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Severity Assessment of Problems in Turkish Building Audit System: A Fuzzy AHP Approach

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ABSTRACT

The Building Audit system (BAS) has often been criticized due to its various drawbacks by researchers, construction practitioners, and professional chambers. Existing studies, however, do not comprehensively investigate the problems seen in Turkish BAS. Since the decision-makers are provided with little knowledge about the drawbacks of the system, they can barely develop new strategies to improve its effectiveness and efficiency. To bridge this gap, this study aimed to identify the drawbacks seen in the implementation of the Turkish Building Audit System (BAS). In addition, the severity of each drawback was also determined to further provide comprehensive guidance to policymakers and non-governmental organizations (NGOs). Initially, an extensive literature review was conducted to identify problems of Turkish BAS. Identified problems were then validated through Focus Group Discussion (FGD) sessions with the participation of 12 experts who have diverse experience in the related field. Later, a questionnaire survey was designed to measure the severity of each problem/drawback and the data was collected from 15 construction practitioners. The data were then analysed using the Fuzzy Analytical Hierarchy Process (FAHP) method to measure the severities of problems seen in Turkish BAS. Then, the problems were prioritized based on their severities. At the final step, sensitivity analysis was conducted to measure the robustness and reliability of the results derived from the FAHP method. Results revealed that problems such as "Lack of practical knowledge of technical staff", "Absence of site supervisor at the site" "Political pressure" and "Neglecting technical specifications and procedures" were determined as the most severe problems that need urgent attention of decision-makers. It is highly believed that this study will guide decision-makers

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for the improvement of existing legislation. Additionally, it is also believed that practitioners will take necessary precautions beforehand by using the outputs of this study.

Keywords: Building audit system, quality control, quality assurance, construction.

1. INTRODUCTION

Turkey - where active plate movements are very common - is located on the Alpine-Himalayan belt [1]. Earthquake constitutes a great danger in Turkey where 96% of the lands are detected as earthquake zones [2]. As a result of earthquake disasters, countless people in our country have suffered [3]. In 1999, 18.373 people died and many people were suffered from the Gölcük Earthquake which was one of the last major earthquakes [4]. After the examination of the structures which were damaged during the earthquakes that occurred in Gölcük, Düzce, Bingöl, Van, Elazığ and İzmir respectively, it was stated that the main factors for the damages occurring in the buildings are mistakes in the designs and ineffective audits made by the building audit firms [5]. By the same token, it can be inferred that uncontrolled structures caused the death of innocent people, not earthquakes [6].

BAS brings along many problems during its practice. Pala and Demir [3] stated that "*As a result of the inspections carried out by the General Directorate of Construction Affairs under the Ministry of Environment and Urbanization, it was revealed that many building audit firms do not even know the locations of the structures*". They concluded that building audit firms inspected the structures only on paper and suggested that the firms performing the inspection should be very strict and have work ethics. In the wake of the Gölcük Earthquake, Ergünay [2] concluded that although many laws and regulations have been enacted to regulate and supervise the constructions, it is an obvious fact that the constructions are rarely inspected. Guner [5] investigated the effects of the earthquake on the damages of structures and concluded that there is a remarkable relationship between the construction period of the buildings and the damage of structures resulting from earthquakes. This can prove that legislations superseding each other have improved the BAS to some extent. Sakalı [6] detected the drawbacks concerning BAS up until 2008. It was stated that since the Gölcük earthquake, significant improvements have been recorded in the BAS system with the lessons learned after the earthquakes; however, he also spotted the continual problems concerning the BAS. Later, regional studies concerning the improvements in the BAS system were conducted in Turkey [7]–[11]. It was highlighted in these studies that there are still major drawbacks occurring during the application of building audit in Turkey and significant precautions shall be taken in advance of any future earthquake. Afterwards, Akbıyıklı et al. [12] investigated the BAS system in 2017 and they also stated that there are still major drawbacks in BAS System. Yılmaz and Koymen [13] evaluated 22 academic research concerning building audits and pinpointed that continual problems still exist and loss of life and property in possible earthquakes affects not only the building owner or their partners but also the demographic structure in the cities and the country's economy. Furthermore, Bayram et al. [14] highlighted that there are major ethical problems in the execution and auditing of the construction in Turkey. Although these studies aimed to identify the problems of Turkish BAS which is considered as the main vulnerability against earthquake disasters, none of them determines the severity of each problem encountered during the application of BAS in Turkey. In other words, existing studies do not determine the relative importance of

problems. Instead, these studies propose that problems have equal severities so that they should be resolved at once by the decision-makers. Considering that resolving all problems seen in Turkish BAS is not a feasible and even possible, the findings of these studies can hardly be utilized by the decision-makers. Due to the lack of this theoretical basis, the decision-makers can barely develop a roadmap to improve Turkish BAS. Consequently, these limitations of the existing studies triggered much of this research and the study aims to identify the existing drawbacks of Turkish BAS and their severities. To detect the problems with regard to BAS, an in-depth literature review was conducted at the outset. Afterwards, detected problems were verified and outdated problems were removed through an FGD session conducted with the participation of 12 experts experienced in Turkish BAS. Later, another FGD session was conducted with the same experts to identify further drawbacks that are not identified in the existing body of knowledge. Next, a questionnaire survey was developed and distributed to 15 experts who were experienced in the domain of building audits. The collected data were analysed by using the FAHP method to detect the severity of each problem. Finally, a sensitivity analysis was conducted to further validate the outputs of the FAHP method. It is believed that this study has great potential to guide decision-makers when it comes to the improvement of existing BAS. By using the findings of this study, the decision-makers can determine and prioritize the vital improvements that should be made to improve BAS regulation. Considering that the quality of the building stocks in Turkey is not at the desired level most probably due to the problems of Turkish BAS, this study is believed to have vigorous practical implications.

2. THEORETICAL BACKGROUND AND RESEARCH MOTIVATION

2.1. Building Audit System in Turkey

Being an essential component of project management, project controlling is a function that is critical for achieving successful project outcomes [15]. Project Control is defined as a process of monitoring a project. Project control helps a project to gather data with the help of inspection, audits, and other mediums. It is the data management process to understand and predict project outcomes [16]. Being required by one or more project stakeholders, inspections and audits are vital mechanisms for the successful management of a project. Inspections aim to check the suitability of completed works according to project requirements. The PMBOK (2017) [16] defines inspections as activities such as measuring, examining, and validating to determine whether work and deliverables meet requirements and product acceptance criteria. A quality audit is a structured and neutral process to determine if project activities comply with organizational policies and procedures as well as the project contract [11]. By the same token, audits help the project team to measure how well a product and process align with project requirements. Audits can be performed by a third party or a self-check of a contractor. In Turkey, the audit is carried out by the audit firms appointed by the concerning ministry [17]. To put forward the duties of building audit organizations, the concept of inspection must be well explained first. The audit is the comparison between the plan and the execution. On the other hand, the building audit concept is a system that controls the structure, ensures the safety of life and property, includes modern standards, and prevents uncontrolled and poor quality in construction [12]. In this sense, building inspection companies play the most crucial role in ensuring life and property safety. The renewal of the auditing mechanism of structures in accordance with the development of

science over time is extremely important for the people who always desire to benefit from safer and more comfortable structures.

In parallel with the development of industry and technology, the construction inspection process is also being developed and complex. Member states of the European Union, which are extremely advanced in this regard, have established "The Consortium of European Building Control" under the leadership of England to develop their inspection systems. There are two building inspection systems in general in Europe. The first of these is the insurance system model adopted by France, and the other is the strict control model applied by Germany [6]. Countries in the European Union apply a similar or mixed of these two building audit systems [6]. Germany, which constitutes 19 per cent of the construction sector in Europe, has established the basis of the building inspection system on discipline and strict supervision [18]. The main principle of the building inspection system implemented in Germany is based on the strict supervision of the construction from the project stage to the operation stage [6]. Structures being carried out by the private sector are supervised by state-established organizations. An audit system should be regarded as a sub-system of an inspection system in a country, because the former focuses that a site is required to do by a compliance obligation but the audit is the process of checking that compliance obligations have been met or not, including that the required inspections have been done before and throughout the construction project. Audit engineers - who are well-equipped and independent engineers working in local administration - are responsible for the buildings for 30 years [19]. France, which has the second largest construction sector in Europe with a percentage of 16 per cent, has a well-established inspection and insurance practice [18]. Administrative Mechanisms for Building Insurance (MARC) carry out the audit process [20]. There are two types of insurance for buildings. The first is ten-year compulsory insurance that directly affects the safety of the building, which starts after final acceptance, and the other is two-year optional insurance that covers parts that wear out over time [21]. When the building inspection system in the USA, which is one of the leading countries in the world in terms of engineering education, is examined, it is seen that the trust in engineers and architects with the title of Professional Engineer (PE) forms the basis of this system. These engineers can apply to official authorities for the preparation and approval of the projects [22]. To have the title of PE, it is necessary to graduate from a four-year university program and to be successful in the Fundamentals of Engineering (FE) exam [23]. Considering its fundamental features, the building inspection system in Turkey is similar to Europe; however, it has been differentiated by undergoing many revisions after the disasters occurred in Turkey.

As it is in Europe and the USA, the construction inspection system to ensure safety and comfort in Turkey has pursued constant development by eliminating the shortcomings. Foundations of the building audit system in Turkey were started to be laid by “Municipal Law” with Law# 1580 in 1930, “General Hygiene Law” with Law # 1593 in 1930, “Municipal Building and Roads Act” with Law # 2290 in 1933, Building “Construction Incentive Law” with Law # 5228 in 1948, “Regulation on Precautions Before and After the Ground Shaking” in 1949. However, as a result of migrations following unplanned industrialization after 1950, the number of illegal buildings increased rapidly, and consequently, laws and regulations on building audits became inapplicable [2]. As a solution after these migrations, the power regarding the zoning plan was gathered in a center with the Zoning Law No. 6785, which could be considered to be quite advanced compared to the time in 1956. Afterwards, the Ministry of Development and Housing was established in 1958.

Although economic losses and loss of life and property in natural disasters resulted from unaudited construction, most of the laws and regulations concerning BAS entered into force were related to covering the losses after natural disasters. [6]. Since continuous problems arose from zoning plan due to gathering the powers in the central government in 1956, 'Zoning Law' came into force with Law# 3194 in 1985, and physical planning activities were separated from the central management, and the zoning planning authority was left to the municipalities within the borders of the adjacent area and the governorships outside the borders of the adjacent area. After 1980, two major successive earthquakes occurred in Erzincan and Dinar in 1992 and 1995, respectively. As a consequence, "Regulation on Structures to be Made in Disaster Areas" entered into force in 1997. After the Marmara earthquake (1999) where 20,000 people lost their lives, 40,000 citizens were injured and financial losses occurred, the building inspection system was further questioned and as a result, "Decree-Law Concerning Building Audit" came into force with Law# 595 in 2000. After publication, the Constitutional Court decided to stop the execution, and "Building Audit Law" with Law# 4708 was legislated in 2001. The building audit system was planned to be implemented in 27 pilot provinces in the first phase, and then this number was reduced to 19. After the 1999 Marmara earthquake, several decree-laws, decrees, regulations, notifications and circulars entered into force with respect to BAS, and the severe problems continued due to intense bureaucracy. To eliminate the deficiencies in BAS, "Regulation on the Amendment to the Building Audit Implementation" was enacted as of 29th December 2018 through Official Gazette No. 30640 and started its implementation on 1st January 2019 [24]. Through this regulation, many drawbacks such as delegation of building audit firms, termination of building audit service agreement, building audit service fees were intended to be overcome. Additionally, the application, which paves the way for electronic monitoring of concrete quality by placing a chip in the concrete samples, has been launched via this regulation.

2.2. Fundamentals of Multi-Criteria Decision Making (MCDM) and Fuzzy AHP

A decision that reaches the goal is very needed in construction projects. However, the existence of various sets of alternatives turns the construction project into a very sophisticated environment in terms of decision-making. Additionally, the existence of conflicting criteria makes the task of decision-makers even more difficult. The term conflicting criteria are defined as the criteria that are inversely proportional to each other. While there are difficulties in making the right decision, it is difficult for decision-makers to choose the most appropriate alternative. To overcome these problems, Multi-criteria Decision Making (MCDM) has been very essential for decision-makers and discussed in the literature comprehensively [25]. MCDM is a term that describes the nature of decision-making and numerous MCDM methods have been proposed in the literature to aid decision-makers. The most frequently adopted methods by the researchers are AHP, VIKOR, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and their integration with fuzzy set theory. Saaty [26] developed the AHP method which has become one of the most popular MCDM methods [27], [28] due to its capability to handle intangibles presented in any decision-making process [29]. Additionally, consistency in the pairwise comparison of the experts can be detected by the AHP method and thus this ensures the reliability of the outputs [26]. The method fractionates a decision-making problem into a system of hierarchies of objectives, criteria

and alternatives, and the mechanism of the AHP is designed to accomplish decompositions, pairwise comparisons, priority vector generation and synthesis [30]. Notwithstanding the advantages of the AHP method, while the experts evaluate the alternatives and criteria, crisp numbers are not sufficient due to imprecision, subjectivity and indefinite source of human judgment in numerous circumstances [31]. Therefore, integration of fuzzy set theory into AHP seems essential to evaluate linguistic variables and deal with ambiguous problems [29]. The decision-making problems involving complexity are not able to be picturized quantitatively. However, the human brain which has a unique feature can cope with these problems by using indefinite knowledge. The fuzzy set theory is proficient to imitate the unique features of the human brain. By the same token, the specific objective of the fuzzy set theory is a numeric illustration of the uncertainty to deliver a formalized medium for dealing with imprecision. The fuzzy set theory proposed by Zadeh [32] adopts a similar mechanism concerning human reasoning which can come to conclusion by using approximate and uncertain information [33]. Thus, the Fuzzy AHP method was developed by Chang [34] to overcome the aforementioned disadvantages of the AHP method.

3. METHODOLOGY

In this study, it was primarily aimed to identify and prioritize the problems observed in BAS in Turkey. In this way, the decision-makers and construction practitioners as well as non-governmental institutions (NGOs) will be provided with a deep insight into the challenges of the existing BAS. Accordingly, the research methodology given in Figure 1 was followed to achieve the objectives of this study. As depicted in Figure 1, the research methodology was established on two pillars, namely problem detection and verification, and problem evaluation. In the problem detection and verification stage, the construction management literature was initially reviewed to identify problems unfolded by researchers. In the wake of

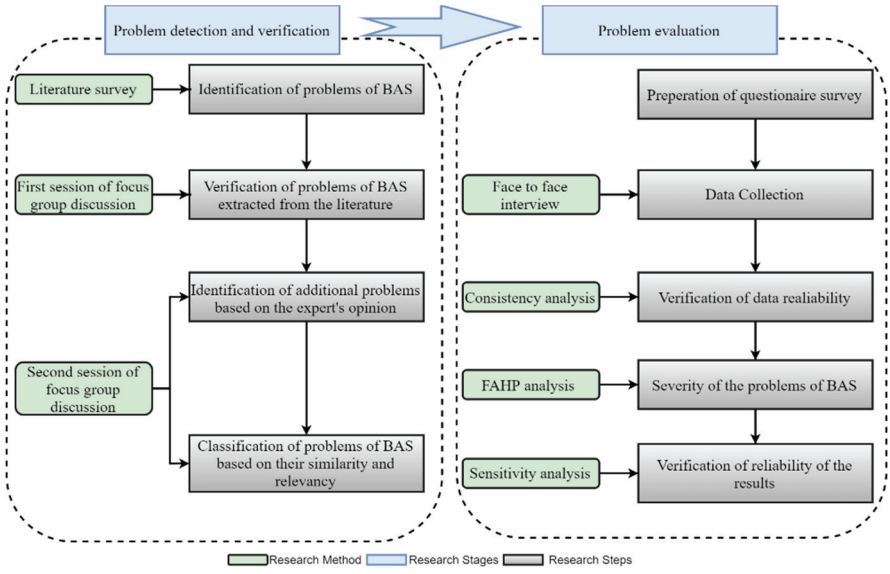

Figure 1 - Flowchart of the analysis procedure

the literature review, FGD sessions were organized with the participation of the 12 experts who have diverse experiences with the BAS in Turkey. In the first FGD session, the experts assessed the validity of the problems of BAS extracted from the literature. Next, experts proposed additional problems that are encountered in the engineering practice. In this respect, it is believed that this study presents vigorous theoretical contribution since it provided a fertile ground to merge the theoretical knowledge of the researchers and practical knowledge of the construction practitioners. At the end of the session, the experts also categorized the problems of BAS based on their similarity and relevancy. It should be noted that this categorization formed the basis of FAHP analysis conducted in the problem evaluation stage. In the problem evaluation stage, the questionnaire survey was designed and distributed to 15 construction practitioners to evaluate the severities of the problems identified through literature review and FGD sessions conducted with the participation. The questionnaire survey was analyzed with FAHP analysis and severities of the problems encountered in BAS were determined. Furthermore, the consistency and sensitivity analyses were conducted to test the reliability, stability and robustness of the results derived from the survey.

3.1. Problem detection and verification

As depicted in Figure 1, two different methods were adopted to identify and verify the problems of Turkish BAS. Initially, an extensive literature review was conducted to obtain detailed knowledge about the fundamentals of Turkish BAS. The existing studies were also examined to comprehend the existing body of knowledge. Based on this examination, as also presented in Section 2, the research gaps that should be bridged to maximize the effectiveness of Turkish BAS were also identified. The second literature review was then conducted to identify the problems of Turkish BAS unfolded by researchers. During this literature review, the search engine Scopus was preferred since Scopus has long been known as one of the most comprehensive and effective search engines [35]–[37]. It should be noted that only peer-reviewed research articles and papers presented in prestigious conferences were utilized to maximize the reliability of the framework. Consequently, the 25 problems and their sources were identified as depicted in Table 1.

Table 1 - Turkish BAS's problems identified through a literature review.

ID	Problems of Turkish BAS	A	B	C	D	E
P1	Inadequate wages given to staff		X		X	X
P2	Lack of practical knowledge of technical staff				X	X
P3	The insufficiency of occupational discipline and ethics concepts		X			X
P4	Insufficient examination of projects					X
P5	Overloaded audit firms and hiring diplomas			X		X
P6	Incomplete project control forms	X				
P7	Problems arising from an insufficient educational background of professional members				X	X
P8	Forgery of documents	X				

ID	Problems of Turkish BAS	A	B	C	D	E
P9	Missing signatures of the parties in the building audit service contracts	X				
P10	Obtaining building licenses despite incompatibilities between projects	X				X
P11	Applications that are not part of the project	X	X	X		X
P12	Absence of the Site supervisor at the site	X				
P13	Problems arising from regulations concerning Building Audit System				X	X
P14	Lack of practices to encourage employees		X			
P15	Frequent change of building audit legislation		X			
P16	Inadequate quality control due to insufficient staff		X	X		X
P17	Differences in practices of administrations of provinces and districts			X	X	
P18	Paying attention to the cost of the audit, not the quality		X	X	X	X
P19	Political pressure		X	X		
P20	Failure of the building owner to assign the building inspection firm			X	X	X
P21	Time consumption due to bureaucratic procedures			X		
P22	Contractors' lack of workforce to meet their technical requirements		X	X		
P23	Unequal and Unfair treatment by administrations to the audit firms		X	X	X	X
P24	Lack of inspections on a continuous basis at the site				X	X
P25	Providing services under the minimum service fee		X	X		X

Note-1: A: Erdiş and Gerek [11], **B:** Doğan [8], **C:** Kural and Ünal [10], **D:** Pala and Demir [7], **E:** Tantekin Çelik and Ünal [9]

The FGD sessions were followed the abovementioned literature review. The FGD is defined as a qualitative research technique that can bridge the scientific research and practical experience of the participants [38]. In particular, the technique aids researchers when it comes to drawing conclusions from sophisticated personal experiences, perceptions and attitudes of experts with the help of dynamic and interactive discussions [39]. The dynamic and interactive discussions differentiate the FGD from other techniques such as unstructured, structured and semi-structured interviews since this feature of FGD allows ideas, experiences and perspectives of participants could be exchanged and finessed [40]. Furthermore, the technique provides a fertile ground to arise individual differences of opinions together with gaining insight into the shared understanding and groups' beliefs [41]. Thus, FGD emerges as a promising technique when a research subject under investigation needs to be extensively examined from the various aspect that cannot be achieved by a single expert in a confined medium [42]. Owing to these promising and vital benefits, the implementation of the FGD technique in scientific studies has skyrocketed in recent years [43]. Nyumba et al. (2018) [43] emphasized that selecting an appropriate sample size is a crucial factor affecting the extraction of interesting and valuable ideas from the FGD sessions. The authors however pinpointed that there are no strict rules and/or equations revealing the appropriate sample size. The experience of the researchers highlighted that a sample size larger than 20 significantly complicated the moderation of FGD while accommodating a small sample size such as 3-5 experts inhibits the extraction of innovative and inventive ideas and the subject

cannot be assessed from various perspectives [44]. Besides the sample size, the competency of the experts is another determinant of the reliability of the FGD method. In other words, identifying eligible participants is of paramount importance for the FGD method. Nyumba et al. [43] recommended using purposive sampling rather than convenience sampling. In purposive sampling, participants' backgrounds are deeply and detailly investigated to check whether they fit the needs of the study or not. Accordingly, the expert selection framework as depicted in Figure 2 was developed for this study and all participants were interviewed to test their eligibility. Consequently, 12 experts who were determined to have diverse experience in the Turkish BAS were invited to FGD discussions. It should be noted that the profile of the experts is provided in Table 2 and sessions were organized and moderated in full accordance with Nyumba et al. [43].

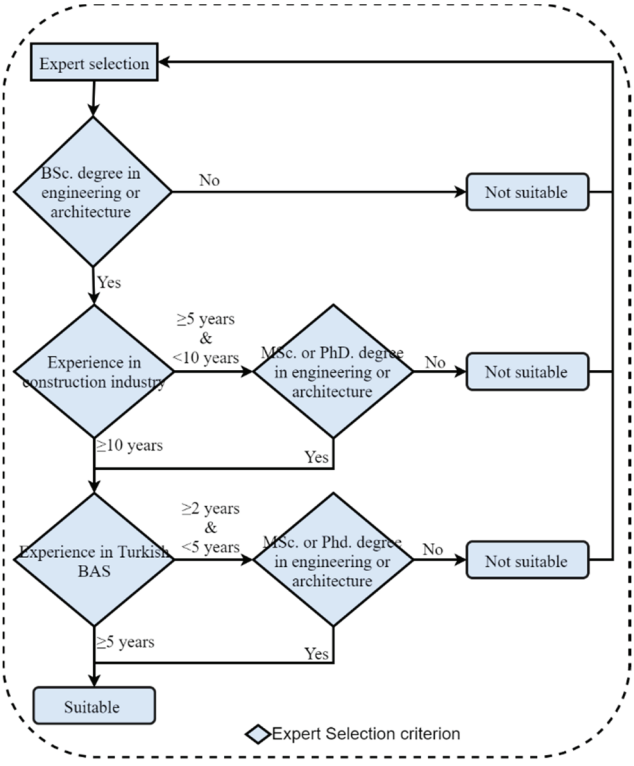

Figure 2 - Expert selection procedure

At the beginning of the first FGD session, extensive theoretical information regarding the existing BAS and its related regulations were provided to experts to further strengthen their knowledge. In this respect, the sessions successfully surfaced the experts' practical knowledge and merged it with the theoretical knowledge of the researchers. Following this, all participants were asked about their general opinions about Turkish BAS. All participants agreed that there are significant problems when it comes to enforcing Turkish BAS. They

stated that it is of paramount importance to identify potential problems and measure their severity so that policymakers are provided with a clear decision-support framework when it comes to addressing these problems.

Table 2 - Profiles of respondents participating in FGD sessions.

ID	BSc. Degree	Degree	Firm	Experience in the construction industry (Year)	Experience in BAS (Year)
1	Civil Engineer	MSc.	Ministry of Environment, Urbanization and Climate Change	12	10
2	Civil Engineer	PhD.	Building Audit Firm	12	7
3	Mechanical Engineer	BSc.	Building Audit Firm	15	15
4	Architect	BSc.	Municipality	10	5
5	Electrical Engineer	BSc.	Building Audit Firm	10	7
6	Civil Engineer	MSc.	Building Audit Firm	6	6
7	Civil Engineer	MSc.	Municipality	10	8
8	Mechanical Engineer	BSc.	Building Audit Firm	10	10
9	Architect	BSc.	Building Audit Firm	11	9
10	Electrical Engineer	BSc.	Municipality	18	12
11	Civil Engineer	BSc.	Building Audit Firm	17	15
12	Mechanical Engineer	MSc.	Building Audit Firm	18	18

Then, the experts were asked to assess the validity of the problems extracted from the literature. Given the fact that some of the studies were published earlier than 2022, the step was crucial to ensure that the problems extracted from the literature are still valid nowadays. During this validity assessment, each of the problems provided in Table 1 was discussed by the experts. The final decision for each problem was made when the experts reached a

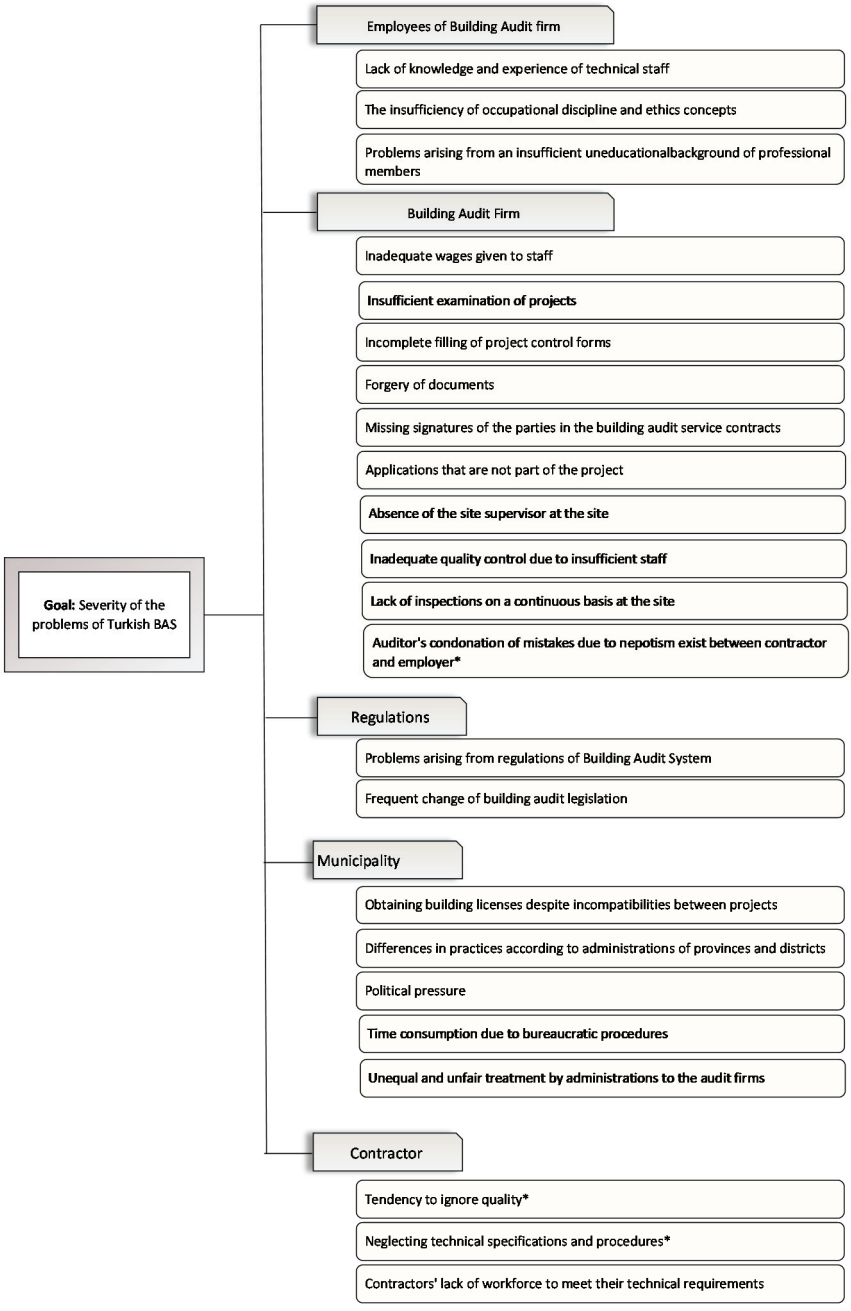

Figure 3 - Decision framework of the study.

consensus about the validity of the problems. If the experts failed to reach a consensus, the final decision was made based on the opinions of the majority. Accordingly, it was detected that some of the problems illustrated in Table 1 were overcome through, "Regulation on the Amendment to the Building Audit Implementation" entering into force on 29 December 2018. It was suggested that problems, namely P5 and P20 were omitted since building inspection firms are appointed electronically by the Ministry. Additionally, P18 and P25 were removed since building audit service fees were standardized in the latest regulation. Furthermore, there was a joint decision during the session that "P14- Lack of practices to encourage employees" was suggested to be removed from the list since this is not related to the auditing system but firms.

Upon refining the list illustrated in Table 1, experts were asked to suggest additional problems that are overlooked in the existing literature. Each suggestion of the experts was discussed, and the final decision was made using the same consensus mechanism explained above. At the final step, experts were asked to categorize identified problems based on their similarity and relevancy. In other words, problems identified through literature review and FGD sessions were categorized as per their common themes. Consequently, the structure given in Figure 3 was obtained.

3.2. Problem evaluation

Problem evaluation is one of the most critical aspects of this study since policymakers can prepare their roadmap based on the findings obtained from the problem evaluation step. There are many MCDM methods available in the literature such as AHP, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Among them, the VIKOR method aims to determine a compromise solution for a discrete decision-making problem in the presence of conflicting criteria [45]. The VIKOR method becomes an ideal method especially when decision-makers cannot select or do not know how to decide on the most suitable alternatives. Unlike the TOPSIS which considers only group utility maximization and individual regret minimization, VIKOR is capable of fully reflecting the experts' subjective preferences in the results [46], [47].

On the other hand, the AHP proposed by Saaty [26] has various advantages over other MCDM methods such as TOPSIS and VIKOR. First, the research design could be represented hierarchically as shown in Figure 3, which, in turn, decision-making processes could be easily comprehended [48]. Second, the method does not require a large sample size to provide reliable results since it can eliminate unreliable datasets by measuring the consistency of each dataset [49]. Finally, the method has been successfully applied to a wide range of disciplines so that its effectiveness has been proven many times [50].

In general, the MCDM methods have widely been criticized for being inapplicable when it comes to solving ambiguous decision problems which are frequently encountered in engineering practice [51]. The integration of MCDM methods with fuzzy set theory is key to further strengthen their abilities to cope with sources of uncertainty. The fuzzy set theory - which was proposed by Zadeh [32] - uses a sophisticated mechanism similar to the human brain. This makes it ideal to solve decision-making problems having imprecise information stemming from experts' subjective judgements. The theory becomes an appropriate concept

for mapping perception, incomplete information, and approximations. By doing so, the effect of imprecision that exists within the datasets could be minimized [52]. In this respect, the fuzzy set theory maximizes the reliability and effectiveness of the MDCM methods [50]. Owing to the unprecedented benefits of fuzzy set theory, the FAHP method outperforms the conventional AHP by effectively dealing with inherent fuzziness and vagueness in the expert's judgements [50]. Therefore, the triangular FAHP method developed by Chang [34] was implemented in this study. The adopted approach involves the research steps shown below:

Step 1. Data collection with pairwise comparison matrices: As stated above, the FAHP method emphasizes the data quality rather than the sample size. In this respect, purposive sampling was recommended in FAHP applications as is in the FGD technique. Accordingly, before the data collection step, the experts' background was deeply examined using the procedure illustrated in Figure 2. To achieve the evaluation of the subject from multiple perspectives, the experts who participated in the FGD sessions were not invited to participate in the questionnaire survey. Instead, another set of respondents was identified specifically for the questionnaire survey. The demographics of the experts were provided in Table 3. Accordingly, it is not controversial to assert that experts certainly meet the needs of this study. Thus, the conclusions drawn from their judgements were presents vigorous practical implications. Besides the data quality, many studies have been investigated in the decision science domain and the sample size was found adequate [53]–[56].

Following the expert selection step, the questionnaire survey was distributed to participants. The survey consisted of three sections. The first section included the questions about the experts and their companies as well as brief information about the research objectives and design. In the second section, the experts were asked to make pairwise comparisons between main problem categories such as regulation, contractor, municipality, etc. Finally, the importance of each problem was assessed by the experts through pairwise comparison. It should be noted that experts were given an opportunity to use linguistic variables given in Table 4 rather than crisp numbers so that they could reflect their judgements clearly [57].

Table 3 - Profiles of respondents participating in the FAHP questionnaire.

Expert #	BSc. Degree	Experience in the construction industry (Year)	Experience in BAS (Year)	Degree	Current Firm	Experience in Project Types
1	Civil Engineer	12	10	M.Sc.	Ministry of Environment, Urbanization and Climate Change	Single-Family Dwellings, Collective Housing, Institutional Projects
2	Civil Engineer	12	7	B.Sc	Building Audit Firm	Single-Family Dwellings, Collective Housing, Hotel Projects
3	Mechanical Engineer	15	15	B.Sc	Building Audit Firm	Single-Family Dwellings, Roads&Bridges Projects
4	Architect	10	5	B.Sc	Municipality	Single-Family Dwellings, Dam Projects

5	Electrical Engineer	10	7	B.Sc	Building Audit Firm	Single-Family Dwellings, Collective Housing, Institutional Projects
6	Civil Engineer	6	6	B.Sc	Building Audit Firm	Single-Family Dwellings, Roads&Bridges, Dam Projects
7	Civil Engineer	10	8	M.Sc.	Municipality	Single-Family Dwellings, Hospital, Commercial Projects
8	Mechanical Engineer	10	10	B.Sc	Building Audit Firm	Single-Family Dwellings, Airport Projects
9	Architect	11	9	B.Sc	Building Audit Firm	Single-Family Dwellings, Dam Projects
10	Electrical Engineer	18	12	B.Sc	Municipality	Single-Family Dwellings, Roads&Bridges Projects
11	Civil Engineer	17	15	PhD	Building Audit Firm	Single-Family Dwellings, Collective Housing, Harbour, Industrial Projects
12	Mechanical Engineer	18	18	M.Sc.	Building Audit Firm	Single-Family Dwellings, Collective Housing, Harbour Projects
13	Mechanical Engineer	15	8	B.Sc	Building Audit Firm	Single-Family Dwellings, Collective Housing, Institutional Projects
14	Electrical Engineer	20	10	B.Sc	Municipality	Single-Family Dwellings, Collective Housing Projects
15	Mechanical Engineer	12	6	M.Sc.	Ministry of Environment, Urbanization and Climate Change	Single-Family Dwellings, Collective Housing Projects

Table 4 - The linguistic variables used during the pairwise comparison

Linguistic variables	**Triangular fuzzy numbers**	**Triangular fuzzy reciprocals**
Just Equal	(1, 1, 1)	(1, 1, 1)
Equally Important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly Important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly More Important	(3/2, 2, 5/2)	(2/5, ½, 2/3)
Very Strongly More Important	(2, 5/2, 3)	(1/3, 2/5, ½)
Absolutely More Important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Step 2. Consistency check: As elaborated above, consistency control is one of the main advantages of AHP over other methods. Following data collection, consistency analysis was conducted for each dataset and only consistent datasets were taken into consideration. In case a dataset was found inconsistent, the corresponding respondent was informed, and the survey was repeated. In this way, the reliability of the survey was maximized. The details of the consistency analysis are provided below. Accordingly, the CR of each dataset should be less than 10% to be considered consistent [58]. In the following equations, the λ_{max} is called as the maximum eigenvalue of the corresponding matrix, while RI, CI, and n are called as, the

random index, consistency index and the number of criteria of the corresponding matrix, respectively.

$$CI = \frac{\lambda max - n}{n-1} \tag{1}$$

$$CR = \frac{CI}{RI} \tag{2}$$

Step 3. Aggregation of decision matrices: Once the consistency of each dataset was found adequate, the pairwise comparison matrices of all experts were aggregated to obtain group decisions. This was achieved by initially converting linguistic variables into triangular fuzzy numbers using the values depicted in Table 4. Then, the geometric means of the scores provided by all experts were calculated to form aggregated decision matrices [52], [57]:

$$l_{ij} = \left(\prod_{k=1}^{K} l_{ijk}\right)^{1/K},\ m_{ij} = \left(\prod_{k=1}^{K} m_{ijk}\right)^{1/K},\ u_{ij} = \left(\prod_{k=1}^{K} u_{ijk}\right)^{1/K} \tag{3}$$

where K is the total number of respondents.

Step 4. Application of Chang's extent analysis: Noting that $X = \{x_1, x_2, x_3, \dots\dots\dots, x_n\}$, and $U = \{u_1, u_2, u_3, \dots\dots\dots u_m\}$ are object and goal sets, the fuzzy synthetic extent value belonging to i^{th} object was computed using the following equations developed by Chang [59]. It should be noted that triangular fuzzy numbers are denoted as M_{gi}^{j} in the following equations.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \tag{4}$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{5}$$

$$\left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right] = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{6}$$

$$\left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} u_i}, \frac{1}{\sum_{j=1}^{n} um_i}, \frac{1}{\sum_{j=1}^{n} l_i}\right) \tag{7}$$

Following this, the degree of possibility should be determined by using a fuzzy synthetic extent value. The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ was found using Equations 8 and 9. It should be noted that $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ were denoted as triangular fuzzy numbers.

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu_{M1}(x), \mu_{M2}(y)\right)\right] \tag{8}$$

$$V(M_2 \geq M_1) = htg(M_1 \cap M_2) = \begin{Bmatrix} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{Bmatrix} \tag{9}$$

M_2 and M_1 are compared by considering two cases of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$. Eq. 10, therefore, reveals the degree of possibility for a convex fuzzy number.

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1),(M \geq M_2),\dots,(M \geq M_k)] = minV(M \geq M_i) \quad (10)$$

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

Noting that $d'(A_i) = \min V(S_i \geq S_k)$ for k =1, 2, …, n; k ≠ I; Eq. 11 was implemented to calculate the weights of each criterion or problem.

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (11)$$

where $A_i (i = 1, 2, 3, \dots \dots \dots, n)$ are n elements. Finally, the weights of each problem were normalized by employing the following equation. The "W" in the following equation is expressed as a crisp number.

$$W = \left(d(A_1), d(A_2), \dots, d(A_n)\right)^T \quad (12)$$

Consequently, the normalized weights of problems of Turkish BAS are provided in Table 5.

The last analysis conducted in this study was the sensitivity analysis as shown in Figure 1. The sensitivity analysis measures the stability and robustness of the FAHP procedure by measuring the covariance of the results and the input data [60]. Sensitivity analysis is eminent to ensure robustness and stability of the decision-making process since complex decision-making problems are often considered unstable due to high-degree of subjectivity [61]. Furthermore, owing to its utmost importance, sensitivity analysis was widely adopted in the decision-making domain to maximize reliability [60], [62], [63]. In the light of this information, the sensitivity analysis was performed in this study to verify the applicability of the results. In essence, the sensitivity analysis was conducted by iterating the FAHP analysis with various degrees of fuzziness. These values were taken as 0.2, 0.4, 0.5 and 0.6 as also proposed by Aladağ and Işık [64] and Tseng and Lin [62]. After completing the FAHP analysis for these values of degree of fuzziness, the variations in the rank of each BAS problem were observed. If the ranks remain stable for all values of degree of fuzziness, the analysis was deemed robust and stable [61]. Consequently, the sensitivity analysis was completed as described above and the results are presented in Figure 4.

4. FINDINGS AND DISCUSSIONS

The results of the FAHP analysis are given in Table 5. Accordingly, the severities of all categorizations were detected as very similar due to their equal effects on the building audit. It was spotted that the most important category is "Employees of Building Audit Firm" which was followed by categories such as "Contractor", "Building Audit Firm", "Regulations" and "Municipality", respectively. Ethical principles of employees in building audit firms are very important and for this reason, the employees must perform their controls in full accordance with the regulations and take the necessary precautions [14]. Furthermore, their technical knowledge is also very critical to conduct their control thoroughly [10]. To attract the most

appropriate employees to the building audit firms for the building inspections, it is highly suggested that there should be a lower limit on the wages. Additionally, certain experiences for employees are to be sought. "Contractor" – which was the second important category – plays a very crucial role in building audits. The contractor shall execute and control his work according to drawings, specifications, and any other documents defined in the project contract. Therefore, contractors should be selected according to their qualification certificates, and it is believed that this will pave the way for future structures to be built properly. Supervision is conducted by "Building Audit Firm" which was a relatively third important category. A building audit firm should have a work ethic and conduct its inspection as per existing regulations. "Regulation on the Amendment to the Building Audit Implementation" entered into force on 29th December 2018 through Official Gazette No. 30640 and started to be enforced on 1st January 2019 [24]. Through this regulation, the delegation of building audit firms, termination of building audit service agreement, building audit service fees were reformed and previous practices were improved. With this regulation, the commercial relationship of building audit companies with the contractor was eliminated and this has enabled building audit firms to supervise the works of the contractors efficiently. As is mentioned in the section of "Building Audit System in Turkey", there have been many legislations enacted and superseded each other. However, constant and rapid change in the regulations prevents the practitioner to carry out the work consistently. Interpretation of the changes in the regulations affects the supervision of municipalities and ends up with significant inconsistency in the applications of different municipalities [10]. Additionally, work training concerning the building audit should be given to the concerned staff in the municipalities to enable them to execute the work in line with the regulations [8]. Moreover, their work should also be supervised by the concerned government agencies and sanctions should be imposed in case of any adverse condition.

In the category of "Employees of Building Audit Firm", the most important problem was identified as "Lack of practical knowledge of technical staff". In contrast to BAS in Turkey, knowledge of the technical staff is deemed as vital in Europe and the USA. The main drawback behind the lack of practical knowledge of the technical staff is due to the low-profit margins of building inspection companies. Therefore, audit firms cannot pay high wages to their employees and sometimes they even pay minimum wages. Additionally, there is no qualification limit requested for the employees. These drawbacks lead to acquiring unqualified staff in the building audit firms. "Lack of practical knowledge of technical staff" was followed by "The insufficiency of occupational discipline and ethics concepts" and "Problems arising from an insufficient educational background of professional members" respectively. Thus, decision-makers should consider these problems for the improvement of Turkish BAS.

In the category of "Building Audit Firm", "Absence of the Site supervisor at the site" came into prominence since it can diminish the quality of building inspection. It was followed by "Insufficient examination of projects", "Inadequate quality control due to insufficient staff" and "Lack of inspection on a continuous basis at the site" whose weights were very close to each other. Since all executions conducted by the contractor are to be inspected by building audit firms, building audit firms should provide adequate number and skilled personnel to the construction site to continuously control the work. These results pinpoint that a mechanism to measure and monitor the qualifications of employees working at the building audit firms could be developed in the forthcoming regulations.

Related to the category of "Municipality", "Political pressure" was rated as the most important problem that undermines the effective implementation of Turkish BAS. Since the mayors have organic bonds with political parties, political relationships can cause significant deviations in the implementation of BAS. Therefore, inappropriate situations arising from political pressures should be prevented and controlled by the concerned government entity. Additionally, "Time consumption due to bureaucratic procedures" was scored as the second most important implementation problem. One of the common problems in Turkey is bureaucracy which is mostly encountered during investment projects, and even a simple permit can take weeks or even months to obtain [8]. It is recommended that procedures such as work permits should have a maximum due date since the duration of obtaining work permits varies from one municipality to another due to time-consuming bureaucratic procedures.

With respect to "Regulations", "Problems arising from regulations concerning Building Audit System" was scored as the first important implementation problem that hinders the implementation of Turkish BAS. It was followed by "Frequent change of building audit legislation". Interpretation of the regulation and vagueness in terms may result in inconsistent applications and disputes between the parties. Therefore, regulations and instructions should be reviewed to avoid readability and sematic issues in the regulation concerning Turkish BAS. In this way, the municipalities could be enabled to execute their work consistently.

Table 5 - The weights and ranks of problems and their categories

Problem ID	Problems of BAS	Weights (Priorities)
Employees of Building Audit Firm		***0.2359 (1)***
EBAF-1	Lack of practical knowledge of technical staff	0.3695 (1)
EBAF-2	The insufficiency of occupational discipline and ethics concepts	0.3308 (2)
EBAF-3	Problems arising from an insufficient educational background of professional members members	0.2997 (3)
Building Audit Firm		***0.2104 (3)***
BAF-1	Inadequate wages given to staff	0.08951 (6)
BAF-2	Insufficiently examination of projects	0.13180 (2)
BAF-3	Incomplete project control forms	0.07582 (7)
BAF-4	Forgery of documents	0.07244 (8)
BAF-5	Missing signatures of the parties in the building audit service contracts	0.06164 (10)
BAF-6	Applications that are not part of the project	0.10065 (5)
BAF-7	Absence of the Site supervisor at site	0.15109 (1)
BAF-8	Inadequate quality control due to insufficient staff of building audit firm	0.12772 (3)
BAF-9	Lack of inspection on a continuous basis at the site	0.12144 (4)

Problem ID	Problems of BAS	Weights (Priorities)
BAF-10	Auditor's condonation of mistakes due to nepotism exist between contractor and employer*	0.06791 (9)
Municipality		***0.1538 (6)***
MNC-1	Obtaining building licenses despite incompatibilities between projects	0.1429 (5)
MNC-2	Differences in practices of administrations of provinces and districts	0.2124 (3)
MNC-3	Political pressure	0.2392 (1)
MNC-4	Time consumption due to bureaucratic procedures	0.2261 (2)
MNC-5	Unequal and Unfair treatment by administrations to the audit firms	0.1794 (4)
Regulations		***0.1876 (5)***
RGL-1	Problems arising from regulations concerning Building Audit System	0.6853 (1)
RGL-2	Frequent change of building audit legislation	0.3147 (2)
Contractor		***0.2122 (2)***
CNT-1	Contractors' lack of workforce to meet their technical requirements	0.2997 (3)
CNT-2	Neglecting technical specifications and procedures*	0.3695 (1)
CNT-3	Tendency to ignore quality*	0.3308 (2)

In the category of the contractor, "Neglecting technical specifications and procedures" was given the highest priority by the experts. It is a widely known fact that contractors tend to neglect technical specifications and procedures to minimize the project duration. For instance, in engineering practice, adding water into the concrete mixer after taking sampling is one of the major problems. Although the latest regulation brought chip which is added to concrete samples [24], experts indicated that samples were mostly taken by the first concrete mixer and later mixer operators tend to add water to the mixer to increase the slump of the concrete. This application however diminishes the strength of the concrete. Moreover, "Tendency to ignore quality" was rated as the second important factor. Most of the construction firms do not have an internal auditing system because there is no sanction in case of any poor-quality executions. Therefore, the effectiveness of the building audit firms must be improved, and penalties should be given for poor-quality executions.

4.1. Sensitivity Analysis

The results obtained from FAHP analysis were deeply discussed in the previous section. However, the stability and reliability of the analysis needed to be further validated [52], [61], [63]. Therefore, for each cluster, a sensitivity analysis was conducted. Hence, as is also

specified before, FAHP analysis was repeated as per the degree of fuzziness of 0.2, 0.4, 0.5, and 0.6, respectively. Consequently, the results of the sensitivity analysis were found as depicted in Figure 4. In the sensitivity analysis, to consider the FAHP analysis as reliable, the rankings of factors should not change according to changes in the degree of fuzziness [57], [65]. More specifically, lines illustrating the weights of factors should not intersect with each other. If any lines were crossed in any figure, the analysis would be considered unreliable because of the occurrence of rank reversal. As is seen in Figure 4, lines do not intersect with each other so that the developed model could be considered stable and robust.

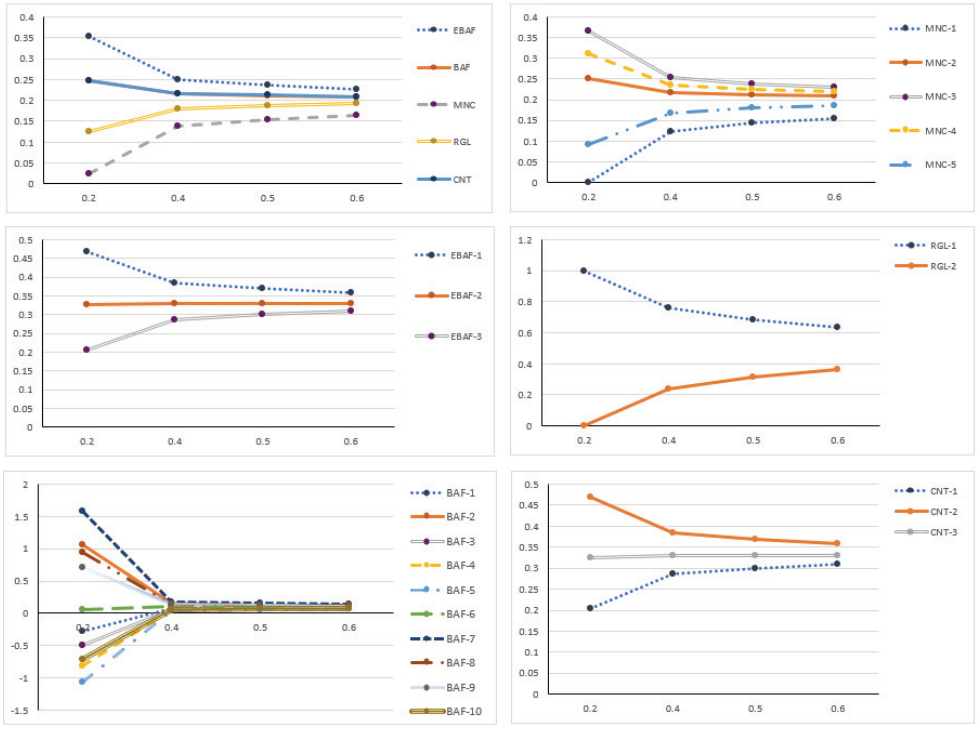

Figure 4 - Sensitivity Analysis

5. CONCLUSION AND RECOMMENDATIONS

This study aims to identify the problems of Turkish BAS and their severities. To achieve this, an in-depth literature review and FGD sessions with 12 experts were conducted to identify and categorize the drawbacks of Turkish BAS. Later, the problems were evaluated with 15 experts with the help of questionnaires and the obtained data were analyzed via FAHP analysis to detect the most important problems affecting building audits in Turkey. Lastly, a sensitivity analysis was conducted to validate the outputs of the FAHP method.

It is beyond the question that the biggest pitfalls in BAS result from the owner who does not pay the attention to the quality of work. The owner must be more proactive and sensitive concerning the quality of work. At the other end of the spectrum, laboratories can be owned by public institutions or universities to plummet the defects in quality issues. An expert stated that "*maintaining the independency of laboratories can force the contractors to obey the standards concerning safety, rebar and concrete*". It is worth bearing in mind that the minimum limit of the staff wages should be regulated to further strengthen the implementation of BAS. One of the interviewees contributed to this proposal by stating that "*the engineering service cannot be given with the minimum wage*'. Also, it is believed that defining the lower limit of wages upsurges the number of qualified employees. In addition to this, the competency levels of employees working in the building audit firm should be increased by vocational exams and certifications. Also, the staffs working in the building audit firm are to be supervised and penalties may be given for the negative actions of employees. Another point worth mentioning is that contractors should be certified and their performance during the execution of works should be measured. Furthermore, differences in practices of BAS among administrations of provinces and districts should be eliminated by providing an in-service training certificate to the administrations. It seems to have drawbacks in regulations concerning BAS; therefore, detected problems are believed to shed light on the development of new legislation concerning BAS.

The aggregated judgments of the participants were utilized to determine severities of the problems seen in Turkish BAS. However, the perception differences that exist between different occupations such as civil engineers, architects, and electrical engineers might also provide valuable information about the existing BAS system in Turkey. Thus, the subject could be examined by forthcoming studies.

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