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# Selecting an Alternative Concrete Batching Plant Location Using IT2 Fuzzy ANP Methodology

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**Abstract:** Ready-Mixed Concrete started to be used after the 1970s, and its importance has gradually increased in recent years. The rapid development of the construction industry in our country in recent years has contributed to the rapid development of Ready-Mixed Concrete plants. Because of this reason, in this study, the concrete plant's location is determined using the Interval Type-2 Fuzzy Analytic Network (IT2 FANP) methodology. As a result of this methodology, the ranking of the alternative concrete plant's location is found as Basaksehir, Ikitelli, and Bagcilar, respectively. To the authors' knowledge, this is the first study in the literature that searches for an alternative concrete batching plant location using Interval Type-2 (IT2) Fuzzy Multi-Criteria Decision Making (MCDM) techniques. The problem may be examined using various MCDM methodologies, and further solutions for selecting alternate concrete plant locations can be researched in the future. The value of this study is that it fills in a gap in the existing literature and serves as a foundation for future research in this sector.
**Keywords:** Ready-Mixed Concrete; concrete batching plant; location selection; decision making; IT2 FANP; Multi-Criteria Decision Making (MCDM)

## 1. Introduction

Although Ready-Mixed Concrete was first used in our country in the 1970s, the construction started in the early 1990s, and the building became widespread in the early 2000s. Today, manual concrete casting is almost nonexistent. Ready-Mixed Concrete technology has become so widespread that nearly every district has at least one concrete plant.

In addition to the widespread use of ready-mixed concrete, the production of concrete in our country has increased in recent years in parallel with the development of the construction industry. Production dimensions in the sector have increased; since 2009, it has become the country with the maximum production in Europe.

Concrete, which has a vast usage area today, has become the most used material after water. Concrete is the essential building material that is economical, safe, durable, and does not require much maintenance. Concrete is chosen with a very high percentage of more than 99% in-house selection in our country [1].

The reasons for the rapid increase in ready-mixed concrete construction in recent years are:

- Growth in the construction industry in recent years,
- The increase in the supply of housing (Mass Housing and Public Partnership Administration's (TOKI's) house constructions throughout the country has been effective), and there are significant projects where ready-mixed concrete is used extensively,
- Selecting the most reinforced concrete structures in Turkey,
- Ready-mixed concrete is cheap, economical, and easy to use,
- It facilitates the supply of ready-mixed concrete thanks to the concrete batching plants opened all over Turkey.

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A concrete batching plant is a system for the production of fresh concrete, consisting of storage parts, combining and blending aggregate, cement, water, and additives when necessary, mixing, obtaining new concrete, and discharging the fresh concrete into the mobile concrete mixer with a trans mixer [2]. The primary element that distinguishes ready-mixed concrete from the concrete prepared at the construction site by hand or mixed with a concrete mixer is the production of ready-mixed concrete in modern establishments with computer control. The qualities that ready mixed concrete users will look for in ready mixed concrete are included in the Turkish Standardization Institute, TS EN 206 [3].

The first scientific study on ready mixed concrete in Turkey was made by Öztekin et al. [4]. In this study, fresh concrete temperature, slump, and compressive strength were investigated to compare the quality of ready-mixed concrete at the plant exit and on-site delivery. As a result of the research, it has been stated that the transportation time, air temperature, and humidity of fresh concrete are adequate for its workability (consistency) [4-6].

The choice of establishment location is one of the most basic and critical strategic decisions that should be considered during the establishment phase. Making this decision wrong significantly reduces future efficiency and competitiveness from a micro point of view. Because the supply of inputs to be used by the enterprise and the effective marketing of the outputs will keep some problems (production costs, transportation expenses, marketing, administrative expenses, etc. high, problems experienced in the supply of work energy of the desired quality) on the agenda. From a macro point of view, it is seen that it prevents the effective use of the country's resources. The selection of the establishment location is made depending on many factors. Due to the nature of this selection, these factors have both quantitative and qualitative characteristics. Persons and managers in the position of decision-makers need a decision support system that will examine these factors in a very complex structure and number, regardless of the limits of the human brain, to make these decisions healthily.

IT2 Fuzzy Set (FS) is a special version of the generalized Type-2 (T2) FS. Many literature studies were done to develop IT2 FS [7-12]. First, to solve a problem, it is necessary to decide. Many areas are faced with decision-making problems. Issues that have multiple criteria and choose one of the alternatives are included in MCDM problems. Many studies using MCDM techniques can be found in the literature [12-25].

IT2 FANP method can also be used to solve MCDM problems. Senturk et al. [26] proposed a new approach, a Fuzzy Analytic Network (FANP) method with interval type-2 fuzzy sets. Wu and Liu [27] proposed the FANP method with IT2 FSs to evaluate the Enterprise Technology Innovation Ability (ETIA). Senturk et al. [28] developed a new IT2 FANP methodology to model a Third-party Logistics (3PL) company selection problem. Ozdemir et al. [29] proposed a new hybrid model based on Interval Type-2 Fuzzy Analytic Network Process (IT2 FANP) and Interval Type-2 Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (IT2 TOPSIS) for the evaluation of store plan alternatives produced with rule-based design method. Ozdemir et al. [30] prioritized store plan alternatives using the Interval Type-2 Fuzzy Analytic Network (IT2 FANP) methodology, and the best alternative for store plans was selected.

Studies related to concrete batching plants in the literature were examined. There are very few studies using MCDM techniques in this area. Simsek et al. [31] used a TOPSIS-based Taguchi optimization to determine optimal mixture proportions of the high-strength self-compacting concrete. Simsek and İc [32] made a fuzzy Failure Mode and Effect Analysis (FMEA) application to reduce the risk level in a ready-mixed concrete plant. Their results showed that the fuzzy FMEA methodology effectively identified and eliminated potential failure modes at the ready-mixed concrete plant.

When the literature was examined, no study could be found on a concrete batching plant using IT2 fuzzy MCDM techniques. Literature studies using fuzzy and IT2 fuzzy MCDM methods related to the construction sector were examined. There are very few studies in the literature in this sector. Abdelgawad and Fayek [33] aimed to extend the application of FMEA to risk management in the construction industry. They combined Fuzzy FMEA and Fuzzy Analytical Hierarchy Process (FAHP) for the construction industry. Moreover, studies on the construction sector using IT2 fuzzy MCDM techniques have been found in the literature. Debnath and Biswas [34] proposed a method for assessing

the risk of the workers at construction sites using an interval type-2 fuzzy analytic hierarchy process. When the literature is examined, there is no study in which the IT2 FANP method is used in the construction industry field.

IT2 fuzzy set has been used to resolve MCDM problems in the published research. Kou et al. [35] evaluated Fintech-based investments of European banking services using an application of an original methodology that takes into consideration interval type-2 (IT2) fuzzy decision-making trial and evaluation laboratory and IT2 fuzzy TOPSIS models. This was done in order to determine the value of the investments. Bera et al. [36] offered two unique MCDM strategies in an interval type-2 fuzzy (IT2F) environment. These techniques can handle uncertain subjective and objective elements concurrently, which is necessary for selecting efficient suppliers to be used in real-world applications. Technique for order preference by similarity to the ideal solution (TOPSIS) and multi-objective optimization on the basis of ratio analysis (MOORA) methods are used in the IT2F environment. Zhou et al. [37] investigated the factors that contribute to the success of the loan application procedure for large-scale energy projects undertaken by financial institutions. In this scenario, a three-stage analysis is used as the appropriate method. When it comes to the topic of financing energy projects, the IT2 fuzzy DEMATEL and IT2 fuzzy QUALIFLEX approach are two methods that are used. Liu et al. [38] analyzed various renewable energy sources and came up with the best options for usage in blockchain-based financial transactions. The significant levels of these criteria are determined with the assistance of the interval type-2 (IT2F) decision making trial and evaluation laboratory (DEMATEL)-analytical hierarchy process (ANP) (DANP) approach. Additionally, the fuzzy IT2 VIKOR technique has been considered.

The originality of this study is to use IT2 FANP, one of the fuzzy multi-criteria decision-making methods, to determine the location of the concrete plant. Because, as can be seen, no study related to the concrete batching plant using this method has been found in the literature. It has been concluded that this method is not used even in the construction industry field. The advantage of this study is to enrich this aspect, which is seen as missing in the literature, and to be a pioneer for studies to be made in this field.

The ANP technique enables the consideration of many primary criteria and sub-criteria, the calculation of the weights of each of these criteria as the choice is being made, pairwise comparisons of criteria, and links between criteria. As a result of the fact that in paired matrices, fuzzy ANP may be used for the computation of the weights of criterion. Additionally, interval type-2 fuzzy sets include fuzziness in the membership functions of the set. Consequently, the interval type-2 fuzzy set technique is more sensitive when modeling uncertainty [26]. The type-2 fuzzy technique allows uncertainty determination by including fuzziness for the membership functions. This contrasts with the fuzzy AHP and fuzzy ANP approaches, which have been the subject of numerous articles in the past. Because they are simpler to calculate with, interval type-2 fuzzy sets are the ones that are recommended [28].

Interval type-2 fuzzy sets (IT2 FSs) can handle linguistic uncertainty variables more flexibly and precisely than type-1 fuzzy sets with their second fuzzy membership functions [27]. So, IT2 FANP was chosen for this study. You may get more detailed information on the procedures involved in this approach from [26, 28, 29]. In [26], an interval type-2 FANP technique is created, and it is given in the academic literature for the first time. Specialists evaluated the criteria following the linguistic scale FANP as type-2 fuzzy numbers. Interval type-2 fuzzy sets and arithmetic operations between trapezoidal interval type-2 fuzzy sets are first explained. An interval type-2 fuzzy ANP method for modeling vagueness originating from both the linguistic variables of experts and membership functions is discussed [26, 28].

In the second section, an IT2 FANP method for prioritizing location alternatives for the concrete plant is made. Finally, the "Conclusion" section concludes the article and discusses the comparison of outcomes and future research directions.

## 2. Problem Definition and a Numerical Case Study

The MCDM problem is selecting an alternative concrete batching plant location. In this study, the IT2 FANP methodology was used to determine the concrete plant's location. In this section, we apply the IT2 FANP technique found in the study [26]. Three decision-makers determined decision criteria and alternatives for the problem in Figure 1. 6 criteria were chosen and shown in Table 1. These criteria are chosen; C1 as Proximity to Market (Construction Site), C2 as Compliance with Legal Conditions, C3 as Competition Conditions, C4 as Proximity to the Center, C5 as Traffic Conditions, and C6 as Proximity to Logistics Centers.

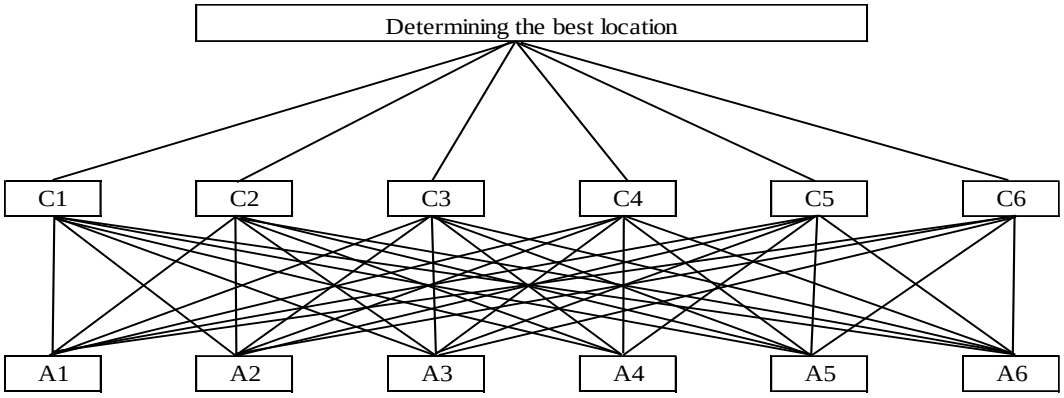


**Figure 1.** Hierarchy of the selection problem.

**Table 1.** Criteria of problem.

| Criteria | |
|---|---|
| C1 | Proximity to Market (Construction Site) |
| C2 | Compliance with Legal Conditions |
| C3 | Competition Conditions |
| C4 | Proximity to the Center |
| C5 | Traffic Conditions |
| C6 | Proximity to Logistics Centers |

The location alternatives are A1, A2, A3, A4, A5, and A6. These alternatives are chosen; A1 as Basaksehir, A2 as Gungoren, A3 as Bagcilar, A4 as Ikitelli, A5 as Esenler, and A6 as Zeytinburnu. These are shown in Table 2.

**Table 2.** Location Alternatives.

| Alternative | Explanation |
|---|---|
| A1 | Basaksehir |
| A2 | Gungoren |
| A3 | Bagcilar |
| A4 | Ikitelli |
| A5 | Esenler |
| A6 | Zeytinburnu |

IT2 fuzzy scales can be seen in Table 3 [39]. Also, these terms can be used in IT2 FANP. Following establishing a network, an expert compared the main criteria using the type-2 fuzzy scale of the linguistic variables shown in Table 3.

**Table 3.** IT2 fuzzy scales.

| Low/high Levels | Linguistic Terms | Trapezoidal IT2 fuzzy scales |
|---|---|---|
| F | Fairly Strong | (3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8) |
| E | Exactly Equal | (1,1,1,1;1,1) (1,1,1,1;1,1) |
| A | Absolutely Strong | (7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8) |
| S | Slightly Strong | (1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8) |
| V | Very Strong | (5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8) |
| F | Fairly Strong | (3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8) |

Decision-makers make comparisons to solve the problem using the IT2 FANP method. A fuzzy pairwise comparison matrix between criteria can be seen in Table 4. Da, Db, and Dc denote the comparisons of decision-maker-A, decision-maker-B, and decision-maker-C in Table 4.

**Table 4.** IT2 fuzzy pairwise comparison matrix.

| | **C1** | | | **C2** | | | **C3** | | | **C4** | | | **C5** | | | **C6** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Da** | **Db** | **Dc** | **Da** | **Da** | **Db** | **Dc** | **Db** | **Dc** | **Da** | **Db** | **Dc** | **Da** | **Db** | **Dc** | **Da** | **Db** | **Dc** |
| **C1** | E | E | E | F | S | F | E | S | 1/S | S | E | S | E | S | 1/S | S | F | F |
| **C2** | 1/F | 1/S | 1/F | E | E | E | 1/F | 1/S | 1/F | 1/S | 1/S | 1/S | 1/F | 1/S | 1/F | 1/S | S | E |
| **C3** | E | 1/S | S | F | S | F | E | E | E | S | 1/S | F | E | E | E | S | S | F |
| **C4** | 1/S | E | 1/S | S | S | S | 1/S | S | 1/F | E | E | E | 1/S | S | 1/F | 1/S | F | S |
| **C5** | E | 1/S | S | F | S | F | E | E | E | S | 1/S | F | E | E | E | S | S | F |
| **C6** | 1/S | 1/F | 1/F | S | 1/S | E | 1/S | 1/S | 1/F | S | 1/F | 1/S | 1/S | 1/S | 1/F | E | E | E |

The geometric mean of the criteria is calculated as in Table 5. According to the Table 5, the ranking of the criteria is found as "C1>C3=C5>C4>C6>C2".

**Table 5.** The geometric mean of the criteria.

| | Geometric mean |
|---|---|
| C1 (Proximity to Market (Construction Site)) | 0.69 |
| C2 (Compliance with Legal Conditions) | 0.31 |
| C3 (Competition Conditions) | 0.64 |
| C4 (Proximity to the Center) | 0.43 |
| C5 (Traffic Conditions) | 0.64 |
| C6 (Proximity to Logistics Centers) | 0.32 |

Then fuzzy weights for criteria are obtained. Alternatives' local weights are found, and their fuzzy weights are aggregated in Table 6.

**Table 6.** Alternatives' fuzzy weights.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | | | | | | | | | | | |
| 0 | 0 | 1 | 4 | 1 | 1 | 0 | 0 | 1 | 3 | 0.7 | 0.69 |
| **A2** | | | | | | | | | | | |
| 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 0.7 | 0.7 |
| **A3** | | | | | | | | | | | |
| 0 | 0 | 1 | 4 | 1 | 1 | 0 | 0 | 1 | 3 | 0.7 | 0.7 |
| **A4** | | | | | | | | | | | |
| 0 | 0.1 | 0.8 | 4 | 1 | 1 | 0 | 0.1 | 0.6 | 2.7 | 0.7 | 0.7 |
| **A5** | | | | | | | | | | | |
| 0 | 0 | 0.3 | 1.6 | 1 | 1 | 0 | 0 | 0.2 | 1.1 | 0.69 | 0.69 |
| **A6** | | | | | | | | | | | |
| 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 2 | 0.69 | 0.69 |

Then, T2 fuzzy numbers are defuzzified using the DTraT method [39], as seen in Table 7. Defuzzification of the alternative weights is carried out for both the inner and the outer dependencies, and the results of this defuzzification are shown in Table 7 below.

**Table 7.** Outcomes of the application using IT2 FANP method.

| | **Fuzzy weights** | **Normalized values** |
|---|---|---|
| A1 | 1.12 | 24.34% |
| A2 | 0.47 | 10.20% |
| A3 | 0.98 | 21.29% |
| A4 | 1.02 | 22.13% |

| | | |
|---|---|---|
| A5 | 0.39 | 8.57% |
| A6 | 0.62 | 13.48% |

Alternatives are ranked and fuzzy weights are found as 1.12, 0.47, 0.98, 1.02, 0.39 and 0.62 in Table 7. Moreover, normalized values are 24.34, 10.20, 21.29, 22.13, 8.57 and 13.48 in Table 7. When the outcomes are analyzed, the ranking is found as "A1>A4>A3>A6>A2>A5". Furthermore, it would be said that choosing A1 is the most relevant result.

## 3. Conclusions

Concrete, which has a wide usage area in today's construction sector, is the most used material after water. In addition, the use of ready-mixed concrete has increased considerably in recent years.

It is imperative that the feasible selection of the location of the concrete facilities required to produce ready-mixed concrete used in this sector. The selection of establishment location is one of the most basic and critical strategic decisions that should be considered during the establishment phase of a business. In this study, the rankings of the alternative locations were found using the IT2 FANP method according to the criteria and alternative locations determined by the experts. Consequently, using the IT2 FANP methodology has obtained the most appropriate outcome as A1 (Basaksehir) and ranking as "A1 (Basaksehir) > A4 (Ikitelli) > A3 (Bagcilar) > A6 (Zeytinburnu) > A2 (Gungoren) > A5 (Esenler)". The fuzzy weights of A1, A4, and A3 alternatives are high. The fuzzy weights of the A6 and A2 alternatives are medium. The fuzzy weight of the A5 alternative is very low. Alternative A1 (Basaksehir) is the best option for the concrete batching plant site when the decision model considers the dependencies and feedback between the different criteria.

Concerning future research, the problem can be evaluated with other MCDM methods, and more solutions can be studied for selecting alternative concrete plant locations. In addition, intelligent software can be developed to calculate solutions to these problems automatically.

**Yazar Katkıları:** Bu çalışmada tüm yazarlar eşit oranda katkı sağlamıştır.

**Finansman:** Bu araştırma dışarıdan fon almadı.

**Çıkar çatışmaları:** Yazarlar çıkar çatışması beyan etmemektedir.

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