensation in response to issues or delays in a construction project. "Deductions" refers to reductions made from a specific amount or the total sum. "Delays in compensation" means that compensation payments are not made within the planned or expected timeframe. "Denial of compensation" refers to the rejection of a claim for compensation for damage, loss, or injury. "Insufficient financial planning" refers to the lack of detailed and effective financial planning for a project, business, or personal finances. "Loss to the client" denotes the financial or non-financial losses incurred by a client or employer due to a project, service, or product. "Non-releasing of deposits" describes the failure to return prepaid deposits upon completion of a transaction, contract, or project, or upon fulfillment of specific conditions. "Payment delays (contractor based such as delays in submitting progress payment claims, errors and insufficiency in submitted documents)" refers to delays in making progress payments at designated project stages. "Inadequate or delayed project funding" involves providing the financial resources required for a project's execution. "Non-availability of spare money for additional work " denotes additional or reserved financial resources allocated for extra work, changes, or unforeseen costs within a project or job. "The low-profit margin" refers to a low difference (profit) between the revenue and costs of a business or project [39]. "Too much inference from client" indicates excessive input or interference by a client in a project or job. "Unfair compensation" describes a situation where a person or party receives inadequate or inappropriate compensation for their damage, loss, or work. "Untimely contractual payment" means that payments required under a contract are not made on the specified dates or within the agreed timeframe. "Insufficient coverage of design liability insurance" describes a situation where a design or engineering project's insurance does not adequately cover potential financial liabilities arising from errors or omissions [40].

Among the technical causes of disputes, "Lack of experience" indicates that an organization does not have sufficient experience in a particular task. "Unavailability of materials" refers to situations where the required materials are not available.

“Material testing technique” encompasses the methods or procedures used to evaluate various properties, durability, reliability, and performance of materials. “Material/modules double-handling” occurs when materials or modules need to be moved from one location to another and then relocated again. “Lack of quality management” reflects an organization's or project's failure to establish, monitor, and improve quality standards, or the absence of adequate systems and processes for these purposes. “Interfacing defects” involve errors or issues that arise in the interactions between different systems, components, or processes. “Poor risk management” is the failure to anticipate potential risks, take appropriate measures, or manage risks effectively. “Project uncertainty (insufficient details, etc.)” signifies the lack of sufficient information or detail about various aspects of a project. “Complexity of project” describes the degree of difficulty, detail, and interaction encountered in executing a project. “Late completion, delivery, and installation of modules” points to the processes of completing, delivering, and installing certain modules occurring later than planned. “Availability/Incompletion of information” refers to the absence or incompleteness of the necessary information for a project or process. “Project revisions” cover the changes or updates made to a project’s plan, design, or other key documents. “Lack of advanced technology” highlights the absence of modern and advanced technologies required by an organization, project, or process. “Cost and time overruns” indicate that a project has exceeded its allocated budget and timeline. “Unlikely industry readiness” refers to a situation where a specific industry is not adequately prepared in terms of technology, infrastructure, or other necessary resources. “Need for systematic design of fault-tolerant systems” emphasizes the requirement for a structured and planned design process to ensure that a system is resilient and reliable against failures. “Difference in construction technique” includes variations in the design of structures, construction processes, materials used, and methods applied, therefore, it may lead to the contractor being insufficiently effective in this job. “Noncompliance to the design requirements” denotes the failure to meet the design specifications or standards established during the design phase of a project or product. “Inadequate knowledge in governing regulations” reflects an organization's insufficient understanding of applicable laws, regulations, or standards. “Slowness of the contractor's decision-making process” could negatively impact project progress, timelines, and overall efficiency. “Time limitation in the

design phase" refers to constraints related to a specific timeframe in the design phase or insufficient time allocated for completing the design process. "Technical inadequacy of the contractor" signifies a contractor's lack of sufficient technical knowledge, skills, or experience. "Delivering defective modules" points to the provision of modules that have not passed quality control or are defective. "Design libraries and automation" pertain to predefined components, standards, and tools (design libraries) used in design processes and issues related to the automation of these processes [41]. "Design limitations (shipment method)" can affect the safety, efficiency, and cost of a product's shipment. "Design standardization" involves the application of specific standards and norms in design processes and outcomes [42]. "Late notification of technical changes" describes the situation where technical changes made during the project are communicated to the relevant parties after the stipulated or necessary time. "Site conditions" include factors such as terrain structure, soil type, weather conditions, existing infrastructure, and other environmental considerations. "Changes incorporated apart from contractual agreements (inc. design)" refers to changes implemented in the project or execution that were not included in the contract terms or design documents. "Delayed design information or drawings" denotes the failure to provide the necessary design information or drawings within the required timeframe for a project.

In the context of managerial dispute causes, "Poor management skills" refers to an individual's or group's inadequacies in effective leadership, planning, organization, direction, and control. "Request for acceleration of works" is made to compensate for delays in the project, meet deadlines, or achieve certain goals faster. "Delays in approvals" occur when necessary authorizations, permits, or approval documents are not obtained in a timely manner within a project or process. "Unrealistic expectations" refer to targets or expectations in a project, task, or situation that are impractically optimistic or not feasible. "Lack of professionalism" describes the failure of an individual or organization to adhere to professional standards and ethical conduct in their work, communication, and overall behavior. "Dispute resolution methods" encompass various techniques used to resolve conflicts or disputes between parties. "Lack of information exchange" arises when necessary information is not adequately shared between parties in a project or process. "Unfamiliarity with local conditions" describes a situation where an individual or

organization lacks sufficient knowledge of the characteristics and conditions of a specific region or local environment. “Cultural differences” highlight the variations in cultural norms, values, beliefs, traditions, and practices among different societies, groups, or individuals. “Lack of communication” occurs when there is insufficient or ineffective exchange of necessary information between individuals, teams, or organizations. “Lack of collaboration” refers to the absence of cooperative work, information sharing, and coordination among individuals, teams, or organizations. “Poor negotiation skills” indicate an individual's or group's ineffectiveness in resolving disputes, reaching agreements, or making compromises on various matters. “Poor coordination of construction activity” refers to the ineffective organization of various activities, processes, and resources in construction projects. “Poor planning and managing of the project” signifies the inadequate planning and management of a project. “Coordination intensity (Lack of involvement of inputs from all groups)” indicates a situation where the contributions and feedback from all stakeholders, groups, or individuals involved in a project or process are not sufficiently considered. “Late giving of possession” refers to the delayed transfer of ownership or usage rights of a project or property beyond the stipulated or contractual date. “Time extensions” involve the extension of the completion time for a project or task beyond the originally specified period. “Unsatisfactory salary” describes a situation where the salary for a position or role is not deemed satisfactory considering the duties, responsibilities, or market standards. “Human behavior related” issues concern the influence of individuals' or groups' behaviors, attitudes, and interactions on a particular matter or situation. “Lack of construction ethics” signifies the violation of fundamental ethical principles such as honesty, fair practices, reliability, and professional responsibility. “Poor progress measurements by the contractor” refer to a contractor's inability to accurately or effectively assess the progress of a project. “Slowness of the owner's decision-making process” points to delays in decision-making by a property owner or project owner. “Needs effective supply chain management” emphasizes the necessity of achieving efficiency in supply chain management for the successful execution of an organization or project. “The ability to manage customers' expectations/the process” refers to the capability of an organization or individual to understand, manage, and align the expectations of customers with the process. “Unclear instructions or failure to issue instructions in time by architects and engineers”

occurs when architects and engineers fail to provide clear instructions or deliver necessary directives within the specified time. “Variations initiated by the owner” refer to changes proposed or requested by the owner or project owner during a project or construction. “Diversity of working style among parties” denotes the existence of different working methods, approaches, and styles among various parties (individuals or groups) involved in a project or task. “Labor union related issues” indicate problems arising from interactions with labor unions in workplaces or projects. “Lack of progress report and meeting” refers to the failure to produce necessary reports and hold regular meetings to monitor progress in a project or work process. “Not following project specifications” occurs when a project or construction does not adhere to the defined project requirements, standards, and technical specifications.

If it is necessary to identify external causes of disputes, “Government processes bureaucracy/approvals” refers to the bureaucratic obstacles and challenges within the processes of government institutions for approvals. “Disasters” describes natural events (earthquakes, floods, hurricanes, etc.) or human-made incidents (industrial accidents, large fires, etc.) that result in significant damage and loss. “Economic factors (change in currency, etc.)” explains the impact of changes in economic conditions on projects or business processes. “Political interest” outlines the policies or decisions made by a specific group, party, or individual in pursuit of political goals. “Changes in laws and regulations” denotes modifications made to existing laws and regulations. “Country security problems, language barriers, different cultural traditions, and religious backgrounds” highlight various challenges encountered due to the socio-cultural situation of the country where the project is located. “Impact on locality in terms of noise, traffic, and pollution/contamination” refers to the negative effects such as noise, traffic congestion, air, and water pollution, which can reduce the quality of life for local residents and harm the environment. “Tower crane lifting limit” defines the maximum weight that a tower crane can safely lift which is important for transporting modules. “Transportation insurance coverage” refers to the insurance policy coverage against risks such as damage, loss, or theft during the transportation of goods from one place to another. “Unfamiliarity with project geographical condition” explains the lack of knowledge by a project team or stakeholders

regarding the geographical features, climate conditions, or terrain of the project location. “Taxation issue” refers to legal or financial problems related to taxes. “Weather” describes the atmospheric conditions in a specific region at a given time that affects working conditions. “State of sector” indicates the economic, commercial, and operational condition of a particular industry or sector. “Building code for offsite construction” refers to the regulations and standards applicable to construction elements produced in a factory or other location and later transported to the construction site for assembly. “The legal system incompatible with the dispute resolution procedures in the contract” refers to a situation where the dispute resolution methods specified in a contract are incompatible with the applicable legal system or regulations. “Lack of legal awareness” explains the insufficient knowledge and understanding by individuals or organizations of legal rights, obligations, and procedures. “The complexity of the expressions in the law” refers to the complex, difficult-to-understand, or technically detailed language and terms used in legal texts and regulations. “Contradiction among legal provisions” describes situations where there is inconsistency or conflict between different legal regulations, laws, or rules. “Lack of awareness about the legal aid effect” defines the insufficient knowledge and consciousness among individuals or communities regarding the benefits, effects, and importance of legal aid (legal advice, representation, or support). “Transport restrictions” refers to restrictions or limitations applied to transportation in a specific region, route, or process. “Credit tightening” indicates the situation where financial institutions or banks make credit conditions stricter. “Increase interest rates for compensation” refers to the rise in interest rates applied for the purpose of compensating for damages or losses. “Inferences with utility lines” refers to assessments or evaluations made regarding public utility lines such as electricity, water, and gas and that is important for working conditions.

4
METHODOLOGY AND FINDINGS

4.1 Focus Group Discussion Technique Sub Title

FGD is a research method where a competent group of individuals, guided by a professional moderator, discusses a topic or issue [43]. As a qualitative research method, FGD is an effective technique for gathering data and information. It is implemented as a method where participants communicate with each other, influence one another, and thus explore different dimensions of the problems [44]. The Focus Group Discussion (FGD) technique helps reveal the views and beliefs of the experienced professional about the discussed topic. In FGD, the data is collected from the selected group of individuals. Thus, it doesn't require data collection from a sample of a broader population [45]. This technique has increased its popularity and application areas across wide range of disciplines (communication and media studies, sociology, health researches, marketing researches, engineering et cetra).

Sometimes, FGD is thought as synonymous with interviews (one-to-one and group interviews). However, they have distinctive characteristics fundamentally. In the interviews, researchers or investigators have a deep discussion about topic by conducting one-to-one meetings. Moreover, the researcher controls the dynamic of discussion within given timeframe. Unlike, the researchers have a facilitator or moderator role in the FGD. These discussions are performed between a group of experts. Therefore, people's perceptions and socio-cultural situation affecting decision-making about the topic can be interpreted [45]. In the FGD technique, participants can affect each other. This facilitates to create innovative ideas with the discovery of practical knowledge.

The size, composition, and execution process of the FGD are crucial to obtaining valuable results for the study [46]. According to the flowchart of the steps of the FGD defined by Nyumba et al. [45], "identification of the objectives of the study, selection of experts, determination of suitable location, familiarization of the participants to the topic and each other, discussions according to questions and follow-up questions, analysis of the FGD findings and reporting, and analysis" should be performed respectively. The size of FGD session can consist of range from 3 to 21. Also, the median value was stated as 10 participants. In another scientific source, Mishra [46] stated that the size of the FGD session can show a variety of 10 to 12 experts. According to Mishra [46], the FGD technique can be used as a stand-alone method to support studies in which quantitative research methods are used before and after them.

This study employed the FGD technique to identify disputes for off-site construction projects. In the FGD session, the execution process of FGD defined by Nyumba et al. (2018) was followed. Experts were invited to the FGD according to the requirements defined in Figure 4.1. The expert profile is presented in Table 4.1. Firstly, the aim of the study was explained to the experts. Secondly, the importance of the identification of dispute list for off-site construction was asked. Thirdly, experts with diverse experience in off-site construction projects reviewed the initial version of the dispute lists. Thus, the experts were asked to eliminate or combine or add new dispute causes for off-site construction projects.

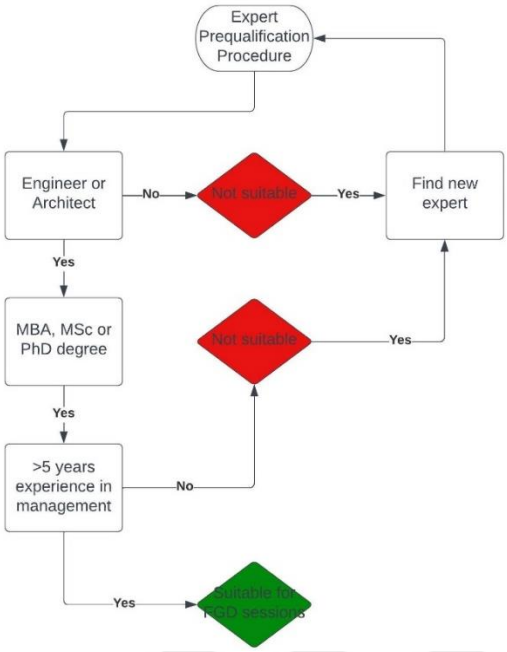

Figure 4.1 Expert prequalification assessment procedure for FGD session and interviews (for questionnaires)

Table 4.1 Expert profile (FGD session)

Expert ID	Personal profession	Education	Years of experience
E1	Purchasing Specialist	Civil Engineer (MSc degree)	CI[1]: 7 years. O[2]: 5 years.
E2	Contract Specialist	Civil Engineer (MSc degree)	CI[1]: 17 years. O[2]: 9 years.
E3	Tender Specialist	Civil Engineer (MSc degree)	CI[1]: 10 years. O[2]: 6 years.
E4	Purchasing and Contract Specialist	Civil Engineer (MSc degree)	CI[1]: 10 years. O[2]: 7 years.
E5	Tender Specialist	Civil Engineer (MSc degree)	CI[1]: 8 years. O[2]: 5 years.
E6	Technical Office Chief	Civil Engineer (MSc degree)	CI[1]: 20 years. O[2]: 7 years.
E7	Project Manager	Architect (MSc degree)	CI[1]: 12 years. O[2]: 5 years.
E8	Project Manager	Architect (MSc degree)	CI[1]: 15 years. O[2]: 6 years.
E9	Project Manager	Architect (MSc degree)	CI[1]: 22 years. O[2]: 12 years.
E10	Academician	Civil Engineer (PhD Degree)	CI[1]: 11 years. O[2]: 5 years.

[1]CI: Construction industry, [2]O: Off-site construction

In the first stage, participants were asked an open-ended question to learn the necessity of identifying dispute causes for off-site construction projects. According to expert responses, off-site construction projects differ from on-site projects due to manufacturing of building components in a controlled environment. Moreover, the experts expressed that the procurement process is differ from on-site projects, since change orders is almost impossible especially in technical features of components manufactured with off-site methods. Therefore, the experts stated that

they need to consider and give utmost importance to off-site construction specific characteristics.

In the second stage of the FGD session, the literature review results (off-site construction dispute causes list) were shown to the experts. The experts were asked to evaluate identified dispute causes in terms of off-site construction projects and the addition of new dispute causes was requested if it is needed. However, the experts expressed that the identified dispute causes are satisfactory to reflect the seen dispute causes in the off-site construction. Moreover, the experts were requested to evaluate each dispute cause with the use of a 1-5 Likert scale (1-least importance, 5-the most importance). The collected data was analyzed with an arithmetic mean formula. As a result of the analysis, 17 factors were found under 3 scores for dispute causes. Therefore, these factors were eliminated. Thus, the dispute causes presented in Table 4.2 were obtained as the final list.

Table 4.2 Dispute causes for off-site construction projects

Dispute Causes		References
Contractual Dispute Causes		
C1	Risk allocation	[9] [10] [11] [28] [29] [30] [31]
C2	Ambiguities in bidding	[9] [10] [25] [32] [33]
C3	Changes of scope	[9] [10] [11] [26] [27] [29] [30] [31] [34]
C4	Poor contract documentation	[12] [26] [32] [33]
C5	Misrepresentation of contract documents	[12]
C6	Noncompliance to contracts terms	[11] [32] [33]
C7	Ambiguities in contracts	[9] [10] [11] [12] [24] [25] [26] [27] [29] [30] [31] [33] [34]
C8	Poor defined general provisions	[12]
C9	Mismatch contract type	[11] [12] [29]
C10	Ambiguities in contract clauses	[12] [25] [27] [28] [32] [34]
C11	Increase in contract value due to revision in scope of work	[34]
C12	Excessive contractual variations	[12]
C13	Failure to examine contract conditions at the time of tender	[30] [31]
C14	Errors and omissions of contract terms	[24] [28] [30] [31]
C15	Legal text layout	[12]
C16	Problems of terminology	[12] [27]
C17	Ineffective contract management & administration	[12] [28] [29]
C18	Unclear method to reduce the delay damages	[31]
C19	Unclear definition and types of defects	[31]
C20	Complexity in contract provisions	[9] [10] [11] [12] [24] [27] [28] [29] [31] [32]

Table 4.2 Dispute causes for off-site construction projects (continued…)

Dispute Causes		References
C21	Illegal and improper work suspension	[11] [12] [34]
C22	Opportunistic behaviour of project parties	[11] [28] [34]
C23	Breach of warranty claims	[11] [12] [26]
C24	Non-practical conditions	[12]
Financial Dispute Causes		
F1	Disagreement on payment method caused by variation of quantities	[24] [31]
F2	Financial failure or inadequacy of contractor	[9] [10] [11] [27] [29] [30] [31] [33]
F3	Payment delays (owner based)	[9] [10] [11] [24] [27] [29] [30] [31] [32] [33] [34]
F4	Adamant non payment	[26]
F5	Disagreement of the compensation amount	[31]
F6	Deductions	[26]
F7	Delays in compensation	[26]
F8	Denial of compensation	[26]
F9	Insufficient financial planning	[25]
F10	Loss to the client	[35]
F11	Non releasing of deposits	[26]
F12	Payment delays (contractor based such as delays in submitting progress payment claims, errors and insufficiency in submitted documents)	[11]
F13	Inadequate or delayed project funding	[11]
F14	Non-availability of spare money for additional work	[33]
F15	The low-profit margin	[36]
F16	Too much inference from client	[32]
F17	Untimely contractual payment	[34]
F18	Insufficient coverage of design liability insurance	[12]
Technical Dispute Causes		
T1	Lack of experience	[12] [24] [25] [27] [28] [32] [33]
T2	Unavailability of materials	[33]
T3	Material testing technique	[25]
T4	Material/modules double-handling	[12]
T5	Lack of quality management	[9] [10] [12] [25] [26] [27] [28] [29] [30] [31] [32]
T6	Poor risk management	[12] [28] [32]
T7	Project uncertainty (insufficient details etc.)	[9] [10] [11] [12] [25] [27] [28] [29] [30] [31] [32] [33] [34]
T8	Complexity of project	[12] [25] [32]
T9	Late completion, delivery and installation of components	[11]
T10	Availability/Incompletion of information	[9] [10] [25] [29] [30] [34]
T11	Project revisions	[11] [12] [24]
T12	Lack of advanced technology	[32]
T13	Cost and time overruns	[9] [10] [11] [24] [26] [30] [32] [34]
T14	Unlikely industry readiness	[12]
T15	Need for systematic design of fault-tolerant systems	[12]
T16	Difference in construction technique	[25]

Table 4.2 Dispute causes for off-site construction projects (continued…)

Dispute Causes		References
T17	Noncompliance to the design requirements	[33] [34]
T18	Slowness of the contractor's decision-making process	[11]
T19	Time limitation in the design phase	[27]
T20	Technical inadequacy of the contractor	[9] [10] [27] [29] [30] [33]
T21	Delivering defective modules	[11]
T22	Design standardization	[12]
T23	Late notification of technical changes	[32]
T24	Site conditions	[9] [10] [11] [12] [25] [27] [29] [30] [32]
T25	Changes incorporated apart from contractual agreements (inc. design)	[9] [10] [11] [24] [25] [26] [27]
Managerial Dispute Causes		
M1	Poor management skills	[27] [32] [34] [47]
M2	Request for acceleration of works	[9] [10] [11] [30] [31] [32]
M3	Delays in approvals	[11] [12] [26] [31] [33]
M4	Unrealistic expectations	[9] [10] [12] [25] [29] [30] [31] [32] [34]
M5	Lack of professionalism	[11] [29]
M6	Dispute resolution methods	[11] [12] [25] [32]
M7	Lack of information exchange	[11] [32]
M8	Unfamilarity with local conditions	[25]
M9	Lack of communication	[9] [10] [11] [27] [28] [29] [30] [32] [34]
M10	Lack of collaboration	[9] [10] [11] [28] [30] [32] [34]
M11	Poor negotiation skills	[28] [32] [34]
M12	Poor coordinattion of construction activity	[28] [32]
M13	Poor planning and managing of the project	[12] [27] [28] [29] [32] [33] [34]
M14	Late giving of possesion	[9] [10] [25] [26] [30] [31]
M15	Unsatisfiable salary	[34]
M16	Human behaviour related	[9] [10] [27] [28] [30] [32] [34]
M17	Lack of construction ethics	[32]
M18	Slowness of the owner's decision-making process	[11] [27] [33]
M19	Needs effective supply chain management	[12] [31]
M20	The ability to manage the customers' expectations/the process	[36]
M21	Unclear instructions or fails to issue instructions in time by architects and engineers	[34]
M22	Diversity of working style among parties	[34]
M23	Lack of progress report and meeting	[32]
M24	Not following project specifications and variations initiated by the owner	[9] [10] [11] [27] [30] [33] [34]
External Dispute Causes		
E1	Government processes bureaucracy/approvals	[11] [25] [27] [32]
E2	Disasters	[10] [25] [28] [31] [32]
E3	Economic factors (change in currency etc.)	[9] [10] [29] [30] [31] [33]
E4	Political interest	[36]
E5	Changes in laws and regulations	[31]
E6	Country security problems, language barriers, different cultural traditions, and religious backgrounds	[31]
E7	Unfamiliarity with project geographical condition	[31]

Table 4.2 Dispute causes for off-site construction projects (continued…)

Dispute Causes		References
E8	Weather	[9] [10] [25] [27] [28] [30] [31] [32] [34]
E9	State of sector	[10] [28] [30] [33] [34]
E10	Building code for offsite construction	[9] [11] [12] [25] [27] [28] [31]
E11	The legal system incompatible with the dispute resolution procedures in the contract	[31]
E12	Lack of legal awareness	[30] [34]
E13	The complexity of the expressions in the law	[10] [12] [29]
E14	Taxation issue	[31]
E15	Contradiction among legal provisions	[12]
E16	Lack of awareness about the legal aid effect	[36]
E17	Transport restrictions	[12] [33]
E18	Credit tightening	[31]
E19	Increase interest rates for compensation	[26]
E20	Inferences with utility lines	[25]

4.2 FMEA Approach

The Failure Mode and Effects Analysis (FMEA) is used as a risk assessment tool that helps to mitigate potential issues or failures in systems, processes, designs or services. FMEA is used in a wide range of industries. The FMEA has proven its usefulness and power in the assessment of potential failures and eliminate them before they occur. The main aim of the FMEA approach is to identify failure modes, causes and effects of failures, and the response to mitigate failure chance [48]. Therefore, the practitioners can focus on elimination or reducing of the occurrence of risks and take a precaution for the severity of risk impact [49]. Although FMEA was initially developed in the late 1940s, it was used as a formal design methodology for improving safety in the aerospace industry in the 1960s. In the FMEA approach, the main components used to assess risk factors are occurrences (O), severity (S), and Detection (D) [50]. The FMEA approach has been widely used to evaluate potential risk factors in the initial stages of construction management processes [50]. The approach helps to make the risk management decisions based on information [48].

On the other hand, construction disputes are another risks that affect the successful completion of construction projects. Within this context, FMEA approach has been used to assess disputes and their effects on construction projects considering

disputes as potential risks, the authors employed FMEA to assess them. Typically, each risk cause is evaluated on a scale of 1-10 in FMEA analysis and the assessments are multiplied by each other. If the result is close to 1000, the priority of dispute cause has more importance than other dispute causes. However, Mohammadi and Tavakolan [50] and Liu et al. [48] criticized that this scaling method is not suitable to get reliable analysis results. The basis of this finding lies in the belief that O, S, and D factors are difficult to be precisely evaluated. Therefore, in this study, the FMEA approach was combined with the Pythagorean fuzzy AHP method.

4.3 Pythagorean Fuzzy AHP Integrated Fuzzy TOPSIS Hybrid Approach

Multi criteria decision-making (MCDM) is an important part of management science. In MCDM, several kinds of methodologies can be implemented to deal with evaluation, prioritization, and selection of alternatives. AHP and TOPSIS are the most widely used MCDM methods. However, the use of numerical values in pairwise comparisons in AHP analysis and TOPSIS analysis leads to vagueness and subjective evaluations [14]. Since the decision makers should use crisp values in their assessments [51].

The fuzzy set theory appeared as an important tool to overcome vagueness and subjectivity issues in the decision-making process. After that, Intuitionistic fuzzy set theory has been offered to represent the degree of not satisfaction of a criterion by assigning non-membership degree. The intuitionistic fuzzy sets theory depends on the sum of membership and non-membership degrees is less than or equal to 1 [51]. However, the theory sometimes fails to meet this condition. In other words, it can be bigger than 1 [14]. As a result of this issue, Yager [52] offered Pythagorean fuzzy set to meet the condition that wasn’t met by intuitionistic fuzzy sets theory. In the literature, the Pythagorean fuzzy set is expressed as more powerful and flexible to solve uncertainty issues [14].

This study aims to examine dispute causes in off-site construction projects by analyzing them based on contractual, financial, technical, managerial, and external factors, and determining their levels of importance. The objective was to facilitate the implementation of preventive measures against risks and uncertainties

according to the results. As for the research methodology, the Pythagorean fuzzy AHP integrated Fuzzy TOPSIS hybrid approach was employed. Moreover, the use of the Pythagorean fuzzy AHP integrated Fuzzy TOPSIS method has been firstly applied to examine the importance level of off-site construction project related disputes rather than analyzing court decisions.

After conduction of FGD and determination of contractual, financial, technical, managerial, and external dispute causes for off-site construction projects, the questionnaire was prepared to collect data and analyze their importance levels. During the data collection process, data was collected from 17 experts who are experienced in the off-site construction projects (See Table 4.4). The data obtained from the questionnaire was collected from Türkiye.The questionnaire consisted of 6 sections. In the first section, the study aim was explained to the participants. In the second section, questions helping to identify expert profile were asked. For the filling questionnaire, examples were explained in the third section. Fourth section was designed to collect data with pair-wise comparison matrix for the analysis of the importance level of criteria (O, S, and D). Fifth section was designed to collect judgements of experts related to main factor groups ("Managerial factors", "External factors", "Technical factors", "Contractual factors", and "Financial factors"). In the final section, questions were designed to collect evaluations related to factors found under "Managerial factors", "External factors", "Technical factors", "Contractual factors", and "Financial factors" groups against to criteria (O, S, and D). Data was collected with the face-to-face interviews. The steps of used Pythagorean fuzzy AHP integrated Fuzzy TOPSIS Hybrid Approach and analysis results were given below sections. gaining knowledge about the causes of conflicts before they escalate into disputes is often used as an important method in conflict resolution [9]. The authors have noted that in the literature, disputes are generally addressed explicitly or synonymously with the terms conflict and claims. Disputes, however, are defined as disagreements among stakeholders that

4.3.1 Pythagorean Fuzzy AHP

The aim of this study is to identify the contractual, financial, technical, managerial, and external factors leading to disputes in off-site construction projects within the framework of Failure Mode and Effects Analysis (FMEA) and determine their priority rankings. Multiple Criteria Decision Making (MCDM) problems, which

encompass various tangible or intangible criteria, employ techniques such as AHP, ANP, TOPSIS, ELECTRE, etc. The Analytical Hierarchy Process (AHP) method is one of the most used MCDM method. The AHP method aims to find out the weights of criteria and calculation of priorities of alternatives. The reasons of the common use of AHP methodology are related to its implementation easiness, systematic handling of problems and easiness of analysis. In the method, the pair-wise comparison matrices are used to collect data. The experts are asked to either compare the criteria by considering aim of the study or compare the alternatives by considering criteria. However, in the evaluation process, precise numbers were used. This leads not to consider uncertainty, vagueness or imprecise of the experts [53] [54]. The Fuzzy AHP methodology was developed to overcome uncertainty, vagueness or imprecise in decisions. The development of fuzzy sets pave the way other extensions such as neutrosophic sets, Pythagorean sets, and orthopair fuzzy sets [55]. Pythagorean fuzzy sets address uncertainty and indeterminacy and it reduces vagueness and impreciseness. The Pythagorean fuzzy AHP steps are summarized below;

Step 1. To obtain expert opinions, pairwise comparison matrices were presented. The following scale (Table 4.3) was used during the data collection process.

Table 4.3 The linguistic terms for Pythagorean fuzzy AHP [39]

Linguistic terms	Pythagorean fuzzy numbers			
	The lower value of membership degree ($\boldsymbol{\mu_L}$)	The upper value of membership degree ($\boldsymbol{\mu_U}$)	The lower value of non-membership degree ($\boldsymbol{v_L}$)	The upper value of non-membership degree ($\boldsymbol{v_U}$)
Certainly low importance – CLI	0.00	0.00	0.90	1.00
Very low importance – VLI	0.10	0.20	0.80	0.90
Low importance – LI	0.20	0.35	0.65	0.80
Below average importance - BAI	0.35	0.45	0.55	0.65
Average importance - AI	0.45	0.55	0.45	0.55
Above average importance – AAI	0.55	0.65	0.35	0.45
High importance - HI	0.65	0.80	0.20	0.35

Table 4.3 The linguistic terms for Pythagorean fuzzy AHP [39] (continued…)

Linguistic terms	Pythagorean fuzzy numbers			
	The lower value of membership degree (μ_L)	The upper value of membership degree (μ_U)	The lower value of non-membership degree (v_L)	The upper value of non-membership degree (v_U)
Very high importance – VHI	0.80	0.90	0.10	0.20
Certainly high importance – CHI	0.90	1.00	0.00	0.00
Exactly equal - EE	0.1965	0.1965	0.1965	0.1965

For the analysis of the importance level of dispute causes for off-site construction projects, seventeen experts were selected by considering expert evaluation flow chart given in Figure 4.1. The expert profiles are tabulated in Table 4.4. The traditional AHP can be conducted with small sample size. Additionally, some researchers asserted that AHP is a helpful method to analyze subjective problems. Therefore, the authors expressed that the large data size isn't needed for the implementation of method. Darko et al. [56] stated that the method can be conducted with single and qualified expert. In the literature, there are other examples for the sample size of the Pythagorean fuzzy AHP implementation such as 5 experts [57].

Table 4.4 Expert profile

Expert ID	Personal profession	Education	Years of experience
E1	Purchasing Specialist	Civil Engineer (MSc degree)	CI[1]: 7 years. O[2]: 5 years.
E2	Contract Specialist	Civil Engineer (MSc degree)	CI[1]: 17 years. O[2]: 9 years.
E3	Tender Specialist	Civil Engineer (MSc degree)	CI[1]: 10 years. O[2]: 6 years.
E4	Purchasing and Contract Specialist	Civil Engineer (MSc degree)	CI[1]: 10 years. O[2]: 7 years.
E5	Tender Specialist	Civil Engineer (MSc degree)	CI[1]: 8 years. O[2]: 5 years.
E6	Technical Office Chief	Civil Engineer (MSc degree)	CI[1]: 20 years. O[2]: 7 years.
E7	Project Manager	Architect (MSc degree)	CI[1]: 12 years. O[2]: 5 years.
E8	Project Manager	Architect (MSc degree)	CI[1]: 15 years. O[2]: 6 years.
E9	Project Manager	Architect (MSc degree)	CI[1]: 22 years. O[2]: 12 years.
E10	Board Member	Civil Engineer (MSc degree)	CI[1]: 15 years. O[2]: 8 years.
E11	Project Manager	Civil Engineer (MSc degree)	CI[1]: 32 years. O[2]: 14 years.
E12	Technical Office Chief	Civil Engineer (MSc degree)	CI[1]: 13 years. O[2]: 8 years.
E13	Project Manager	Civil Engineer (MSc degree)	CI[1]: 11 years. O[2]: 6 years.
E14	Technical Office Chief	Civil Engineer (MSc degree)	CI[1]: 13 years. O[2]: 6 years.
E15	Technical Office Engineer	Civil Engineer (MSc degree)	CI[1]: 9 years. O[2]: 5 years.
E16	Contract Specialist	Civil Engineer (MSc degree)	CI[1]: 14 years. O[2]: 7 years.
E17	Tender Specialist	Civil Engineer (PhD degree)	CI[1]: 26 years. O[2]: 10 years.

[1]CI: Construction industry, [2]O: Off-site construction

Step 2. The expert evaluations should be tested in terms of consistency to obtain reliable results in the AHP method. In the AHP method, Consistency ratio (CR) should be calculated for each pairwise comparison matrix. If the CR value is less than 0.1, it means that the expert judgements are consistent for the filled matrix [58]. The CR values for FMEA criteria (O, S, and D) are presented in Table 4.5 for each expert. The results indicated that the CR values are less than 0.1 and suitable to make a further analysis. After calculating the CR values, the consensus matrix should be created. To create consensus matrix, the geometric mean method is applied [58].

Table 4.5 Consistency Index analysis results for pair-wise comparison matrix

Expert ID	Consistency Index for FMEA Criteria
E1	0.02
E2	0.07
E3	0.004
E4	0.08
E5	0.03
E6	0.04
E7	0.02
E8	0.0
E9	0.08
E10	0.09
E11	0.08
E12	0.04
E13	0.01
E14	0.01
E15	0.02
E16	0.01
E17	0.02

Step 3. The differences matrix ($D = (d_{ik})_{mxn}$ are constructed by using the lower and upper values of membership and non-membership degrees. Eq. 4.1 and 4.2 are employed to calculate lower and upper values.

$$d_{ikL} = \mu_{ikL}^2 - v_{ikU}^2 \quad (4.1)$$

$$d_{ikU} = \mu_{ikU}^2 - v_{ikL}^2 \quad (4.2)$$

Step 4. The interval multiplicative matrixes ($S = (S_{ik})_{mxn}$) are constructed by using Eq. 4.3 and 4.4.

$$S_{ikL} = \sqrt{1000^{d_L}} \quad (4.3)$$

$$S_{ikU} = \sqrt{1000^{d_U}} \tag{4.4}$$

Step 5. The determinacy value $(\tau = (\tau_{ik})_{mxn})$ is calculated from aggregated matrix by using Eq. 4.5.

$$\tau_{ik} = 1 - (\mu_{ikU}^2 - \mu_{ikL}^2) - v_{ikU}^2 - v_{ikL}^2 \tag{4.5}$$

Step 6. To calculate the weight matrix (Eq. 4.6), the arithmetic value of Eq. 4.3 and 4.4 is calculated and multiplied by the result of Eq. 4.5.

$$t_{ik} = \left(\frac{S_{ikL} + S_{ikU}}{2}\right) * \tau_{ik} \tag{4.6}$$

Step 7. The normalized priority weights are calculated by using Eq. 4.7.

$$W_i = \left(\frac{\sum_{k=1}^{m} t_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{m} t_{ik}}\right) \tag{4.7}$$

The calculation of the weights of the factors (O, S, and D) is important to create inputs to the fuzzy TOPSIS analysis. Therefore, the aggregated matrix and its' weights results were calculated with the use of Eq. 4.1-4.7. Table 4.6 shows the normalized weights' scores for O, S, and D criteria.

Table 4.6 Pythagorean fuzzy AHP analysis results for the calculation of weights of O, S, and D criteria

	O				S				D				Result
	ml	mu	vl	vu	ml	mu	vl	vu	ml	mu	vl	vu	W
O	0,19	0,19	0,19	0,19	0,1	0,2	0,8	0,9	0	0	0,9	1	0,12
S	0,8	0,9	0,1	0,2	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,34
D	0,9	1	0	0	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,54

The analysis results indicate that detectability of dispute causes is more important than severity and occurrences in off-site construction projects. This criterion is followed by severity and occurrence, respectively. The results of the Pythagorean fuzzy AHP (weights) will be used in the fuzzy TOPSIS analysis.

4.3.2 Fuzzy TOPSIS

The TOPSIS method is another useful MCDM method to deal with multi attribute decision making problems. The classical form of the TOPSIS method was developed by Hwang and Yoon. In this method, the alternatives are evaluating with the consideration of conflicting criteria. The aim of the TOPSIS method is to find out "the shortest distance to the positive ideal solution and the farthest distance to the negative ideal solution" [59]. The difference of Fuzzy TOPSIS method from the classical TOPSIS is that the Fuzzy TOPSIS method consider ambiguous and vague issues during the decision-making process. Therefore, Fuzzy TOPSIS method employs linguistic values rather than numerical assessments. As being in F-AHP, linguistic value take into consideration of ambiguities, uncertainties and vagueness [60]. In other words, the use of numerical assessment will involve unclear judgement due to the uncertainty [59]. The linguistic variables are transformed to the triangular fuzzy numbers a (the smallest value), b (the peak value), and c (the largest value) for the analysis of problem. If there are more than one data set, geometric mean can be used to create aggregated decision-makers' judgements [58]. In this study, the same linguistic variable scale given in Table 4.7 was used in the F-TOPSIS.

Table 4.7 Linguistic scale [44,45]

Fuzzy number	Linguistic	The scale of fuzzy number
1	Equal	1,1,1
2	Weak advantage	1,2,3
3	Not bad	2,3,4
4	Preferable	3,4,5
5	Good	4,5,6
6	Fairly good	5,6,7
7	Very good	6,7,8
8	Absolute	7,8,9
9	Perfect	8,9,10

The FTOPSIS method is widely employed in the construction management literature as one of the extensively utilized MCDM. For example, the F-TOPSIS method was applied in risk evaluation [61], risk allocation [62], the selection of dispute resolution method [63], et cetera. The procedural steps of FTOPSIS method steps are outlined below [64];

Step 1: After aggregation of expert judgements, normalization of fuzzy decision matrix is conducted with the use of Eq. 4.8 and 4.9.

$$r_{ij} = \frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \text{ and } c_j^* = max_i c_{ij} (benefit\ criteria \tag{4.8}$$

$$r_{ij} = \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \text{ and } a_j^- = max_i a_{ij} (cost\ criteria) \tag{4.9}$$

Step 2: The normalized matrix is multiplied by the criteria weights determined with the use of Pythagorean fuzzy AHP (See Eq. 4.10).

$$v_{ij} = w_j r_{ij} \tag{4.10}$$

Step 3: The positive and negative ideal solutions are calculated by employing Eq. 4.11 and Eq. 4.12.

$$A^* = \{v_1^*, \cdots, v_n^*\} \tag{4.11}$$

$$A^- = \{v_1^-, \cdots, v_n^-\} \tag{4.12}$$

Step 4: The vertex method is employed to calculate the separation measures of alternatives (the negative ideal alternative separation and positive ideal alternative separation). For the negative ideal alternative separation:

$$S_i^* = \sum_{j=1}^{n} d\left(v_{ij}, v_{ij}^*\right) \tag{4.13}$$

For the positive ideal alternative separation:

$$S_i^- = \sum_{j=1}^{n} d\left(v_{ij}, v_{ij}^-\right) \tag{4.14}$$

The Euclidian distances between each of the alternatives were calculated with the use of Eq. 4.15.

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - 3)^2]} \tag{4.15}$$

Step 5: As a final step, Eq. 4.16 is used to calculate relative closeness index.

$$CCi = \frac{S_i^*}{S_i^* + S_i^-} \tag{4.16}$$

The FTOPSIS analysis results for the calculation of factor groups were tabulated in the Table 4.8. Analysis results indicated that the most important factor groups for dispute causes are contractual, financial and technical factors respectively.

Table 4.8 FTOPSIS analysis results for the analysis of importance level of factor groups

	Normalized Weighted Matrix									Results			
	O			S			D						
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank
Managerial factors	0.05	0.08	0.10	0.13	0.20	0.27	0.28	0.39	0.49	2.35	0.68	0.225	4
External factors	0.04	0.07	0.10	0.15	0.23	0.29	0.13	0.24	0.36	2.47	0.57	0.186	5
Technical factors	0.07	0.10	0.12	0.16	0.23	0.30	0.31	0.43	0.54	2.25	0.78	0.257	3
Contractual factors	0.07	0.10	0.12	0.22	0.29	0.34	0.29	0.41	0.52	2.22	0.81	0.266	1
Financial factors	0.07	0.09	0.12	0.20	0.27	0.33	0.28	0.41	0.52	2.25	.78	0.258	2

After the calculation of the importance level of factor groups, contractual dispute causes were analyzed with the use of FTOPSIS method. The analysis results showed that C11 (Increase in contract value due to revision in scope of work) and C21 (Illegal and improper work suspension) are the most important and common contractual dispute causes for off-site construction projects. Moreover, these dispute causes are the most important dispute causes in the global ranking (See Table 4.9).

Table 4.9 FTOPSIS analysis results for the analysis of the importance level of contractual dispute causes

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
C1	0.07	0.09	0.11	0.21	0.25	0.30	0.27	0.35	0.43	2.31	0.70	0.2335	16	51

Table 4.9 FTOPSIS analysis results for the analysis of the importance level of contractual dispute causes (continued…)

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
C2	0.09	0.10	0.12	0.22	0.26	0.31	0.27	0.34	0.41	2.30	0.72	0.2378	13	40
C3	0.08	0.09	0.11	0.21	0.26	0.30	0.30	0.38	0.46	2.27	0.74	0.2462	8	32
C4	0.07	0.09	0.11	0.21	0.25	0.29	0.29	0.37	0.44	2.30	0.71	0.2372	14	44
C5	0.06	0.07	0.09	0.22	0.26	0.30	0.27	0.36	0.45	2.31	0.70	0.2333	17	52
C6	0.07	0.09	0.10	0.27	0.30	0.34	0.27	0.36	0.44	2.26	0.75	0.2505	5	25
C7	0.08	0.09	0.11	0.22	0.27	0.31	0.25	0.33	0.41	2.32	0.70	0.2320	18	55
C8	0.07	0.08	0.10	0.19	0.23	0.28	0.25	0.33	0.42	2.35	0.66	0.2202	20	66
C9	0.06	0.08	0.10	0.18	0.22	0.26	0.26	0.34	0.43	2.36	0.66	0.2178	22	71
C10	0.08	0.10	0.11	0.21	0.25	0.29	0.27	0.36	0.44	2.30	0.71	0.2364	15	45
C11	0.09	0.11	0.12	0.26	0.29	0.32	0.36	0.42	0.49	2.18	0.83	0.2749	1	19
C12	0.08	0.09	0.11	0.20	0.24	0.29	0.31	0.39	0.48	2.27	0.74	0.2455	9	33
C13	0.08	0.09	0.11	0.21	0.25	0.29	0.29	0.38	0.47	2.28	0.73	0.2429	10	34
C14	0.08	0.09	0.11	0.21	0.25	0.30	0.28	0.37	0.45	2.29	0.72	0.2395	12	38
C15	0.07	0.08	0.10	0.20	0.25	0.29	0.25	0.33	0.41	2.35	0.67	0.2220	19	62
C16	0.06	0.08	0.09	0.17	0.21	0.25	0.26	0.34	0.42	2.37	0.64	0.2120	24	78
C17	0.07	0.09	0.10	0.18	0.22	0.26	0.25	0.33	0.41	2.37	0.64	0.2130	23	77
C18	0.07	0.08	0.10	0.20	0.25	0.29	0.31	0.39	0.48	2.28	0.73	0.2429	11	35
C19	0.06	0.08	0.10	0.19	0.23	0.27	0.26	0.34	0.43	2.35	0.66	0.2200	21	67
C20	0.07	0.09	0.10	0.21	0.25	0.30	0.31	0.39	0.48	2.27	0.74	0.2463	7	31
C21	0.06	0.08	0.09	0.22	0.26	0.30	0.38	0.46	0.54	2.21	0.80	0.2668	2	20
C22	0.08	0.10	0.11	0.23	0.26	0.30	0.36	0.43	0.51	2.21	0.80	0.2659	3	21
C23	0.06	0.07	0.09	0.20	0.24	0.29	0.36	0.44	0.52	2.25	0.76	0.2537	4	24
C24	0.06	0.08	0.09	0.20	0.24	0.28	0.35	0.42	0.50	2.27	0.75	0.2477	6	28

The analysis of financial dispute causes were calculated with the use of FTOPSIS method. According to the analysis results, F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)) are the most important and common financial dispute causes for off-site construction projects. Moreover, the analysis results referred that the utmost attention to these dispute causes should be given according to the global ranking results (See Table 4.10).

Table 4.10 FTOPSIS analysis results for the analysis of importance level of financial dispute causes

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
F1	0.10	0.11	0.12	0.26	0.28	0.31	0.31	0.36	0.42	2.25	0.76	0.2524	15	15
F2	0.09	0.10	0.12	0.29	0.31	0.34	0.31	0.36	0.42	2.22	0.79	0.2616	11	11
F3	0.10	0.11	0.12	0.28	0.31	0.34	0.33	0.39	0.46	2.19	0.82	0.2732	2	2
F4	0.08	0.10	0.11	0.26	0.28	0.31	0.34	0.40	0.46	2.22	0.78	0.2604	12	12
F5	0.08	0.10	0.11	0.26	0.28	0.31	0.37	0.43	0.49	2.19	0.82	0.2717	4	4
F6	0.09	0.10	0.11	0.24	0.27	0.30	0.33	0.39	0.46	2.24	0.77	0.2555	14	14
F7	0.09	0.10	0.12	0.24	0.27	0.30	0.36	0.42	0.48	2.21	0.80	0.2645	6	6
F8	0.08	0.10	0.11	0.25	0.28	0.31	0.38	0.44	0.50	2.19	0.82	0.2727	3	3
F9	0.09	0.10	0.12	0.26	0.29	0.32	0.31	0.38	0.45	2.23	0.78	0.2582	13	13
F10	0.08	0.09	0.11	0.24	0.28	0.32	0.30	0.36	0.43	2.27	0.74	0.2472	17	17
F11	0.08	0.09	0.11	0.25	0.28	0.32	0.35	0.41	0.47	2.22	0.79	0.2626	9	9
F12	0.09	0.11	0.12	0.27	0.30	0.33	0.34	0.38	0.43	2.21	0.79	0.264	7	7
F13	0.10	0.11	0.12	0.26	0.29	0.32	0.35	0.37	0.44	2.22	0.79	0.2620	10	10
F14	0.09	0.10	0.12	0.23	0.27	0.31	0.38	0.45	0.52	2.18	0.83	0.2748	1	1
F15	0.08	0.10	0.11	0.25	0.29	0.32	0.29	0.35	0.41	2.27	0.74	0.2459	18	18
F16	0.07	0.09	0.10	0.22	0.26	0.30	0.37	0.46	0.54	2.20	0.81	0.2695	5	5
F17	0.08	0.10	0.11	0.22	0.25	0.29	0.33	0.39	0.45	2.26	0.75	0.2477	16	16
F18	0.08	0.09	0.10	0.22	0.26	0.29	0.37	0.44	0.51	2.22	0.79	0.2631	8	8

Technical dispute causes were analyzed with the use of the FTOPSIS method and importance level of main factors given in Table 4.11. The analysis results showed that T9 (Late completion, delivery and installation of components), T13 (Cost and time overruns) and T11 (Project revisions) are the most important and common technical dispute causes for off-site construction projects.

Table 4.11 FTOPSIS analysis results for the analysis of the importance level of technical dispute causes

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
T1	0.09	0.10	0.12	0.25	0.28	0.32	0.31	0.37	0.43	2.24	0.77	0.2544	12	50
T2	0.07	0.09	0.10	0.26	0.29	0.33	0.30	0.36	0.42	2.26	0.75	0.2489	14	57
T3	0.06	0.08	0.10	0.24	0.27	0.30	0.27	0.36	0.44	2.30	0.72	0.2373	21	70
T4	0.05	0.07	0.08	0.18	0.22	0.26	0.28	0.36	0.45	2.36	0.66	0.2178	25	88
T5	0.07	0.09	0.11	0.22	0.26	0.30	0.33	0.41	0.49	2.24	0.77	0.2564	8	46
T6	0.08	0.09	0.11	0.24	0.28	0.31	0.29	0.38	0.46	2.26	0.75	0.2505	13	56
T7	0.09	0.10	0.11	0.27	0.31	0.34	0.34	0.40	0.45	2.20	0.81	0.2687	4	29
T8	0.08	0.09	0.11	0.24	0.27	0.31	0.28	0.36	0.43	2.28	0.73	0.2418	16	60
T9	0.08	0.10	0.11	0.26	0.29	0.32	0.39	0.46	0.54	2.15	0.86	0.2859	1	22
T10	0.07	0.09	0.10	0.24	0.27	0.31	0.33	0.40	0.47	2.24	0.77	0.2554	10	48
T11	0.10	0.11	0.12	0.27	0.30	0.33	0.33	0.40	0.47	2.19	0.82	0.2710	3	26
T12	0.08	0.10	0.11	0.24	0.27	0.31	0.36	0.43	0.50	2.20	0.81	0.2675	5	30
T13	0.09	0.10	0.12	0.27	0.30	0.33	0.38	0.45	0.51	2.16	0.85	0.2819	2	23
T14	0.06	0.08	0.09	0.20	0.24	0.28	0.25	0.33	0.41	2.36	0.66	0.2182	24	86
T15	0.07	0.08	0.10	0.22	0.26	0.30	0.35	0.43	0.50	2.24	0.77	0.2563	9	47
T16	0.07	0.08	0.10	0.20	0.24	0.27	0.31	0.40	0.48	2.29	0.72	0.2401	18	63
T17	0.07	0.08	0.10	0.20	0.25	0.29	0.36	0.44	0.52	2.24	0.78	0.2578	7	41
T18	0.08	0.10	0.11	0.23	0.27	0.31	0.28	0.35	0.43	2.28	0.73	0.2417	17	61
T19	0.09	0.10	0.12	0.23	0.27	0.31	0.32	0.41	0.49	2.23	0.79	0.2608	6	37
T20	0.08	0.09	0.11	0.24	0.28	0.32	0.26	0.34	0.42	2.29	0.72	0.24	19	64

Table 4.11 FTOPSIS analysis results for the analysis of the importance level of technical dispute causes (continued…)

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
T21	0.07	0.08	0.10	0.21	0.25	0.29	0.29	0.35	0.41	2.31	0.70	0.2313	22	75
T22	0,08	0,09	0,11	0,20	0,24	0,28	0,31	0,39	0,47	2,28	0,74	0,2440	15	58
T23	0,08	0,09	0,11	0,25	0,28	0,31	0,32	0,39	0,46	2,24	0,77	0,2551	11	49
T24	0,09	0,10	0,12	0,22	0,26	0,30	0,23	0,30	0,37	2,33	0,68	0,2247	23	81
T25	0,08	0,10	0,11	0,23	0,27	0,30	0,28	0,36	0,41	2,29	0,72	0,2378	20	69

As a result of the FTOPSIS method, M13 (Poor planning and management of the project), M7 (Lack of information exchange) and M10 (Lack of cooperation) were found as the most important and common managerial dispute causes for off-site construction projects. However, the analysis results referred that these dispute causes have moderate importance according to the global rank (See Table 4.12).

Table 4.12 FTOPSIS analysis results for the analysis of the importance level of managerial dispute causes (continued…)

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
M1	0.07	0.09	0.10	0.25	0.27	0.30	0.29	0.37	0.45	2.27	0.74	0.2449	9	82
M2	0.08	0.10	0.11	0.19	0.23	0.26	0.22	0.29	0.36	2.39	0.62	0.2071	23	107
M3	0.08	0.09	0.10	0.20	0.24	0.27	0.20	0.29	0.38	2.38	0.63	0.2105	21	105
M4	0.06	0.07	0.09	0.16	0.20	0.23	0.29	0.36	0.44	2.37	0.64	0.2135	19	102
M5	0.07	0.08	0.10	0.23	0.26	0.29	0.29	0.37	0.46	2.29	0.73	0.2408	10	83
M6	0.07	0.08	0.10	0.21	0.25	0.29	0.31	0.39	0.48	2.27	0.74	0.2462	8	80
M7	0.10	0.11	0.12	0.27	0.30	0.33	0.34	0.43	0.51	2.16	0.85	0.282	2	39
M8	0.07	0.08	0.10	0.16	0.19	0.23	0.33	0.40	0.48	2.32	0.69	0.2283	17	95
M9	0.09	0.10	0.11	0.26	0.29	0.33	0.34	0.43	0.51	2.19	0.83	0.2746	4	54

Table 4.12 FTOPSIS analysis results for the analysis of the importance level of managerial dispute causes (continued…)

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
M10	0.08	0.09	0.11	0.25	0.29	0.33	0.37	0.46	0.54	2.17	0.85	0.2811	3	42
M11	0.07	0.08	0.09	0.20	0.23	0.27	0.27	0.34	0.42	2.35	0.66	0.2205	18	99
M12	0.08	0.09	0.10	0.23	0.26	0.29	0.27	0.34	0.42	2.31	0.70	0.2333	15	92
M13	0.10	0.11	0.12	0.28	0.31	0.34	0.36	0.43	0.50	2.15	0.86	0.2848	1	36
M14	0.07	0.08	0.10	0.20	0.24	0.27	0.25	0.31	0.37	2.37	0.64	0.2121	20	104
M15	0.09	0.10	0.11	0.23	0.26	0.30	0.33	0.40	0.47	2.24	0.77	0.257	6	72
M16	0.09	0.10	0.12	0.20	0.24	0.28	0.36	0.45	0.53	2.22	0.80	0.2648	5	59
M17	0.06	0.08	0.09	0.17	0.20	0.24	0.33	0.41	0.49	2.32	0.70	0.2313	16	93
M18	0.08	0.09	0.11	0.22	0.26	0.30	0.27	0.34	0.42	2.31	0.71	0.2342	14	90
M19	0.07	0.08	0.09	0.18	0.22	0.26	0.24	0.31	0.38	2.39	0.62	0.2072	22	106
M20	0.06	0.07	0.09	0.15	0.19	0.22	0.27	0.35	0.43	2.39	0.62	0.2051	24	108
M21	0.08	0.09	0.11	0.21	0.26	0.30	0.33	0.41	0.49	2.25	0.77	0.2542	7	73
M22	0.08	0.09	0.11	0.19	0.23	0.27	0.30	0.39	0.48	2.29	0.72	0.2404	11	84
M23	0.07	0.08	0.10	0.20	0.24	0.28	0.31	0.38	0.46	2.30	0.72	0.2377	12	87
M24	0.07	0.09	0.10	0.21	0.25	0.29	0.29	0.37	0.45	2.30	0.71	0.2359	13	89

The FTOPSIS analysis results of external factors showed that E3 (Economic factors (change in currency, etc.)), E18 (Credit tightening) and E19 (Increase in interest rates) are the most important and common external-based dispute causes for off-site construction projects. Global ranks of external-based dispute causes indicate that these dispute causes are important, but they stay behind other factors (See Table 4.13).

Table 4.13 FTOPSIS analysis results for the analysis of the importance level of external dispute causes

	Normalized Weighted Matrix									Results				
	O			S			D							
	a	b	c	a	b	c	a	b	c	D+	d-	CCi	Rank	Global Rank
E1	0,08	0,09	0,11	0,21	0,26	0,30	0,37	0,43	0,48	2,22	0,78	0,2607	5	68
E2	0,08	0,09	0,11	0,27	0,29	0,32	0,29	0,34	0,39	2,28	0,72	0,2403	9	85
E3	0,10	0,11	0,12	0,29	0,31	0,34	0,40	0,46	0,51	2,12	0,89	0,2955	1	27
E4	0,06	0,08	0,09	0,22	0,25	0,28	0,34	0,42	0,50	2,26	0,75	0,2493	8	79
E5	0,06	0,07	0,09	0,21	0,25	0,28	0,28	0,33	0,39	2,35	0,65	0,2177	15	100
E6	0,06	0,06	0,07	0,15	0,18	0,22	0,28	0,35	0,42	2,41	0,60	0,2006	19	110
E7	0,06	0,07	0,09	0,19	0,23	0,27	0,26	0,34	0,42	2,36	0,65	0,2164	16	101
E8	0,06	0,07	0,09	0,17	0,21	0,25	0,24	0,32	0,39	2,40	0,61	0,2028	18	109
E9	0,07	0,09	0,10	0,22	0,26	0,30	0,36	0,43	0,51	2,22	0,79	0,2624	4	65
E10	0,05	0,07	0,08	0,20	0,24	0,28	0,27	0,36	0,45	2,34	0,68	0,2255	13	97
E11	0,06	0,08	0,09	0,19	0,23	0,27	0,31	0,39	0,47	2,31	0,71	0,2349	10	91
E12	0,07	0,08	0,10	0,20	0,23	0,27	0,28	0,36	0,45	2,33	0,69	0,2276	12	96
E13	0,06	0,07	0,09	0,18	0,22	0,26	0,28	0,37	0,46	2,34	0,68	0,2251	14	98
E14	0,05	0,07	0,08	0,20	0,24	0,27	0,31	0,39	0,46	2,32	0,69	0,2305	11	94
E15	0,05	0,06	0,08	0,18	0,23	0,27	0,26	0,34	0,43	2,37	0,64	0,2132	17	103
E16	0,05	0,06	0,07	0,17	0,20	0,24	0,24	0,32	0,39	2,42	0,59	0,1963	20	111
E17	0,07	0,08	0,10	0,22	0,25	0,29	0,34	0,42	0,50	2,25	0,76	0,2532	6	74
E18	0,08	0,09	0,11	0,24	0,27	0,31	0,42	0,48	0,54	2,16	0,85	0,282	2	43
E19	0,07	0,09	0,10	0,25	0,28	0,31	0,40	0,46	0,52	2,18	0,83	0,2755	3	53
E20	0,07	0,09	0,10	0,24	0,27	0,31	0,32	0,40	0,47	2,25	0,76	0,253	7	76

4.3.3 Sensivity Analysis

Sensitivity analysis is used to evaluate the robustness of preference decisions of experts. The analysis is performed with the change of weights of main factors. Therefore, the observation on the ranks is realized and reported. In this study, the

weights of main factors (O, S, and D) that was founded with Pythagorean fuzzy AHP are changed in the FTOPSIS analysis. Six scenarios were generated according to the number of factors [65]. These scenarios are S1 (O: 0.123, S: 0.3387, D: 0.538), S2 (O: 0.123, S: 0.538, D: 0. 3387), S3 (O: 0.538, S: 0.3387, D: 0.123), S4 (O: 0. 3387, S: 0.123, D: 0.538), S5 (O: 0. 538, S: 0.123, D: 0.3387), and S6 (O: 0.3387, S: 0.538, D: 0.123). In the scenarios, S1 represents main analysis results.

The sensitivity analysis results for contractual dispute causes for off-site construction projects are presented in Figure 4.2. The analysis result indicated that C2, C6, C10, C20, C21, and C23 are sensitive, and they can show variety depending on the weights of criteria.

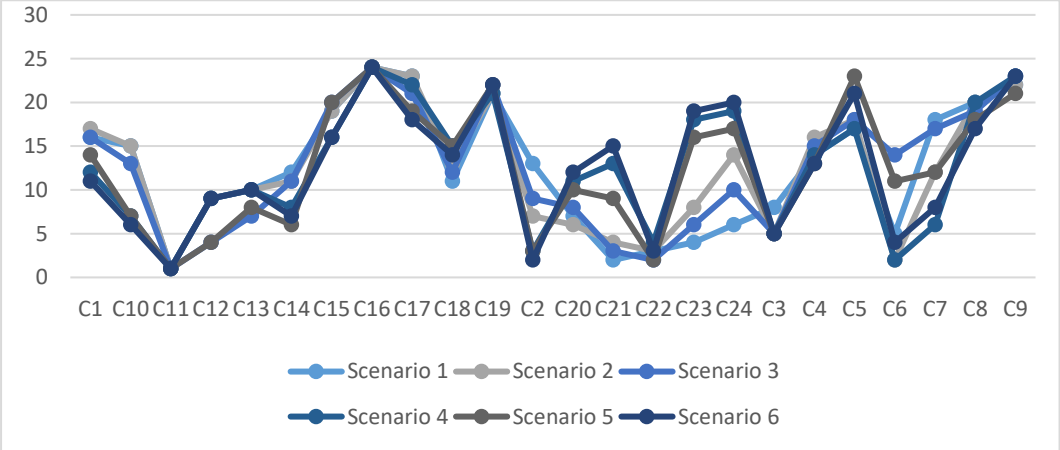

Figure 4.2 Sensitivity analysis for contractual dispute causes

The sensitivity analysis results for financial dispute causes for off-site construction projects are presented in Figure 4.3. According to the sensitivity analysis results, F1, F2, F7, F8, F9, F12 are sensitive dispute causes.

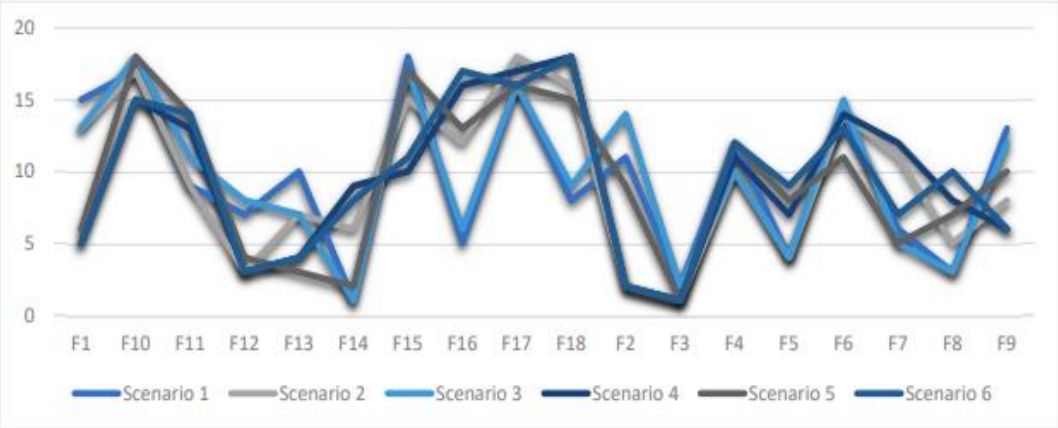

Figure 4.3 Sensitivity analysis for financial dispute causes

The sensitivity analysis results for technical dispute causes for off-site construction projects are presented in Figure 4.4. The analysis result shows that the results change little when the evaluation criteria (O, S, D) are changed sharply about 3 or 4 times. However, the ranking levels of factors are not changed sharply.

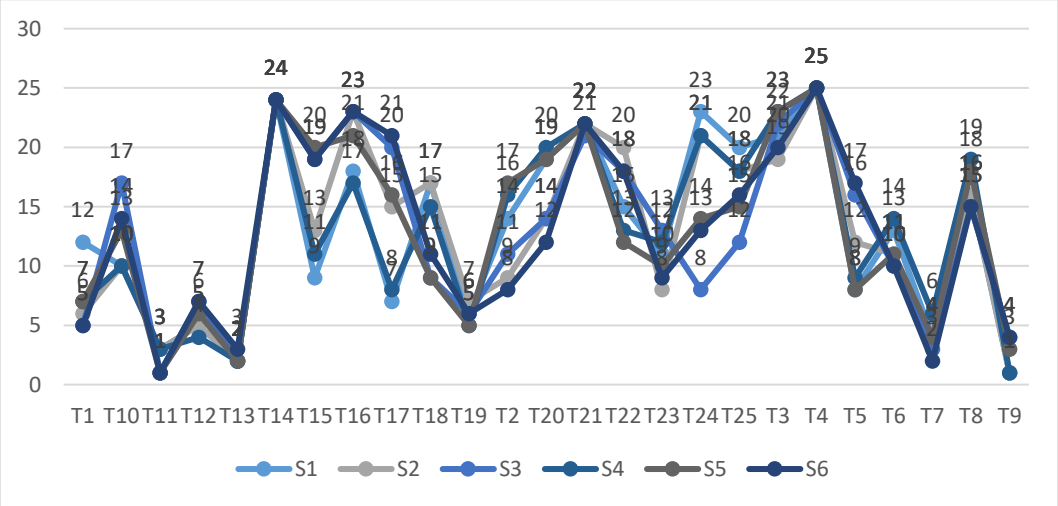

Figure 4.4 Sensitivity analysis for technical dispute causes

The sensitivity analysis results for managerial dispute causes for off-site construction projects are reported in Figure 4.5. According to the sensitivity analysis results, M2, M3, M6, M8, M17, and M18 are sensitive dispute causes.

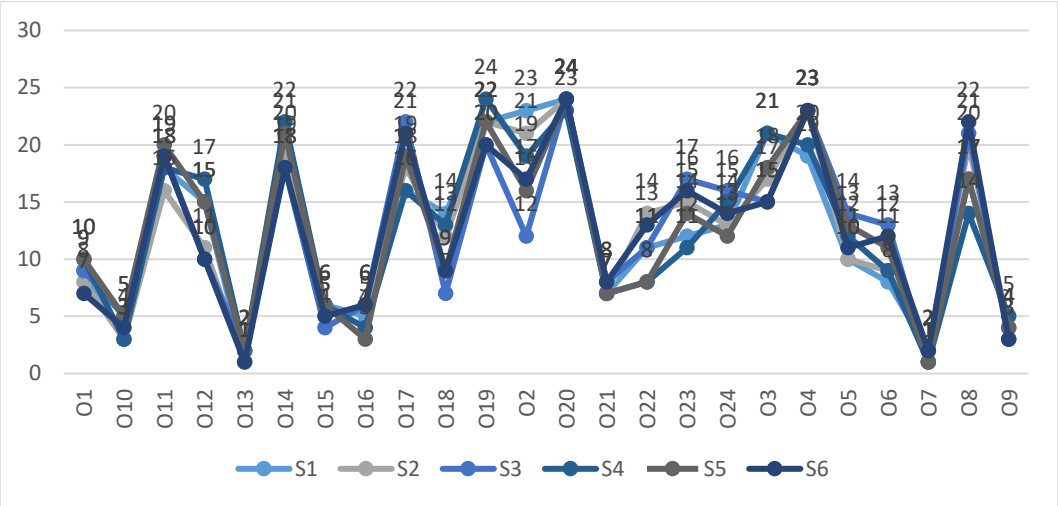

Figure 4.5 Sensitivity analysis for managerial dispute causes

The sensitivity analysis results for external-based dispute causes for off-site construction projects are reported in Figure 4.6. According to the sensitivity analysis results, E3 and E18 that are the most important dispute causes in external-based factors are not sensitive. However, E2, E5, E12, E13, and E14 were found as sensitive when the weights either approximately 3 or 4 times are changed.

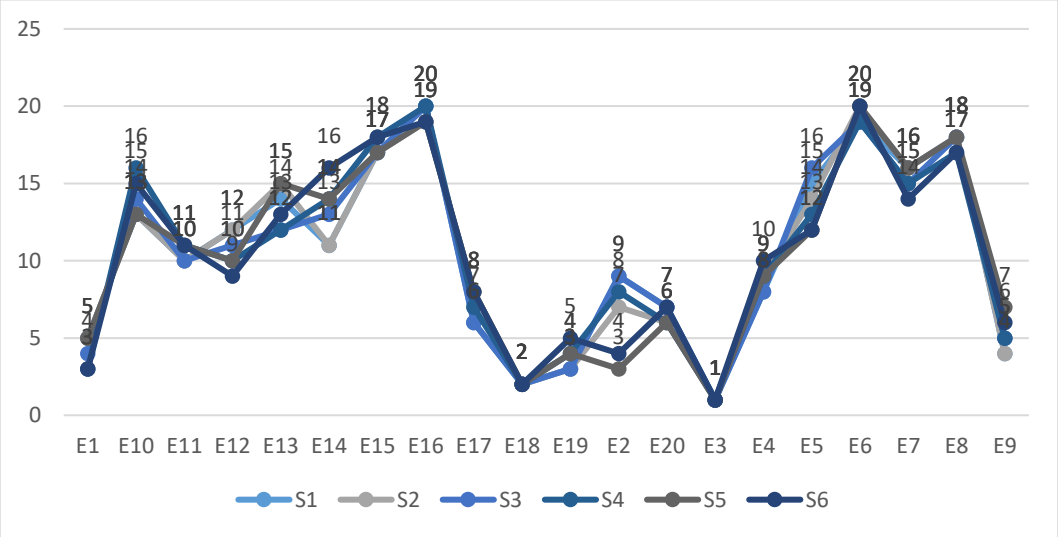

Figure 4.6 Sensitivity analysis for external dispute causes

However, although both some contractual, financial, technical, managerial and external-based dispute causes are sensitive depending on the value of criteria weights, the sensitivity of these dispute causes is clearly due to the increase in the weights of lowest criteria approximately three times (from 0.1233 to 0.3387) and four times (from 0.1233 to 0.538). Therefore, the analysis results for the main results were more satisfactory.

5
DISCUSSION

Off-site construction, an innovative method in the construction industry, offers many advantages such as time savings, labor savings, and waste reduction. However, there are several barriers to the adoption and implementation of off-site construction. These barriers are fundamentally rooted in the construction industry's cautious approach to innovation and technological developments, making it difficult to accept off-site construction methods [15]. Examples of these problems include the lack of standards in off-site construction, distrust of off-site products, and insufficient knowledge about this method. Since the product in off-site construction projects is produced at one location and assembled at another, the transfer phase must be well-planned to avoid project delays. Off-site construction projects involve managing tight schedules and meeting deadlines. Particularly, the importance of transportation and assembly activities is heightened due to their impact on product quality in off-site construction projects. Good communication and proper collaboration among project members will enable the smooth completion of the project process. However, issues in these areas can lead to cost overruns by deviating from the planned budget in off-site construction projects [66]. Considering all these differences, the causes of disputes may differ from those in traditional construction. Consequently, this study aims not only to increase the knowledge about off-site construction projects but also to identify the causes of disputes and thus alleviate industry professionals' distrust of this method.

According to the analysis results, the importance levels of dispute factor groups are as follows: contractual factors, financial factors, technical factors, managerial factors, and external factors. This outcome can be attributed to the significance and role of contracts in disputes. Contracts can prevent conflicts of interest among

stakeholders and maintain order in relationships. The subsequent prominence of financial factors can be related to the high initial costs due to production activities preceding assembly in off-site construction projects. Moreover, off-site construction management requires new technologies and different production methods during the production phase. This necessitates both additional financial resources and adequate technical equipment. Another aspect to consider is the correlation between transportation and assembly in off-site construction projects. This necessitates a management perspective unique to off-site construction projects. Additionally, the geographical, political, and economic context of the project's location can be evaluated in the context of off-site construction projects due to differences in production methods and techniques used.

First of all, according to the results obtained from the research, C11 (Increase in contract value due to revision in scope of work) and C21 (Illegal and improper work suspension) have emerged as the most significant contractual dispute causes in off-site construction projects. Throughout the process of construction projects, changes in design and scope can occur. Consequently, the scope of work initially assigned to subcontractors may change. Due to these changes, it is possible for the contract value to increase. However, disputes often arise between the employer and subcontractors regarding the extent of this increase. In off-site construction projects, where production and assembly occur in different locations, such disputes can significantly impact the project timeline. C21 (Illegal and improper work suspension) was found the most important second contractual dispute causes. The illegal suspension of works can jeopardize and deteriorate the relationship between parties. In addition to tense relationship between stakeholders, it will induce project delays, cost overruns, and harmful impact on the environment. Moreover, material procurement planned according to the contract can be affected severely. This won't only cause additional costs for materials, but also it will hamper the trust relationship between producers and suppliers.

Secondly, the most significant financial dispute causes in off-site construction projects are identified as F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)). Off-site construction projects are generally constructed with the use of fabricated components. The changes in the design and scope require additional costs for materials, labor and manufacturing

process. Even though the changes are seen unimportant, they can affect manufacturing processes negatively. Therefore, the scope of the work and compensation mechanism for changes should be clearly addressed in the contracts. Furthermore, change order management and approval procedures for the changes and their compensation are another important factor to reduce financial disputes by considering unforeseen conditions in the projects. F3 (Payment delays (owner based)) was found the most important second dispute causes for off-site construction projects. As is stated above, the production of off-site construction components requires upfront costs to procure materials, technologies and other expenses. If the delays in the payments are realized in the process, it can affect the cash flow of the manufacturers. Moreover, the dispute can jeopardize tense relationship between manufacturers and material suppliers. Additionally, it can activate the penalties in the contracts. Furthermore, if there are subsequent activities, it will also affect other parties. Therefore, the timeline for the payments should be clearly negotiated and defined in the contracts.

Within the context of technical disputes, T9 (Late completion, delivery, and installation of components) and T13 (Cost and time overruns) have emerged as prominent dispute causes. Off-site construction projects include interconnected building components that should be assembled on-site. Any delay in the completion or delivery of construction components will negatively affect the schedule and cause delays in the construction projects. Moreover, “Late completion, delivery, and installation of components” leads to cost overruns due to the additional expenses incurred for labor, equipment, storage of components, and penalties. Sometimes, contractors try to mitigate lost time. However, this can be detrimental to the quality of workmanship, safety, and assembly of components [11]. Also, material shortages or equipment malfunctions can delay the timely production and delivery of components. If the dispute is considered to be originated from the supplier, if the completion time is extended, it may be requested to advance the delivery and installation times, based on the contract. Moreover, “cost and time overruns” may be directly affected by “late completion, delivery, and installation of components.” However, “late completion, delivery, and installation of components” is not the only factor that causes time and cost overruns. Throughout the assembly of construction components, weather conditions can be the cause of

time overruns. Moreover, site conditions and possession can prolong the assembly of manufactured components. Change orders are not possible when the procurement process is completed. However, technical failures or unplanned changes can cause cost overruns and will affect the project's success [9]. On the other hand, to prevent cost and time overruns, it is crucial to be very knowledgeable about the project from the tendering process onwards. A competent contractor with technical proficiency can accurately forecast costs with well-informed price quotations, thereby preventing cost overruns and also accurately estimating the project duration.

According to the FTOPSIS analysis of the causes of managerial disputes, M13- "Poor planning and management of the project" was the most important cause of off-site construction projects. This dispute cause was followed by M7 (Lack of information exchange). Deficiencies in organizing, coordinating, and overseeing project-related activities may underscore poor planning and project management [34]. Using off-site construction components with conventional construction methods is a relatively new concept for professionals. In the conventional project planning, the schedule management is based on estimations and planners' experience. Therefore, professionals may be prone to error when predicting off-site production, transportation, and assembly. Moreover, materials needed for manufacturing off-site components are procured outside the control of owners or contractors. Resource shortages or any issue in the supply chain can hamper productivity, schedule management, and project management. Therefore, the planners and project managers should prioritize contingency planning to overcome these deficiencies. To avoid disputes caused by inadequate planning, adherence to work schedules should be ensured. Project progress should be monitored, and work schedules should be updated as necessary, paying special attention to critical paths. Inadequate project planning leads to disputes as well as additional costs [27].

It is important to deliver information to the stakeholders in a timely manner to avoid misunderstandings. The construction works require close collaboration of stakeholders to detect the need for off-site components and design them according to the project. If the collaboration level is low, it affects discrepancies between as-designed and manufactured components [32]. Moreover, it will affect the identification of specifications and standards. Therefore, the plans for M7 "information exchange" with the identification of responsible parties and their

delivery time can be an effective solution for preventing managerial dispute cause. The lack of information exchange is also crucial for internal organizational communication and can be seen as one of the major causes of disruptions in workflow. Therefore, efforts should be made to enhance internal communication within the organization, ensuring continuous information exchange. Additionally, establishing a communication matrix can facilitate the delivery of accurate information to the right individuals. Maintaining a professional level of communication among individuals is essential to ensure uninterrupted flow of information.

The economic constraints experienced during the pandemic have significantly affected the construction industry, which has been particularly strained by shortages in raw materials. Issues such as inflation and currency fluctuations have led to increases in the prices of materials, labor, and machinery, creating substantial obstacles to completing projects within the estimated costs [67]. Therefore, when investigating the causes of disputes in off-site construction projects, it is inevitable that the most important external factor will be E3 (Economic factors (change in currency, etc.)). Currency increases play an even larger role in projects that use materials procured from abroad. Consequently, at the start of the project, the economic conditions of the region where the project is located should be taken into account, cost estimates should be prepared accordingly, and budgets should be revised as necessary.

E18 – "Credit tightening" was found the most important second external off-site construction dispute cause. Credit tightening that is taken by the government has a significant impact on the financial stability of companies and individuals. If the access to credits or debts are restricted by the government, financing of off-site construction projects can be negatively affected [68]. As a result, if there are delays in payments to subcontractors, it could disrupt the progress of the work. Therefore, the contract clauses about financing or credits should be clearly declared. Also, the solutions for specific conditions for "Credit tightening" such as breach of contract, suspension of projects or seeking alternative financing options should be elaborated in the contracts. Furthermore, ratio for credits and capital stock can be determined in the contracts.

In existing literature, Nabi and El-adaway [11] identified the primary causes of disputes as delays in work progress, communication deficiencies, and lack of team spirit in one of their studies. In another study, they highlighted payment delays and defaults, lack of collaboration among different project segments, project completion delays, and poor communication among project participants as the main dispute causes [10]. Chan et al. [12], on the other hand, focused on contractual disputes and found that ambiguous contract terms, stakeholder-related confusions, and payment issues were the most significant causes of disputes.

Comparing these findings to the present study, which does not focus solely on court cases, it's evident that in terms of contractual disputes, the present study emphasizes the parts of the contract affecting the progression of work rather than the contract terminology itself. Financially, issues related to payment delays are consistently highlighted as significant causes of disputes in both the literature and the present study. Similarly, regarding technical causes, delays in project completion show alignment with the literature; however, the present study also identifies issues specific to off-site construction, such as the completion, transportation, and assembly of modules, which are not commonly seen in the literature.

Regarding managerial causes, while the literature often highlights communication and team spirit, the present study points to issues related to the transfer of information and the planning and management of the project. Despite this, there is some overlap between the findings of the literature and this study. Interestingly, unlike in this study, none of the literature works identified external factors as one of the primary causes of disputes. This discrepancy might be due to the fact that most literature studies did not categorize dispute causes comprehensively or focused exclusively on contractual causes. If categorization were removed in this study, external causes might not emerge as prominent.

In the study, dispute causes were collected from the literature without distinguishing between on-site and off-site construction. The data for the analysis was obtained from industry experts working in Türkiye. As a limitation, this study focuses specifically on Türkiye. Türkiye is a developing country and is economically dependent on the construction sector, which is also interconnected with other industries. However, it has been observed that construction activities in Türkiye often have negative environmental impacts [69]. The use of off-site

construction methods, which are innovative and environmentally friendly, remains quite low in the Turkish construction sector. The industry is still in the initial stages of adopting this method. Nevertheless, examples of off-site construction emerging after potential disasters have increased familiarity with this method in the sector. Prefabricated hospital buildings constructed during the pandemic and prefabricated homes built for temporary shelter after earthquakes are examples of this.

When examining the literature on off-site construction, global studies tend to focus on enhancing the applicability of off-site construction and integrating it with new technologies [70] whereas studies in Türkiye are primarily aimed at removing barriers to the adoption of off-site construction. Hence, if the limitations of this study were removed, it is likely that the results would differ.

In the construction sector in Türkiye, the main risks have been identified as working with insufficient numbers of workers, subcontractors, and personnel, inflation and price speculation, delays in responding to project change requests, and budget overruns [71]. When the causes of disputes are seen as risk factors, it is observed that the findings of this study align with the current situation in Türkiye. The study is also compatible with certain aspects of existing literature on the causes of disputes in off-site construction projects. However, since the construction sector in Türkiye is highly dependent on external factors such as economic conditions, this factor becomes more prominent in this research. Additionally, while previous studies have focused on the contractual structure, this study emphasizes specifying and avoiding situations in the contract that could hinder project progress. This approach is due to the inflationary environment in Türkiye, where any delay or extension of work may lead to budget overruns and negatively affect project success. Therefore, the findings of this study are particularly important for the off-site construction sector in Türkiye. However, in other countries where the inflationary environment is less significant, the results might differ.

In order to prevent these disputes from occurring, payment terms in the contracts of off-site construction projects should be clearly defined to avoid any ambiguity. Issues that cause delays should be identified and distinguished based on whether they originate from the employer or the contractor. Financial resources should be selected, taking into account the country's economic conditions, and an organization appropriate for the project should be established.

6
CONCLUSION

In recent years, off-site construction projects have gained significance in the construction industry due to their benefits such as providing safer working conditions, contributing to sustainability, reducing labor requirements, and shortening project durations. However, the construction industry is known to be quite traditional and resistant to change and innovation. Moreover, there is a lack of information available regarding off-site construction practices. Consequently, the adoption rate of off-site construction compared to on-site methods remains relatively low in the industry. Additionally, a review of the literature has indicated that the management practices and manufacturing processes in traditional construction projects differ significantly from those in off-site construction projects.

Due to the productivity and material shortages experienced by traditional construction methods in recent years, there is an increasing need for off-site construction. Therefore, to raise awareness among practitioners regarding off-site construction projects, it is necessary to increase the existing knowledge and address potential cost-related issues. When seeking information on dispute causes in off-site construction projects through literature review, it is observed that there are three studies specifically related to modular construction, which is one of the off-site construction terms. In these studies, the authors aimed to investigate dispute causes by analyzing litigation cases. However, resolving dispute causes before they escalate to litigation can greatly benefit stakeholders in terms of cost and time. Moreover, disputes can be resolved even before reaching the litigation process. Therefore, in this study, the questionnaire method was used to collect all dispute causes by leveraging the experiences of industry professionals.

In this study, the FGD, Pythagorean fuzzy AHP, and FTOPSIS methods were employed to identify contractual, financial, technical, managerial, and external dispute causes, calculate the weights of criteria, determine the weights of factor groups, and calculate the weights of factors. According to the research findings, it is observed that contractual and financial factor groups are the most significant factors. Additionally, the analysis results indicate that the detection of dispute causes holds more importance than the occurrence and severity of disputes. The factors were analyzed using the weights of the factor groups and criteria. According to the analysis results, in the contractual factors group, C11 (Increase in contract value due to revision in scope of work) and C21 (Illegal and improper work suspension), in the financial factors group, F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)), in the technical factors group, T9 (Late completion, delivery, and installation of components) and T13 (Cost and time overruns), in the managerial factors group, M13 (Poor planning and management of the project) and M7 (Lack of information exchange), and in the external factors group, E3 (Economic factors such as changes in currency) and E18 (Credit tightening) are the most significant dispute causes. Additionally, when a ranking encompassing all categories within these five groups was conducted, contractual factors emerged as the most significant category while on an individual basis F14 (Non-availability of spare money for additional work) and F3 (Payment delays (owner based)) are the most important dispute causes for off-site projects. Therefore, to prevent disputes, necessary attention should be paid to the contract preparation process and preparation of cash flow diagrams.

This study contributes both practically and theoretically by identifying the contractual, financial, technical, managerial, and external causes of disputes in off-site construction projects. Using the results of this study, researchers can improve standardisation by considering the most important causes of disputes. Since the causes of disputes point to the most important areas in off-site construction projects, understanding the causes of disputes and the root causes of their occurrence can serve as a pathway for off-site construction project management and dispute resolution methods. Properly designed and well-implemented project management by industry professionals can help prevent disputes in advance. Uncovering the causes of disputes can be used to implement and facilitate risk management. On the

other hand, this study can provide awareness for practitioners in the sector about the causes of disputes in off-site construction projects, increasing their contribution to dispute resolution and enabling disputes to be resolved in a shorter time. In essence, professionals in the industry can interpret the contractual, financial, technical, managerial, and external risks associated with off-site construction projects and devise strategies to mitigate them. Additionally, the results of the study can also be viewed as a checklist and used for improving contract clauses.

Future studies can utilize the results of this study as a foundation when conducting research on resolving dispute causes. Additionally, this study can be utilized in developing a project management strategy for off-site construction. It can also be considered in the preparation of regulations for off-site construction projects and can assist in the development of a contract model specifically tailored for off-site construction.

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A
QUESTIONNAIRE

YILDIZ TECHNICAL UNIVERSITY

CIVIL ENGINEERING FACULTY/ CIVIL ENGINEERING DEPARTMENT

The survey we prepared for this study evaluated the dispute causes found through a literature review that affect cost, time, and quality parameters in off-site construction projects, slow down the project delivery process, and cause conflicting cultures among project stakeholders.

Off-site construction involves planning, designing, and manufacturing a structure outside its permanent location and assembling it on-site. It includes prefabricated structures, modular construction, and precast elements.

Our survey has two parts. The first part contains questions about general information about the respondent and the company the respondent works for, which is used to test the reliability of the survey. The second part includes a section where your evaluations will be included.

Information such as the respondent's name and surname is not requested, and the results will not be used for any commercial purpose. I would like to thank you in advance for your support.

1. **Respondents' Information**

- Size of the company you work for:
- Your age:
- Your position in the company you work for:

- Your company's service period:
- Your company's international service period:
- Your experience in the construction sector:
- Your off-site construction project experience:
- Your profession:
- Your education status:

2. Instructions on how the questionnaire can be filled

The survey has three different evaluations. In the first of these, the criteria to be used in the next stage will be compared. A scale given below (Table 1) will be used for this purpose.

Table 1. Pythagorean fuzzy numbers

Linguistic terms	Pythagorean fuzzy numbers			
	The lower value of membership degree (μ_L)	The upper value of membership degree (μ_U)	The lower value of non-membership degree (v_L)	The upper value of non-membership degree (v_U)
Certainly low importance – CLI	0.00	0.00	0.90	1.00
Very low importance – VLI	0.10	0.20	0.80	0.90
Low importance – LI	0.20	0.35	0.65	0.80
Below average importance - BAI	0.35	0.45	0.55	0.65
Average importance - AI	0.45	0.55	0.45	0.55
Above average importance – AAI	0.55	0.65	0.35	0.45
High importance - HI	0.65	0.80	0.20	0.35
Very high importance – VHI	0.80	0.90	0.10	0.20
Certainly high importance – CHI	0.90	1.00	0.00	0.00
Exactly equal - EE	0.1965	0.1965	0.1965	0.1965

In short, you need to enter abbreviations indicating the degree of importance in each box. Such as EE or CLI etc.

An example.

The “Occurrences” and “Severity” were compared, and the “Occurrences” was found to be highly important. Then, enter HI in the cell.

Example	Occurrences	Severity	Detectability
Occurrences	EE	HI	
Severity		EE	
Detectability			EE

In the second part, it is expected that the dispute causes that emerged as a result of the literature review and FGD session will be evaluated according to the criteria stated above (“Occurrences,” “Severity,” and “Detectability”). During the evaluation, the evaluation table provided below (Table 2) should be used. In short, you need to enter a number in each box that indicates the importance level of the specified factor according to the criteria. For this, it is recommended that you use the evaluation table below.

Table 2. Linguistic scale

Fuzzy number	Linguistic	The scale of fuzzy number
1	Equal	1,1,1
2	Weak advantage	1,2,3
3	Not bad	2,3,4
4	Preferable	3,4,5
5	Good	4,5,6
6	Fairly good	5,6,7
7	Very good	6,7,8
8	Absolute	7,8,9
9	Perfect	8,9,10

Example	Occurrences	Severity	Detectability
Delivering Defective Modules	5	7	4

3. Comparison of Criteria

When scoring, please use the abbreviations given in Table 1. Do not take any action in the shaded areas.

	Occurrences	Severity	Detectability
Occurrences	EE		
Severity		EE	
Detectability			EE

4. Comparison of Main Dispute Factors

When scoring, please use the abbreviations given in Table 1. Do not take any action in the shaded areas.

	Organizational Factors	External Factors	Technical Factors	Contractual Factors	Financial Factors
Organizational Factors	EE				
External Factors		EE			
Technical Factors			EE		
Contractual Factors				EE	
Financial Factors					EE

5. Evaluation of Dispute Causes

Please use the values presented in Table 2 when scoring. Also, please consider the off-site construction projects.

Off-site Construction Projects' Dispute Causes	**Occurrences**	**Severity**	**Detectability**
Managerial Dispute Causes			
Poor management skills			
Request for acceleration of works			
Delays in approvals			
Unrealistic expectations			
Lack of professionalism			
Dispute resolution methods			
Lack of information exchange			
Unfamilarity with local conditions			
Lack of communication			
Lack of collaboration			
Poor negotiation skills			
Poor coordinattion of construction activity			
Poor planning and managing of the project			
Late giving of possesion			
Unsatisfiable salary			
Human behaviour related			
Lack of construction ethics			
Slowness of the owner's decision-making process			
Needs effective supply chain management			
The ability to manage the customers' expectations/the process			
Unclear instructions or fails to issue instructions in time by architects and engineers			
Diversity of working style among parties			
Lack of progress report and meeting			
Not following project specifications and variations initiated by the owner			
External Dispute Causes			
Government processes bureaucracy/approvals			
Disasters			
Economic factors (change in currency etc.)			
Political interest			
Changes in laws and regulations			
Country security problems, language barriers, different cultural traditions, and religious backgrounds			
Unfamiliarity with project geographical condition			
Weather			
State of sector			
Building code for offsite construction			
The legal system incompatible with the dispute resolution procedures in the contract			

Lack of legal awareness			
The complexity of the expressions in the law			
Taxation issue			
Contradiction among legal provisions			
Lack of awareness about the legal aid effect			
Transport restrictions			
Credit tightening			
Increase interest rates for compensation			
Inferences with utility lines			
Technical Dispute Causes			
Lack of experience			
Unavailability of materials			
Material testing technique			
Material/modules double-handling			
Lack of quality management			
Poor risk management			
Project uncertainty (insufficient details etc.)			
Complexity of project			
Late completion, delivery and installation of components			
Availability/Incompletion of information			
Project revisions			
Lack of advanced technology			
Cost and time overruns			
Unlikely industry readiness			
Need for systematic design of fault-tolerant systems			
Difference in construction technique			
Noncompliance to the design requirements			
Slowness of the contractor's decision-making process			
Time limitation in the design phase			
Technical inadequacy of the contractor			
Delivering defective modules			
Design standardization			
Late notification of technical changes			
Site conditions			
Changes incorporated apart from contractual agreements (inc. design)			
Contractual Dispute Causes			
Risk allocation			
Ambiguities in bidding			
Changes of scope			
Poor contract documentation			
Misrepresentation of contract documents			
Noncompliance to contracts terms			

Ambiguities in contracts			
Poor defined general provisions			
Mismatch contract type			
Ambiguities in contract clauses			
Increase in contract value due to revision in scope of work			
Excessive contractual variations			
Failure to examine contract conditions at the time of tender			
Errors and omissions of contract terms			
Legal text layout			
Problems of terminology			
Ineffective contract management & administration			
Unclear method to reduce the delay damages			
Unclear definition and types of defects			
Complexity in contract provisions			
Illegal and improper work suspension			
Opportunistic behaviour of project parties			
Breach of warranty claims			
Non-practical conditions			
Financial Dispute Causes			
Disagreement on payment method caused by variation of quantities			
Financial failure or inadequacy of contractor			
Payment delays (owner based)			
Adamant non payment			
Disagreement of the compensation amount			
Deductions			
Delays in compensation			
Denial of compensation			
Insufficient financial planning			
Loss to the client			
Non releasing of deposits			
Payment delays (contractor based such as delays in submitting progress payment claims, errors and insufficiency in submitted documents)			
Inadequate or delayed project funding			
Non-availability of spare money for additional work			
The low-profit margin			
Too much inference from client			
Untimely contractual payment			
Insufficient coverage of design liability insurance			

PUBLICATIONS FROM THE THESIS

Conference Papers

1. M. P. Yıldıran and G. Demirdöğen, "The Investigation of Dispute Related Studies in The Off-Site Construction Projects" *6. International Antalya Scientific Research and Innovative Studies Congress*, 2023.

Papers

1. M. P. Yıldıran and G. Demirdöğen, "Identification of Contractual and Financial Dispute Causes in the Off-Site Construction Projects," *Buildings*, *14*(8), 2530, 2024.