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Estimation of ideal construction duration in tender preparation stage for housing projects

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Abstract: Despite the potential of various methods for calculating construction duration, few studies have focused on the application of these methods in the tender preparation stage, and even fewer have focused on their application in public housing projects. Moreover, research related to construction duration in Turkey has indicated that considerable delays occur in public housing projects. Therefore, we investigated the factors affecting the construction duration of housing projects and developed a novel calculation method for estimating the ideal construction duration. Data on public housing projects were obtained from a major Turkish construction authority. Statistical data analysis was performed using multiple linear regression analysis, chi-squared automatic interaction detection (CHAID), and classification and regression tree (CART) methods. The results revealed that several factors significantly affected the ideal construction duration for each statistical method. The cutoffs and standard errors were calculated to test the validity of all three statistical methods. The regression formula indicated statistical significance when the calculation method was tested. The implementation of the methods for other public housing projects significantly reduced the number of delayed projects. The findings of this study are expected to contribute by way of enabling senior project managers to estimate the ideal construction duration for housing projects during the tender preparation stage.

Keywords: construction management, construction delays, ideal construction duration, Turkey, regression, CHAID, CART

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1 Introduction

Construction projects are considered successful if they are completed on time and satisfy other criteria such as cost, quality and stakeholder satisfaction (Chan and Kumaraswamy 2002; Majid 2006). The ideal construction duration must be estimated to avoid common delays, increase the efficiency of organisations and benchmark the execution of projects in the construction industry (Chan and Kumaraswamy 2002; Mensah et al. 2016). Effective planning and scheduling prevent delays, enhance construction project performance, and yield time and cost savings (Gibson et al. 2006; Luu et al. 2009; Ismail 2013; Lines et al. 2014; Tunç and Özsaraç 2015), whereas poor planning and scheduling negatively affect clients, contractors and owners (Ndekugri et al. 2008). However, few studies have been performed on planning and scheduling to estimate the construction duration during the tender preparation stage.

Time planning in the tender preparation stage is regulated by relevant laws and authorised organisations (International Federation of Consulting Engineers [FIDIC] 2017). However, a different state of affairs is observed in the public construction industry in Turkey (Yitmen and Dikbaş 2002; Birgonul et al. 2007; Erbaş and Çıracı 2013; Akkaynak 2014; Usta 2014), wherein legal regulations disregard planning and prioritize only the lowest tendered price (Türesoy 1989; Karapinar 2005; Tokalakoglu 2010; Kaplan 2012). Lower costs should not be the only basis for selecting contractors; time and performance factors should also be considered (Obodo et al. 2021). Moreover, better tender offer systems and effective plans focusing on development have not been implemented (DPT 2001, 2007; Turkish Republic Presidency of Strategy and Budget 2019). Although stakeholders in the construction industry emphasise construction duration, many contractors do not complete projects' work within the specified deadlines (Lin et al. 2011). Evidently, the on-time completion of construction projects is a prevalent issue, and projects in Turkey lack time planning.

In Turkey, the most significant factor affecting housing-project duration is cost (Odabasi 2009; Baltaci

2012). Arditi et al. (1985) surveyed public agencies and contractors involved in public construction projects in Turkey and classified the causes of delays as 'those influenced by national policies' and 'those that can be controlled by public agencies and contractors'. They found that the overall state economy influenced the construction duration. Sonmez (2019) emphasized that the total construction duration that affected the cost of housing projects could not be calculated using a single mathematical equation and that time-planning failures depended on the characteristics of the housing project. In practice, most methods for estimating construction duration depend on the 'subjective skill and cognition of the estimators and planners, rather than on objective assessment' (Lin et al. 2011). In Turkey, the Supreme Court adjudicates many legal disputes concerning housing-project delays (TOKI v Beneficiary[1] 2010, 2011, 2013, 2014, 2015). This has also been indicated by previous studies (Al-Khalil and Al-Ghafly 1999; Aibinu and Jagboro 2002; Odabasi 2009), suggesting that clients use modern planning and scheduling techniques in place of data obtained from previously completed housing projects. Therefore, a reliable estimation tool is needed owing to the complex nature of housing projects.

As mentioned previously, methods for calculating the construction duration during the tender preparation stage of public housing projects have not been extensively studied. Similar to other developing countries such as Nigeria (Mansfield et al. 1994; Elinwa and Joshua 2001; Ubani et al. 2013), Saudi Arabia (Bin Seddeeq et al. 2019; Alshihri et al. 2022), Malaysia (Endut et al. 2009; Memon 2014) and Indonesia (Kaming et al. 1997; Susanti 2020), Turkey suffers from construction delays and poor construction planning. Therefore, in this study, a novel method is developed to estimate the ideal construction duration and prevent delays in public housing projects by considering the influencing factors and evaluation criteria. The calculation method is compatible with the existing bidding system and is user-friendly. Therefore, it can be used for ensuring time saving as well as cost reduction. The method is based on data collected from construction authorities regarding construction duration in Turkey. The findings of this study are expected to enable senior project managers to estimate the ideal construction duration for housing projects during the tender preparation stage.

1 Random beneficiaries who are the future owners of the TOKI (Housing Development Administration of the Republic of Turkey) houses after mortgage payments are completed.

In Section 1, we review previous studies. In Section 2, we examine factors affecting construction duration by surveying the literature and identify the selected factors for the proposed model. Section 3 presents the research methodology; we explain how the relevant data were collected and describe the statistical methods used for analysis. Section 4 presents the results of the statistical analysis for our calculation method to obtain ideal construction durations for public housing projects. The final sections present a discussion and conclusions.

2 Literature review

The completion of housing projects within the specified construction duration is one of the main criteria for evaluating the performance of a construction company (Bromilow 1969; Chan and Chan 2004; Aibinu and Odeyinka 2006; Ting et al. 2021). However, delays in housing projects remain a common problem (Lin et al. 2011). Studies have indicated that only 12.5% of building contracts were completed within the scheduled periods, and the average completion time was approximately 40% longer than the contract duration (Bromilow 1969). Moreover, 40%–70% of these projects deviated from the original schedule, and some incurred delays that lasted for months (Al-Khalil and Al-Ghafly 1999; Blyth et al. 2004; Iyer and Jha 2005).

The duration of a construction project is often overlooked owing to incorrect assumptions or comparisons, and it is easily evaluated during the early stages of the project (Elinwa and Joshua 2001; Walraven and de Vries 2009; Ibironke and Elamah 2011; Oyedele 2013; Oyedele et al. 2015, 2021; Shokri-Ghasabeh and Chileshe 2016). In the tender-issue stage of a construction project, stakeholders seek a reliable estimation of the project duration (Qiao et al. 2019). The project duration must be estimated before beginning a project to complete the project in a timely manner (Thing 2006). Underestimation of the project duration may lead to disputes between the contractor and owner, and overestimation may reduce competitiveness during the tender-issue stage (Jin et al. 2016). Studies have indicated that planning and scheduling during the early stages of construction projects significantly impact the final project outcomes (Wang et al. 2012).

Various factors affect construction duration (Oo et al. 2022). Several factors that affect the construction duration at the pre-construction stage, as reported in the literature, are presented in Table 1.

Tab. 1: Literature review of factors affecting construction duration.

Authors	Factors affecting construction duration	Type of projects	Significance level
Kaka and Price (1991)	Project type, form and type of tender	Public buildings and civil engineering projects	
Chan and Kumaraswamy (1997)	Project characteristics, ground conditions, project design complexity, procurement scheduling and environmental factors	Building and civil works	
Kaming et al. (1997)	Weather conditions, project location, inadequate planning and project design	High-rise projects	
Chan and Kumaraswamy (2002)	Site condition, project characteristics, design aspects and pre-construction planning	Public housing, public non-residential buildings and private sector buildings	
Meeampol and Ogunlan (2006)	Construction method and schedule management	Highway construction projects	$p = 0.000$
Hoffman et al. (2007)	Project cost, design/construction agent and temperature	Facility projects	$p = 0.01$, $p = 0.0072$ and $p = 0.0028$
Salleh (2009)	Weather and site conditions, and inadequate planning	Residential, office, hotel, academic buildings and mosques	$p < 0.05$
Mauriya et al. (2010)	Geological condition, seismicity and difficult terrain	Tunnel construction	
Doloi et al. (2012)	Client's influence and improper planning	Construction projects	$p = 0.000$ and $p = 0.003$
Dursun and Stoy (2012)	Project type, project location, availability of construction area and market conditions	Buildings	$p < 0.05$
Shanmugapriya and Subramanian (2013)	Market conditions, contract modification and project location	Buildings, roads and bridges, industrial projects and others	–
Sweis (2013)	Planning and scheduling, and weather conditions	Public construction projects	–
Faremi et al. (2016)	Design and documentation issues, poor labour productivity and financial resource management	Construction projects	$p < 0.05$
Oyedele (2017)	Cash flow, type of design (complexity), project type, topography and geology, supply chain management and weather	Construction projects	–
Nayak (2019)	Environmental conditions, equipment and cash flow	Rural infrastructure projects	–
Mahmoodzadeh et al. (2022)	Geological conditions and machinery	Tunnel construction	$p = 0.000$

Note: In studies with no significance levels, the RII was used for factors affecting the construction duration.
RII, relative importance index.

Although project duration significantly affects project costs, the dependence of the cost on the complexity and size of projects, rate of return, cash flow, type of contract, priority of projects, previous experiences of the contractor, and geographical area are given more importance worldwide (Ahmad and Minkarah 1988; Shash 1993; Fayek et al. 1998, 1999; Hillebrandt 2000; Bageis and Fortune 2009; Jarkas et al. 2013; Alsaedi et al. 2019). Previous studies on estimating construction duration have mainly focused on the financial, economic (Türesoy 1989; Alaghbari et al. 2005; Shane et al. 2009; Musarat et al. 2021), climatic, geographical and topographic factors (Elhag et al. 2005; Shane et al. 2009; Cheng 2014;). Other factors that have been considered are the complexity and size of projects (Chevallier and Russell 2001), project priorities (Yang et al. 2014), supply and logistic conditions of the project region (Asnaashari et al. 2009; Ramli et al. 2018; Tunji-Olayeni et al. 2018; Nayak 2019) and social and cultural factors (Imbert 1990; Assaf and Al-Hejji 2006; Salleh 2009; Al-Sabah et al. 2014). Relative to the several factors considered in various studies, construction duration is mostly ignored.

Several methods have been developed for estimating construction duration according to these factors. Many studies have demonstrated the applicability of regression analysis for estimating the duration in the early phases of a project (Khosrowshahi and Kaka 1996; Lin et al. 2011). Simulation models have also been used to estimate construction duration. Sanni-Anibire et al. (2021) developed a machine-learning model that involved multilinear regression analysis (MLRA), k-nearest neighbours (KNNs), an artificial neural network (ANN), a support vector machine

(SVM) and ensemble methods for tall-building projects; the most crucial factor affecting construction duration was the total number of floors. Fan et al. (2021) used an ANN to estimate the construction duration in the preliminary stage and found that accurate durations could be obtained by using two-stage ANNs and feature selection via sensitivity analysis. Yogesh and Rao (2021) developed a system to estimate road construction duration using individual activity output rates and Delphi analysis. Yaseen et al. (2020) developed an accurate method using a hybrid artificial-intelligence model to estimate construction duration and monitor risk levels. Lines et al. (2014) demonstrated that a scheduling model used during the tender preparation stage could realise cost and time reductions of 44.0% and 44.9%, respectively. In another study, Lines et al. (2015) proposed a planning model for the tender preparation stage that reduced the cost and duration by 54% and 70%, respectively. Decision-tree algorithms, e.g. classification and regression tree (CART) and chi-squared automatic interaction detection (CHAID), are also used for estimating duration (Godinho and Costa 2004). However, there have been few studies on the use of the CART and CHAID algorithms in the construction industry. Lin and Fan (2019) used CHAID and CART to identify defects in public construction projects and reduce adverse delays. Pospieszny (2015) used CHAID to estimate the effort and duration required for software projects. Papatheocharous and Andreau (2012) developed a hybrid software cost estimation approach using CHAID and CART.

The time performance can be enhanced by selecting appropriate factors to reduce delays in construction projects. The construction duration should be estimated at the tender preparation and initial planning stages such that stakeholders can prevent potential disputes, as well as time and cost losses.

3 Selection of key factors

Delay factors hinder construction activities during construction and consequently affect the project completion time (O'Brien and Plotnick 1999). Research published over the past few decades has identified numerous factors that generate delays in construction projects. The delay factors encountered by many construction projects as reported by previous studies were remarkably similar (Doloi et al. 2012). Table 2 presents 56 factors that affect the construction duration; these factors were collected through a literature review.

Tab. 2: List of factors affecting construction duration from the literature.

No.	Factors	Factors encountered during the implementation stage	Factors encountered during the bidding stage	Factors caused by the contractor	Factors caused by the owner	Factors selected for the calculation method	Factors encountered during the bidding stage and caused by the owner	Authors
1	Delivery of material on time	+	–	+	–	–	–	Alaghbari et al. (2007), Asnaashari et al. (2009) and Tunji-Olayeni et al. (2018)
2	Productivity of labour	+	–	+	–	–	–	Faremi et al. (2016) and Smugala and Kubečková (2021)
3	Using an effective construction programme (schedule)	+	+	+	+	+	–	Chan and Kumaraswamy (2002), Sweis (2013) and Lines et al. (2015)
4	Design–implementation coordination	+	–	+	–	–	–	Faremi et al. (2016)
5	Recruitment of labour	+	–	+	–	–	–	Ahuja and Nandakumar (1985)
6	Changes in design	+	–	+	+	–	–	Shanmugapriya and Subramanian (2013)

(*continued*)

Tab. 2. Continued

No.	Factors	Factors encountered during the implementation stage	Factors encountered during the bidding stage	Factors caused by the contractor	Factors caused by the owner	Factors selected for the calculation method	Factors encountered during the bidding stage and caused by the owner	Authors
7	Seismicity of project location	+	+	+	+	+	+	Mauriya et al. (2010) and Mahmoodzadeh et al. (2022)
8	Sufficient number and experience of management staff	+	–	+	–	–	–	Lo et al. (2006)
9	Selection of subcontractors	+	–	+	–	–	–	Polat et al. (2015)
10	Project type and features	–	+	+	+	+	–	Dursun and Stoy (2012) and Oyedele (2017)
11	Effective organisation structure	+	–	+	–	–	–	Arditi et al. (1985)
12	Company-based financial issues	+	+	+	–	–	–	Lo et al. (2006) and Nayak (2019)
13	Technology used in construction	+	+	+	+	+	–	Chan and Kumaraswamy (2002)
14	Ensuring business continuity	+	–	+	–	–	–	Alfalasi (2016)
15	Ensuring additional drawings, specifications and technical details provided on time	+	–	–	+	–	–	Ahuja and Nandakumar (1985)
16	Scope changes	+	–	–	+	–	–	Arditi et al. (1985) and Shanmugapriya and Subramanian (2013)
17	Maintaining coordination between subcontractors	+	–	+	–	–	–	Hwang et al. (2013)
18	Motivation of labour	+	–	+	–	–	–	Nasirzadeh and Nojedehi (2013)
19	Natural disasters	FM	–	FM	–	–	–	Nayak (2019)
20	Degree of project difficulty	+	+	+	+	+	+	Kaka and Price (1991), Chan and Kumaraswamy (1997), Chan and Kumaraswamy (2002) and Oyedele (2017)
21	Design-planning coordination	+	–	+	–	–	–	Walker and Vines (2000)
22	Efficient auditing and control	–	–	+	+	–	–	Long et al. (2008)
23	Delays in site handover	–	+	–	+	+	–	Iyer et al. (2008)
24	Rational use of construction equipment	+	–	+	–	–	–	Oleinik et al. (2019)

(*continued*)

Tab. 2. Continued

No.	Factors	Factors encountered during the implementation stage	Factors encountered during the bidding stage	Factors caused by the contractor	Factors caused by the owner	Factors selected for the calculation method	Factors encountered during the bidding stage and caused by the owner	Authors
25	Having experienced staff during design phase	+	+	+	+	+	–	Oyewobi and Ogunsemi (2010) and Lessing et al. (2017)
26	Maintaining suitable site conditions	+	–	+	–	–	–	Dursun and Stoy (2012)
27	Implementation mistakes	+	–	+	–	–	–	Kaliba et al. (2009)
28	Extreme weather conditions	FM	–	FM	–	–	–	Kaming et al. (1997), Salleh (2009) and Oyedele (2017)
29	Sufficiency of design consultancy services	+	+	+	+	+	–	Le-Hoai et al. (2008)
30	Efficiency of engineers	+	–	+	+	–	–	Chan and Kumaraswamy (1995)
31	Selection of suitable construction equipment	+	–	+	–	–	–	Mahmoodzadeh et al. (2022)
32	Efficient use of information technologies	–	+	+	+	+	–	Li et al. (2005)
33	Experience in use of applied construction technology	+	–	+	–	–	–	Memon et al. (2012)
34	Equipment failures	+	–	+	–	–	–	Aibinu and Odeyinka (2006) and Mahmoodzadeh et al. (2022)
35	Excess bureaucracy	+	+	+	+	+	–	Abd El-Razek et al. (2008)
36	Adaptation to work and willingness to learn tasks	+	–	+	–	–	–	Doloi et al. (2012)
37	Selection of material	+	–	+	–	–	–	Koushki et al. (2005)
38	Financial risk of project	+	+	+	+	+	+	Arditi et al. (1985), Türesoy (1989), Hoffman et al. (2007) and Musarat et al. (2021)
39	Sufficiency of construction consultancy services	+	–	+	+	–	–	Alaghbari et al. (2007) and Hwang et al. (2013)
40	Claim issues and disputes between stakeholders	+	–	+	+	–	–	Al-Khalil and Al-Ghafly (1999) and Aibinu and Jagboro (2002)
41	Ground conditions and topography of construction site	+	+	+	+	+	–	Cheng, (2014) and Oyedele (2017)

(*continued*)

Tab. 2. Continued

No.	Factors	Factors encountered during the implementation stage	Factors encountered during the bidding stage	Factors caused by the contractor	Factors caused by the owner	Factors selected for the calculation method	Factors encountered during the bidding stage and caused by the owner	Authors
42	Communication with other authorities	+	–	+	+	–	–	Doloi et al. (2012) and Hwang et al. (2013)
43	Changes in importance levels of activities	+	–	+	+	–	–	Woolery and Crandall (1983) and Nguyen et al. (2013)
44	Emergency plans for unforeseen conditions, risk, and crisis management plans	+	+	+	–	–	–	Hosseinian and Reinschmidt (2015)
45	Document control and management	+	–	+	–	–	–	Faremi et al. (2016)
46	Suitability of contract for project type	+	+	–	+	+	–	Oyedele (2017)
47	Using imported materials	+	+	+	+	+	–	Odeh and Battaineh (2002)
48	Material storage facilities	+	–	+	–	–	–	Kumar and Cheng (2015)
49	Project procedures	+	+	+	+	+	–	Williams (2008)
50	Quality control	+	–	+	+	–	–	Aliverdi et al. (2013)
51	Distance to construction site	+	+	+	+	+	–	Ramli et al. (2018)
52	Applied tax policies and government incentives to construction industry	+	–	–	–	–	–	Chan and Kumaraswamy (1995) and Girth and Lopez (2019)
53	Legislative changes and legal regulations	+	–	–	+	–	–	Ahuja and Nandakumar (1985)
54	Preparation of reliable project programme (schedule)	+	+	+	+	+	–	Meeampol and Ogunlan (2006) and Salleh (2009)
55	Cultural, religious and social factors in project location	+	+	+	+	+	–	Assaf and Al-Hejji (2006) and Al-Sabah et al. (2014)
56	Theft	+	–	+	–	–	–	Haas et al. (2022)
Total		50	21	48	29	18	3	

+, Effective.
–, Not effective.
FM, force majeure.

Among the 56 factors presented in Table 2, the two FM factors were eliminated, and the remaining 54 factors were categorised into factors associated with the *tender stage* and those related to the *construction stage*. Since the proposed calculation method is to be used in the tender stage, only the 21 factors belonging to the tender-stage category were considered. The 54 factors were also categorised as *factors attributable to the employer* and *factors attributable to the* *contractor*, and only 29 factors belonging to the former were selected. In total, there were 18 factors belonging to both the *tender stage* and *attributable to the employer* categories, which were then considered for calculating the ideal construction duration. Next, these factors were examined individually with regard to their eligibility and applicability to statistical methods, and three factors were finally selected.

Eight factors used by construction authorities were selected, and their validity was crosschecked through a literature review to confirm that they were consistent with the selection criteria. These eight factors were the number of flats, number of working days with a schematic design or construction documents, number of non-working days, priority of the project, complexity of the project, special request for the project, logistic conditions of the project region and climatic conditions of the project region. The first three factors (number of flats, number of working days with a schematic design or construction documents, and number of non-working days) are combined and considered as one factor: the baseline construction duration (BCD).

The formula used by construction authorities to estimate the total construction duration for public housing projects is given below.

BCD (days) = (number of working days in Factor #2a corresponding to Factor #1) + (50 working days in case of use of Factor #2b) + (Factor #3) (1)

Here, Factors #1, #2a, #2b and #3 represent the number of flats, duration with construction documents, duration with a schematic design, and number of non-working days, respectively.

If the number of flats and construction documents are available in the tender stage, the corresponding duration with construction documents can be determined. The durations corresponding to ranges of the number of flats are as follows: 400 days for 0–250 flats, 500 days for 250–750 flats, 550 days for 750–1,250 flats, and 600 days for 1,250 or more flats (for example, the duration for a public construction project with 850 flats is 550 days). If a project uses a schematic design, 50 days are added to its duration with construction documents. Additionally, the number of non-worked days is added to the construction duration. The list of non-worked days by province was obtained from the Ministry of Environment, Urbanization, and Climate Change.

Other factors used by construction authorities are the priority of the project, complexity of the project, special request for the project, logistic conditions of the project region, and climatic conditions of the project region, which were shown to be effective for calculating the construction duration in various studies. In total, 11 key factors were selected as variables for the calculation method, and they are presented in Table 3.

Tab. 3: Description of factors used to determine the total construction duration for public housing projects.

Factors	Description of factors	Variable type
F1 + F2 + F3 (standardised)	BCD	Independent
F4	Priority of project	Independent
F5	Complexity of project	Independent
F6	Special request for project	Independent
F7	Difficulty of project	Independent
F8	Financial risk of project	Independent
F9	Logistic conditions of project region	Independent
F10	Climatic conditions of project region	Independent
F11	Seismicity of project region	Independent

BCD, baseline construction duration.

To quantify the effect of each variable on the construction duration, evaluation criteria values were used. For the first eight factors, the evaluation criteria values were set as '0, 1, and 2', where 0 indicates that the factor had no effect on the duration, and 1 and 2 indicate that the factor tended to reduce and increase the duration, respectively. For F9 and F10, the evaluation criteria values were set as numbers ranging from 1 to 7; a larger number corresponded to a more significant effect of the factor on the duration. For F11, the evaluation criteria values were coded with numbers ranging from 1 to 5; a larger number corresponded to a less significant effect of the factor on the duration.

4 Research methodology

A quantitative methodology was adopted in this study. The research method and procedure included two stages in line with the research objectives. In the first stage of the study, the statistical calculation methods were developed and validated, and in the second stage, these methods were tested and implemented.

4.1 Data collection

To develop and validate a method for estimating the ideal construction duration, data were selected from 3,500 public housing projects, which were obtained using the 'Projects Status Table'2 from the Public Housing Administration construction authority in Turkey. Some of the sample data pertaining to 1,530 housing projects in this Projects Status

2 Contact the corresponding author for raw data pertaining to public housing projects.

Table are shown in Appendix 1. Out of the 3,500 projects, only 2,800 completed projects were selected. There were 22 different types of projects, most of which (1,530) were public housing projects. Of the 2,800 construction projects in Turkey, 1,367 were delayed (i.e. approximately 49% of the projects were not completed on time). Of the 1,530 public housing projects, 720 were delayed. The ratio of the number of delayed public housing projects to the total number of public construction projects (720/2800 = 0.2571) was 25.71%. The ratio of the number of delayed public housing projects to the total number of public housing projects (720/1,530 = 0.4706) was 47.06%. Among all construction projects, housing projects exhibited the largest ratio of delayed projects (25.71%). Therefore, we developed a calculation method for only housing projects.

4.2 Statistical methods

MLRA with the backward elimination method and non-parametric CHAID and CART analyses were used to determine the factors affecting the ideal construction duration. MLRA is a statistical method that simulates the causality relationship between more than one independent variable and illustrates the extent to which the dependent variable is explained by the independent variables (Soong 2004).

CHAID is used to identify and analyse the classified dependent variables. The purpose of this analysis method, which is frequently used in data mining, is to divide the dataset, dependent variables and independent variables used in the analysis into subcategories that are more homogeneous. The reliability and accuracy of the analysis results depend on the division of the dataset into homogeneous subcategories (Ozdamar 2004).

CART is a non-parametric statistical method used to estimate categorical and continuous dependent variables. Depending on whether the dependent variable is continuous or discrete, CART provides regression or classification trees (Fu 2004). The decision tree is obtained by categorising the independent variables that affect the dependent variable into binary subgroups according to the interactions between the variables. Repetitive binary subgrouping continues until decision points are reached (Chipman and McCulloch 2000).

In regression analysis, the significance of the independent variables is evaluated using numerical rather than categorical variables. In contrast, the CHAID and CART methods introduce variables as decision trees instead of equations. Therefore, in this study, three different statistical analysis methods were used (one equation and two decision trees). These three methods were used to estimate the ideal duration to determine the optimal solution. Data analyses were performed using IBM SPSS 26.0. A p-value <0.05 indicates that the findings are significant at the level of 95%.

5 Results

5.1 Regression, CHAID and CART methods

The ideal construction durations obtained from the three methods were compared and analysed to determine the optimal calculation method.

Table 4 presents the results of the regression analysis. As shown, the ideal construction duration was significantly affected by the BCD (F1 + F2 + F3), priority of the project (F4), complexity of the project (F5), difficulty of the

Tab. 4: Results of the regression analysis.

Variables	R^2	β	t	P	VIF
Regression method	0.356	663.630	21.009	0.000**	
Standardised BCD (F1 + F2 + F3)		146.447	27.833	0.000**	1.160
Priority of project (F4)		−48.437	−3.733	0.000**	1.341
Complexity of project (F5)		−47.053	−4.057	0.000**	1.402
Special request for project (F6)		−0.029	−1.249	0.212	1.279
Difficulty of project (F7)		43.870	3.800	0.000**	1.047
Financial risk of project (F8)		−18.510	−2.326	0.020*	1.011
Logistic conditions of project region (F9)		−3.953	−1.716	0.086	1.088
Climatic conditions of project region (F10)		−13.676	−4.768	0.000**	1.045
Seismicity of project region (F11)		−0.024	−1.205	0.228	1.115

*$p \leq 0.05$.
**$p \leq 0.01$.
BCD, baseline construction duration; VIF, Variance Inflation Factor.

project (F7), financial risk of the project (F8) and climatic conditions of the project region (F10). A 1-unit increase in the BCD would result in the following increases: ideal construction duration, 146 days; complexity of the project, 47 days; priority of the project, 48 days; difficulty of the project, 43 days; financial risk of the project, 18.5 days; and climatic conditions of the project region, 14 days. Thus, the BCD (F1 + F2 + F3) had a major impact on the ideal construction duration.

The equation consisting of the significant variables was obtained as follows:

$$Y = 663.630 + 146{,}447 \times \text{Std.BCD} - 48{,}437 \times \text{F4} - 47.053 \times \text{F5} - 43.870 \times \text{F7} - 18.510 \times \text{F8} - 13.676 \times \text{F10}, \quad (2)$$

where Y represents the ideal construction duration.

In the CHAID and CART analyses, detailed decision trees[3] were used to estimate the ideal construction duration. In the CHAID tree diagram, the root node was divided into six groups in terms of the BCD (Plat. $p = 0.000$; $F = 163.239$; sd1 = 6; sd2 = 1,523), whereas the root node in the CART tree diagram was divided into two groups in terms of the BCD ($p < 0.05$).

As shown in Table 5, the regression analysis indicated that six variables, i.e. the standardised BCD (F1 + F2 + F3), priority of the project (F4), complexity of the project (F5), difficulty of the project (F7), financial risk of the project (F8) and climatic conditions of the project region (F10), significantly affected the ideal construction duration ($p < 0.05$). Similarly, the CHAID and CART analyses indicated that five and three variables, respectively, significantly affected the ideal construction duration ($p < 0.05$).

In contrast to the results of the regression method, the CART and CHAID analyses indicated that the logistic conditions of the project region (F9) were significant. In contrast to the results of the regression and CART analyses, the seismicity of the project area (F11) was determined to be a significant factor in the CHAID analysis. Special request for the project (F6) was not a significant factor for any of the three methods. The logistic conditions of the project region (F9) and priority of the project (F4) were found to be significant in both the CHAID and CART analyses. The CHAID and CART analyses provided alternative solutions for the calculation method using decision trees for all independent variables. The regression method did not categorise the effects of the independent variables but evaluated them as numerical outcomes in the form of an equation. The main purpose of all three methods was to estimate the optimal construction duration.

5.2 Results of statistical method

The CHAID and CART results were validated using 10-fold cross-validation, with training set (70%) and test set (30%) and standard error values were for the estimations. The enter and stepwise methods were used to validate the regression method.

5.2.1 Validation of the regression method

Collinearity exists if the tolerance is <0.1 or if VIF >10 (Yeom et al. 2018). The VIF of the ideal construction duration was <10; therefore, collinearity did not exist. Findings related to the enter and stepwise methods are presented in Table 6.

The results of the analysis indicated that the regression method was valid because the β, t and p values of the enter and stepwise methods were similar.

Tab. 5: Findings of the three statistical methods.

Variables	Regression	CHAID	CART
Standardised BCD (F1 + F2 + F3)	Significant	Significant	Significant
Priority of project (F4)	Significant	Significant	Significant
Complexity of project (F5)	Significant	-	-
Difficulty of project (F7)	Significant	-	-
Financial risk of project (F8)	Significant	-	-
Logistic conditions of project region (F9)	-	Significant	Significant
Climatic conditions of project region (F10)	Significant	Significant	-
Seismicity of project region (F11)	-	Significant	-
Special request for project (F6)	-	-	-

BCD, baseline construction duration; CART, classification and regression tree; CHAID, chi-squared automatic interaction detection.

3 Contact the corresponding author for detailed decision trees.

Tab. 6: Validity of the regression method.

	Group 1 (enter method)			Group 2 (stepwise method)		
	B	*t*	*p*	β	*t*	*p*
Regression variables	696.696	18.876	0.000**	646.473	21.562	0.000**
Standardised BCD (F1 + F2 + F3)	146.765	27.548	0.000**	148.020	28.551	0.000**
Priority of project (F4)	−55.102	−3.981	0.000**	−50.401	−3.897	0.000**
Complexity of project (F5)	−48.665	−4.179	0.000**	−47.116	−4.060	0.000**
Special request for project (F6)	−18.039	−1.329	0.184	−0.033	−1.431	0.153
Difficulty of project (F7)	43.636	3.781	0.000**	47.520	4.185	0.000**
Financial risk of project (F8)	−17.797	−2.231	0.026*	−18.340	−2.304	0.021*
Logistic conditions of project region (F9)	−4.285	−1.800	0.072	−0.037	−1.716	0.086
Climatic conditions of project region (F10)	−13.893	−4.835	0.000**	−14.443	−5.081	0.000**
Seismicity of project region (F11)	−5.978	−1.205	0.228	−0.014	−0.680	0.496

*$p \leq 0.05$.
**$p \leq 0.01$.
BCD, baseline construction duration.

5.2.2 Validation of the CHAID method

The estimation values ranged from approximately 36.600 to 42.500. The standard error was similar to that calculated using 10-fold cross-validation and differed from those obtained using the training (70%) and test sets (30%), as shown in Table 7.

Tab. 7: Validity of the CHAID method.

Method	Estimation	Standard error
CHAID	37,227.186	3,109.763
10-fold cross-validation	40,115.651	3,524.340
Training set (70%)	36,616.334	5,011.920
Test set (30%)	42,521.916	4,823.904

CHAID, chi-squared automatic interaction detection.

5.2.3 Validation of the CART method

The estimated values ranged from approximately 33.300 to 43.300. The standard error was similar to that calculated using 10-fold cross-validation and differed from those obtained using the training (70%) and test sets (30%), as shown in Table 8.

Tab. 8: Validation of the CART method.

Method	Estimation	Standard error
CART	33,379.264	3,166.306
10-fold cross-validation	41,092.216	3,860.222
Training set (70%)	43,341.801	5,111.257
Test set (30%)	41,189.758	5,133.594

CART, classification and regression tree.

5.2.4 Comparison of validity and descriptive statistics

A comparison of the validity results indicated that the regression method yielded results that were more accurate than those of the CHAID and CART methods, as shown in Table 9. The regression method can be used to estimate the ideal construction duration with respect to the six identified factors in future studies. The standard errors were similar among the three methods.

A comparison of descriptive statistics implied that the average ideal construction durations obtained using the CHAID and CART methods were slightly longer than those obtained using regression, with smaller standard deviations. The minimum and maximum values of the ideal construction duration differed significantly (Table 10).

Tab. 9: Comparison of the validity results of the regression, CHAID and CART methods.

Statistical methods	Number of significant variables	Estimation	Standard error
Regression	6	36,495.932	3,039.935
CHAID	5	37,227.186	3,109.763
CART	3	33,379.646	3,166.306

CART, classification and regression tree; CHAID, chi-squared automatic interaction detection.

The results obtained from the decision-tree method were similar to those obtained from the regression method. However, the results produced by the CHAID and CART methods were more significant and specific.

5.3 Results obtained from testing of the calculation method

Data for 40 delayed public housing projects were selected for the pilot study to test the calculation method. These public housing projects were chosen from among 3,500 projects listed in the 'Project Status Table' via random sampling. The 40 selected public housing projects out of 1,530 public housing projects were recently completed with delays. The number of test data points was kept above the minimum value to satisfy the normality condition (30 data points) (Field 2009; Cevahir 2020).

The regression formula with the variables that exhibited statistical significance in the regression method was applied to test the selected data. The regression formula results obtained using SPSS 26.0 were found to be accurate and conveniently achievable. Therefore, the test results of the calculation method were reliable. The pre- and post-test method values, including the number and percentage of delayed public housing projects, are presented in Table 11.

The application of the regression method to the test data reduced the number of delayed housing projects by 42.50% as the number of delayed housing projects decreased from 40 to 23.

Pre-test delays were obtained from the test data. As shown in Figure 1, the post-test ideal construction durations were significantly longer than the durations determined by the construction authority. In addition, the ideal construction durations were slightly longer than the BCDs, and the logarithmic trend lines of the two durations were parallel.

Tab. 10: Descriptive statistics for the ideal construction duration.

Methods	Number	Average (days)	Standard deviation	Minimum
Regression	1,530	679.16	133.20	387
CHAID	1,530	704.38	113.13	635
CART	1,530	705.98	109.50	640

CART, classification and regression tree; CHAID, chi-squared automatic interaction detection.

Tab. 11: Test results for the developed calculation method.

	Pre-test	Post-test
Number of delayed housing projects	40	23
Delay percentage	100%	57.50%
Reduction amount of delayed housing projects (%)	42.50	

As shown in Figure 2, the post and pre-test delays and the number of delayed housing projects decreased significantly. The post-test delays were calculated by subtracting the ideal construction durations obtained using the regression formula from the actual completion time of the housing projects in the test data. Positive values indicated that the delays, though still present, were reduced, whereas negative values indicated that the delays were prevented.

5.4 Results obtained via implementation of proposed calculation method

The ideal construction duration obtained using the developed calculation method and the results calculated by construction authorities were compared using the data for 1,530 public housing projects. While calculating the ideal construction duration of each public housing project in the data file, factors that were found to be significant by each statistical method were used, and the values of the evaluation criteria were simultaneously assigned.

For the implementation of the proposed calculation method, the ideal construction durations were replaced with the contract periods for all 1,530 public housing projects, and the delays were recalculated. Out of the 1,530 projects, 720 were delayed before the proposed calculation method was implemented. The numbers and rates of delayed public housing projects calculated for each statistical method after the implementation of the proposed calculation method are presented in Table 12.

As shown in Table 12, after the implementation of the proposed calculation method, the number of delayed public housing projects decreased to 350 for the regression method, corresponding to a percentage reduction of 22.88%. For the CHAID method, the number of delayed public housing projects decreased to 285 (18.63%), whereas it decreased to 299 (19.54%) for the CART method.

The results for the implementation of the proposed calculation method indicated that the calculation method reduced the delays and number of delayed public housing projects. The calculation method was shown to be meaningful and valid, and it supported the optimisation of the ideal construction duration, which was the main objective of this study.

6 Discussion

In project management, one of the most difficult tasks is to estimate the ideal project duration. Our results

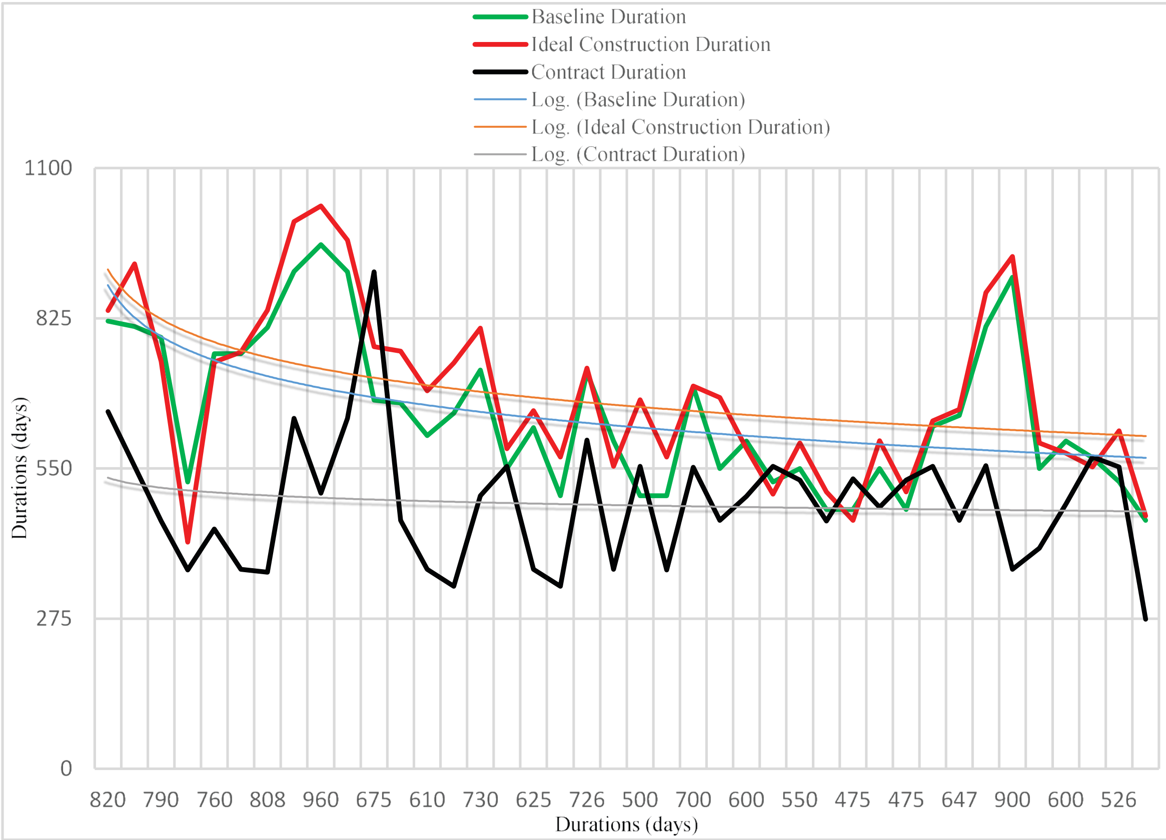

Fig. 1: Comparison of the post-test BCD, ideal construction duration and contract durations. BCD, baseline construction duration.

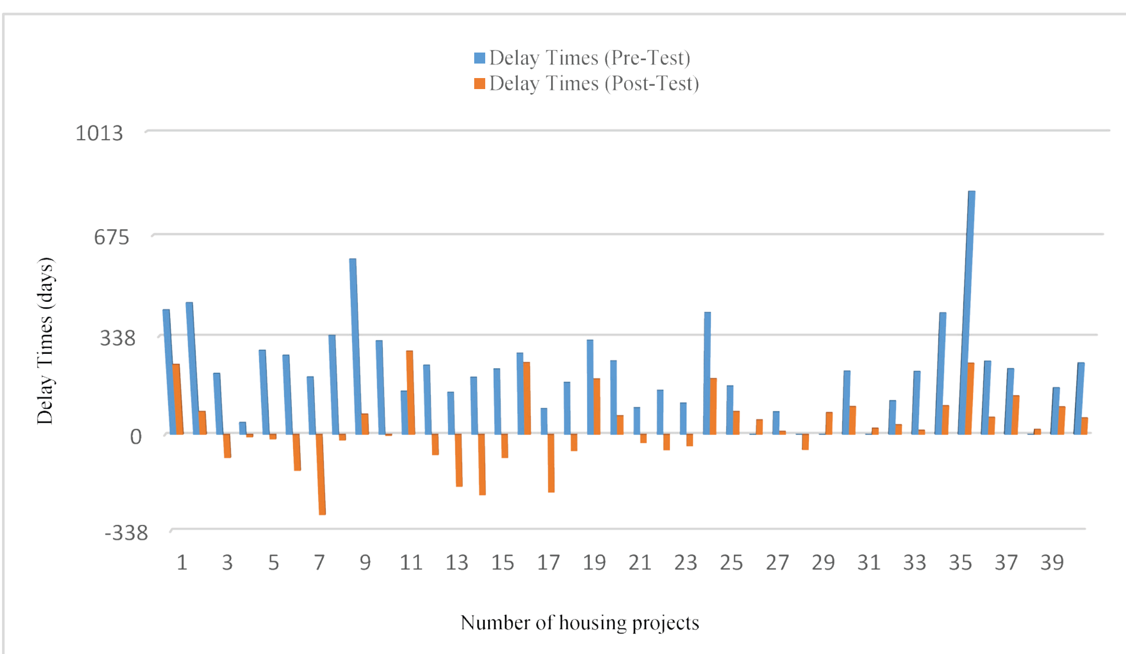

Fig. 2: Comparison of the pre- and post-test delay times of public housing projects.

Tab. 12: Results for the implementation of the proposed calculation method.

	Before implementation	After implementation		
Number of delayed public housing projects	720	350	285	299
Percentage of delayed public housing projects (%)	47.06	22.88	18.63	19.54
Amount of decrease for delayed public housing projects (%)	51.39		60.42	58.47

indicated that construction delays can be reduced using the proposed calculation method, as suggested by previous studies concerning related methods. A similar study by Lin and Fan (2019) demonstrated that the CHAID and CART methods exhibit good accuracy for predicting defects in public construction projects, which have an indirect effect on completion time in that they result in a prolongation of the desired completion time. Papatheocharous and Andreau (2012) developed software to estimate project costs using CHAID and CART. In both of these papers, alternatives to traditional techniques such as regression were proposed, along with the use of analogies considering the problematic nature of public project data. However, in these studies, larger datasets were needed to evaluate the accuracies of the CHAID and CART methods. Moreover, no research has been conducted on the use of CHAID and CART to estimate the construction duration of public housing projects. Studies have been performed on alternative methods for project duration evaluation in the construction industry. For example, the linear scheduling method and Delphi process were used to assess highway building projects, and it was concluded that various risks and the production rates of activities are important for estimating project duration (Yogesh and Rao 2021). Yeom et al. (2018) used MLRA to estimate the project duration for office buildings in the planning phase. Their model provided accurate results with regard to duration prediction, as well as ease of use for owners and other stakeholders. It is important that these models present data and results in a simple and accurate manner such that the users can easily understand how and which data should be used. In other studies focussing on the pre-planning phase of construction projects, similar results were obtained using different methodologies. The use of AAN and sensitivity analysis exhibited good accuracy for estimating construction duration considering the simulation of complex behaviours, which is a limitation for regression analysis and other traditional methods such as standard-curve models (Chao and Chien 2010; Fan et al. 2021). Ujong et al. (2022) showed that the duration prediction performance of the ANN model is better than that of MLRA for buildings. However, ANN has limitations for determining various control features considering input–output processes, and the construction duration can be determined by considering critical activities rather than via the summation of all activities (Fan et al. 2021). Additionally, inaccurate training data can affect the predictive accuracy of and distort ANN models during their development, as they are data-driven models (Adul-Hamid 1996). Conversely, an action-based research methodology was used by Lines et al. (2014) to develop a scheduling model for the tender stage, and they showed that their model could reduce cost and time overruns by up to 44.0% and 44.9%, respectively. Similar findings were obtained by Lines et al. (2015) for construction cost and duration.

Regression analysis evaluates the significance of the independent variables numerically rather than categorically. In contrast, the CHAID and CART methods introduce variables as decision trees instead of equations. Regression analysis is used to predict continuous outcomes, while CHAID and CART are used for classification and segmentation tasks. The choice of technique depends on the research question and the type of data being analysed. The type of data for housing projects in this study involve both continuous and categorical data. For example, a categorical ranking was made by considering the values in the ranking of the geographical regions in Turkey according to the number of rainy days (precipitation). As an evaluation criterion for Climatic Conditions of Project Region (F10), '1' represents the geographical region that receives the least amount of precipitation and '7' represents the highest precipitation. Likewise, F9 and F11 are categorical variables that should be evaluated by classification methods such as decision trees. Overall, to improve the evaluation method used by the construction authority, involving calculation of the ideal construction duration by means of an accurate equation, regression would be needed. On the other hand, CHAID and CART are preferred when the need is felt for an accurate computation of the ideal construction duration, owing to categorical data in the factors affecting housing projects, such as F9, F10 and F11. These three methods were used to estimate the ideal duration to determine the optimal solution. Therefore, the cons of regression analysis for categorical variables is fixed by decision trees while the need for an equation is resolved by regression.

The goodness of fit of a regression model is measured by varying R^2 values between 0 and 1. It is difficult to suggest a rule for how appropriate R^2 is due to its varying value by research area. For example, R^2 values of 0.90 and higher are common in longitudinal studies while values around 0.30 are common in cross-sectional designs, and R^2 values around 0.10 are acceptable for exploratory research using cross-sectional data (Mooi and Sarstedt 2011). Since the study was exploratory and cross-sectional data were used, the R^2 value of 0.356 can be considered acceptable. In addition, since a large number of independent variables, such as the six variables employed in the present study, were used in the regression analysis, it is an expected result that the deviations increase and the R^2 value decreases due to the numerator being 'the regression sum of the variance of squares', while the denominator the 'total sum of the variance of squares' in the R^2 equation (Lewis-Beck 1980; Hagquist and Stenbeck 1998). The CHAID and CART results were validated using 10-fold cross-validation, with 70 training sets and 30 test sets, and standard error values were derived for the estimations. The standard deviation increases and an overtraining problem can occur when 90%/10% is used for the training and data set (Geng et al. 2015). Besides avoiding this problem, studies also suggested that 70%/30% was found to have the highest classification success compared to 60%/40% and 75%/25% (Koc and Ulucan 2016; Aksoy and Boztosun 2021).

7 Conclusion

The objective of this study was to develop a novel calculation method for the ideal construction duration. The factors used by construction authorities to determine the BCD were proven to be insufficient. Additional factors from the literature were needed to achieve more accurate duration predictions. Using the proposed calculation method reduced the number of delayed public housing projects and associated delay times. Therefore, the results indicated that the proposed calculation method was useful and valid, and the objective of the study was achieved. This method can also be used to determine the ideal construction duration, which can ensure the on-time completion of public housing projects and prevent delays. This will improve cost management and result in fewer disputes among stakeholders.

The results of a statistical analysis indicated that all three investigated statistical methods were valid. The regression method yielded results that were more accurate than those of the CHAID and CART methods. Therefore, in future studies, the ideal construction duration based on six identified factors can be predicted using the proposed regression method (Table 9). Although the CHAID and CART methods exhibited lower performance than the regression method, they required fewer factors to estimate the ideal construction duration. Therefore, it was proven that the ideal construction duration could be calculated using all three methods. All factors that exhibit significance in any of the investigated statistical methods should be considered in the estimation of the ideal construction duration.

This study had three limitations. First, the proposed calculation method involves only public housing projects because the majority of Turkish public construction projects are public housing projects, which incur major delays. Second, the proposed method is limited by the accuracy of public construction project data, which may influence its predictive accuracy. Third, key factors identified as having significant impacts on the construction duration in previous studies were only partially included because many factors are not related to the pre-construction (procurement) stage. Therefore, only the factors affecting the construction duration at the procurement stage were considered in this study.

We developed a practical and consistent project management tool using the proposed calculation method. It can be used to prevent problems during the tender stage and lead to fewer risks during the construction stage. In future research, the proposed calculation method can be applied to a digital environment and converted into computer software to ensure ready availability and that a greater number of users have access to it, as well as accommodate international users and authorities such that it can be utilised worldwide.

8 Data availability statement

Raw data were generated at TOKI (Housing Development Administration of the Republic of Turkey). Derived data supporting the findings of this study are available from the corresponding author on request.

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Appendix 1. Sample data for 20 construction works.

Project No.	Construction project description	District	Number of flats	Number of working days with construction documents	Number of working days with schematic design	Number of non-working days	Contract duration (days)	Number of time extension	Delay (days)
1	North Ankara city entrance 7th stage 318 houses, 1 commercial centre, infrastructure and landscaping	Altındağ	318	500	550	145	505	1	0
2	North Ankara city entrance villas 584 houses, 3 elementary schools, 1 kindergarten and mosque, infrastructure and landscaping	Altındağ	584	500	550	388	554	1	681
3	Elazig city centre 336 houses and social facilities (mosque, fountain, trade centre, library) infrastructure and landscaping	City centre	336	500	550	120	365	1	0
4	Isparta 96 houses, 1 trade centre, infrastructure and landscaping	Yalvaç	96	400	450	90	504	0	0
5	Karabük 2nd region 432 houses, 1 primary school, 2 trade centres, 1 mosque, infrastructure and landscaping	City centre	432	500	550	105	44	1	359
6	North Ankara city entrance 477 houses, infrastructure and landscaping	Altındağ	477	500	550	165	651	1	0
7	North Ankara city entrance 488 houses, 1 unit centre, 1 nursery, infrastructure and landscaping	Altındağ	488	500	550	165	651	1	0
8	North Ankara city entrance 799 houses, 1 unit centre, infrastructure and landscaping	Altındağ	799	550	600	175	654	1	0
9	Trabzon urban transformation project 96 houses, 1 health centre, infrastructure and landscaping	Çağlayan	96	400	450	97	554	1	0
10	Trabzon Çamlı area 88 houses, infrastructure and landscaping	Of	88	400	450	97	454	1	0
11	Tunceli city centre Atatürk neighbourhood 222 houses, trade centre, infrastructure and landscaping	City centre	222	400	450	150	483	1	0
12	Ankara upper Yurtçu Kuyupınar area, 3rd region 1272 houses, 1 commercial centre, infrastructure and landscaping	City centre	1,272	600	650	160	514	0	0
13	North Ankara city entrance, 3rd stage 530 houses	Altındağ	530	500	550	120	505	1	730
14	North Ankara city entrance 341 villas, infrastructure and landscaping	Altındağ	341	500	550	360	602	1	444
15	Ankara 5th region 226 houses, 1 primary school, 1 high school, infrastructures and landscaping	Yapracık	226	400	450	360	654	1	427
16	Ankara 196 houses, trade centres, mosques, fountains, infrastructure and landscaping	Haymana	196	400	450	360	554	1	451
17	Antalya revenue sharing business for urban service area	Çıplaklı	406	500	550	0	548	1	478
18	Antalya 892 houses, infrastructure and landscaping	Çıplaklı	892	550	600	0	395	1	539
19	Bingöl 89 farm village houses, infrastructure and landscaping	Kiğı	89	400	450	150	404	0	0
20	Bolu city centre Paşaköy 2nd stage 500 houses, 1 commercial centre, health centre, infrastructure and landscaping	City centre	500	500	550	240	454	1	211