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ARTICLE

Assessment of stakeholder satisfaction as additive to improve building design quality: AHP-based approach

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Abstract
It is possible to obtain better, qualified and error-free structures by evaluating the multidimensional criteria reflects all manner of opinions in the building production process. Stakeholders' integration plays a major role in achieving this evaluation expecting the targeted quality in building production, and different priorities could be defined by various type of stakeholders. Therefore, applicable approaches should be used where the stakeholders of the building production process will be included to determine priority levels of criteria. All the criteria considered should provide that all dimensions of demands and expectations are met in the creation of the new building and the built environment. In this study, which is a widely used multi-criteria decision-making method, is applied to ensure mutual satisfaction of decision-makers and beneficiaries in construction process. Four main criteria and sub-criteria related to these main criteria were determined by adding "green and sustainability issues" to the "functionality", "build quality" and "impact" trilogy determined by Vitruvius for the development of architectural quality. The method used here is based on an evaluation system takes into account all of the stakeholders' expressions. Necessary data is gathered from three type of stakeholders; a technical team of five individuals consists of architects and engineers, a focus group of twelve individuals consist of occupiers as mass housing clients and the last one is the focus group of three individuals from building production firms as facilities manager. It was observed that distinct type of stakeholder ranked the weight of each main and sub-criterion differently. Therefore, it has been concluded that definition of criteria and determination of the weights of them shall not be determined by only one stakeholder in a project, but also all particular stakeholder are also shall be included during planning and application process.

Keywords Analytic hierarchy process (AHP) · Building design quality · Mass housing · Multiple criteria decision-making (MCDM) · Stakeholder satisfaction

Abbreviations

MCDM	Multiple criteria decision making
AHP	Analytic hierarchy process
PROMETHEE	Preference ranking organization method for enrichment evaluations

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TOPSIS	Technique for order preference by similarity to ideal solution
ELECTRE	Elemination and choice translating reality english
DQI	Design quality indicator
HQI	Housing quality indicator
HQS	Housing quality standart
POE	Post-occupancy evaluation
ODPM	Office of the deputy prime minister
GDM	Group decision-making
CI	Consistency index
CR	Consistency ratio
RI	Random consistency index

1 Introduction

Housing, one of the basic human needs, should create a sense of satisfaction and trust and play an important role in improving people's quality of life. Baird and friends stated that "Buildings affect our health, our work, our leisure, our thoughts and emotions, our sense of place and belonging. If buildings work well, they enhance our lives, our communities and our culture" (Baird, 1996). In addition to that statement, achieving the appropriate quality level in building production provides significant gains for countries in terms of time and economy. (Kazaz & Birgonul, 2005). For this reason, quality approach studies should be included more in the building industry. However, considering the diversity of building types, serving different functions, and the role of different stakeholders in the production cycle, it can be said that the building production process is a complex process. The complexity of this process directly affects the "quality improvement" problem. Cornick states the building quality as the sum of the successes of the "customer", "design team", "contractor" and "subcontractor" (Cornick, 2006).

According to International Organization for Standardization, underlying principles and success factors of these processes include customer focus, leadership, involvement of people, continuous improvement, factual approach to decision-making, and mutual beneficial relationships with service providers (Abdirad & Nazari, 2015). In other words, in order to ensure building design and production quality, many stakeholders should be satisfied. In his research, Sikorsky argued that the inadequacies in establishing the right targets to reflect user needs and converting these targets into final products directly affect the relationship between falling productivity and poor quality in the American building industry (Sikorsky, 1990).

This study shows that in order to reach the performance and efficiency targets in building production, satisfaction targeted determination should be done based on the usage process and data should be presented for the newly designed buildings. Meeting the needs and demands in the building production process is the most important factor in the success of the product (Zavadskas, 2018). The communication of the stakeholders in the process with each other is of great importance in terms of quality. Therefore, it is of great importance to determine the criteria that will fully reveal the expectations and to develop methods to evaluate these criteria (Safapour, 2019). In this study, it is accepted that, in the process of building production, it is possible to obtain better, more qualified and flawless buildings only with various quality based criteria that can be objectively evaluated. Another important acceptance that shapes this study is that stakeholder satisfaction plays a major role in achieving the targeted quality in building production, but this satisfaction can be met at the rate of meeting different stakeholder demands (Li et al., 2012, 2016).

Design efforts carried out without taking the form, the function, constructional relations into account, not complying with standards in construction investments not only in Turkey but also in other countries of the world prevent building productions from being used in accordance with their intended purpose. In order to reach the desired quality, developing qualitative criteria in the light of current standards should be considered as a research tool to measure quality (Pekuri et al., 2011). For this reason, case studies from different parts of the world should be diversified and added to the literature for each building type as Kowaltowski emphasizes the inadequacy of the studies on building and design quality in his research (Kowaltowski, 2019).

In this study, a case study was conducted in the area of mass housing as a building type. Main criteria and sub-criteria were determined hierarchically for the determination of mass housing production quality. These criteria are prioritized based on the satisfaction of the stakeholders in the production process. Evaluation standards set by some countries have been compiled to improve the quality of housing design. Some of these are Design Quality Indicator (DQI), Housing Quality Indicator (HQI) and Housing Quality Standards (HQS) (Preiser & Nasar, 2008; Sanni-Anibire et al., 2016; Simon, 1962; Thomson, 2003). As these standards diversify, it becomes difficult to make criteria selections. Besides, preference of these criteria depends on the satisfaction of many stakeholders steering design and production. Variety is the greatest reason why complications and uncertainty regarding the determination of criteria for quality in the process of design emerge. For this reason, the method of Multiple Criteria Decision Making (MCDM) was opted for in the study to determine the matters of priority of the criteria. MCDM methods are analytical methods providing the opportunity to assess tangible and intangible strategic and operational factors simultaneously, able to incorporate a lot of persons into decision-making processes (Mareschal, 1988). In other words, Multiple criteria decision making (MCDM) is a range of methods that renders aggregation and contemplation of many and mostly conflicting criteria for selection or ranging (Mulliner et al., 2013; Razavi et al., 2011). Employment of MCDM systems is believed to be useful for the purpose of assessing architectural design quality, for MCDM systems are scientific systems that render assessment of alternatives by decision-makers within the framework of determined criteria and sub-criteria (Hsieh et al., 2004).

Regarding multi-criteria decision-making (MCDM), realistically modelling an individual's decision process is an ongoing and often unsolvable problem. This gets complicated when considering a group decision-making (GDM) environment. That is, with a few people making judgments where a final group decision should be made. As a research problem, techniques such as AHP have been introduced and developed to assist individuals with MCDM and GDM problems (Beynon, 2006).

AHP renders smoothing of choice by creating an order of priority among the desired criteria. Since AHP allows for calculation of the consistency index during ranging, it was preferred for decision-making in MCDM. Because of its simplicity, ease of use, and great flexibility, the analytic hierarchy process (AHP) has been studied extensively and used in nearly all applications related to multiple criteria decision making (MCDM) since its development (Ho & Ma, 2018; Saaty, 1990). Thus, the application of AHP has become a popular research method in various fields for assessing, rating, and determining the importance weightings for selection indicators or criteria (Kamaruzzaman, 2018). Considering these, AHP, one of MCDM methods, was employed in this study. Improvement of building design quality was tested on exemplary case studies using AHP-based approach proposal.

The primary goal of this paper is to assess design quality of buildings and to create awareness regarding the production of design knowledge for preferences through comparison of the criteria by all manner of stakeholders. For this reason, some highlights coming to the fore from among the criteria adopted across the world were exemplified on a mass housing area produced after the earthquake in Turkey and the criteria were prioritised by all type of stakeholders during the production of mass housing in this area was determined. It was observed that productive usage of knowledge was secured, and that knowledge was directly communicated by all stakeholders, thereby supporting the decision-makers through analytical analyses carried out.

2 Literature review

2.1 Quality and building design practice

Since quality is a multidimensional concept, it has many different definitions in the literature and it is without doubt that it will have much more various definitions in forthcoming years through contribution not only by rapid alterations experienced but also by technological developments. While Deming (1952) and Kondo (2000) define quality as production of goods and services able to meet customer needs and their reasonable expectations fully and continuously in the most economical manner, Rounce (1998) says quality meeting agreed requirements or conformance to requirements. Juran (1974), whose studies in the field of quality are recognized all over the world, defines quality simply as "appropriateness for use".

Based on expressed definitions, building design quality is a combination of objective and subjective criteria and it is not easy to measure it (Gann et al., 2003). Although objective criteria can be measured as they are dependent on physical parameters, subjective criteria depend on divergent opinions, experiences and preferences of different concerned parties. So, it is difficult to determine such criteria in exact terms. However, such unique criteria make a project architecturally matchless and significant (Blyth & Worthington, 2002).

There are various approaches in the literature oriented toward the assessment of building design quality. Many of these have been developed for the purpose of guiding building designs (ASCE. Quality in the constructed project: A guide for owners, designers & and constructors., 2012.ASCE Reston, VA., 2012; Bernus et al., 2012). Nevertheless, as early planning processes of buildings cannot be implemented fully properly, significant losses occur regarding economy, duration and resources (Gibson & Gebken, 2003).

Harputlugil et al. (2016) advocate the notion that criteria constituting building design quality might change considering society, age, technology, situation and resources; therefore, the notion of having a flexible structure able to assess different criteria likely to be put forward for each design team, must be regarded as the fundamental element. Yudelson (2010), Mlecknik et al. (2010) and Adinyira et al. (2018) have suggested that identification, comprehension and integration of stakeholder requirements for the purpose of rendering design and energy productivity oriented toward quality in mass housing is the fundamental for successful implementation of strategies oriented toward sustainability in residential development. Svahnberg et al. (2003) stated that quality elements could not be incorporated into the system in the form of cogitation; that, therefore, they need incorporating into the system from the very start. These studies carried out reveal the necessity of quality phenomenon being added to all processes beginning from the design process, the first stage of building production.

The triplet of "Utilitas, Firmitas and Venustas" (Rowland & Howe, 2001) (most commonly translated as "commodity, firmness and delight"), defining Vitruvius' design quality in the eyes of many contemporary architects, has been a source of inspiration in determination of criteria (Boschi, 2002; Gann et al., 2003; Thomson, 2003; Volker, 2008). Building performance indicators set by Vitruvius have been transformed into a hierarchical system of user needs by Lang and synthesized by Preiser within the framework of liveability (Lang, 1974; Preiser & Vischer, 2006). In addition, taking into account the trilogy of Vitruvius, some standards have been developed to improve building quality (Design Quality Indicator (DQI), Housing Quality Indicator (HQI), Housing Quality Standards (HQS) etc.).

2.2 Design quality indicator (DQI)

The Construction Industry Council's design quality indicator is a questionnaire designed to gather feedback from a diverse group of people affected by the building at any stage of the building's lifecycle (Sanni-Anibire et al., 2016). Design Quality Indicator (DQI) has been developed to assess the quality of construction projects. Its purpose is to communicate assessments during the process of usage to all stakeholders of the process synchronously with developing design quality. DQI defines Vitruvius' quality triplet as "commodity = functionality", "firmness = build quality" and "delight = impact" (Thomson, 2003). Brophy and Lewis (Brophy & Lewis, 2012) presents a definition that is in the form of "commodity = Suitability for use", "firmness = durability in performance" and "delight = visual delight" (Table 1).

DQI conducts quality assessment by taking user satisfaction into account (Simon, 1962). Therefore, it employs the post-occupancy evaluation (POE) technique. Preiser and Nasar (2008) claim that systematic attempts at assessing building performance through the use of POE method in terms of user satisfaction were carried out by Sim van der Rijn from the University of California, by Victor Hsia from University of Berkeley and University of

Table 1 Relationship of design quality fields to Vitruvian principles

Vitruvian principle	Thomson et al. (2003)	Brophy and Lewis (2012)	DQI assessment quality fields Thomson et al. (2003), Gann et al. (2003)
Commodity	Functionality	Suitability for use	Use
			Access
			Space
Firmness	Build quality	Durability in performance	Performance
			Engineering systems
			Construction
Delight	Impact	Visual delight	Form & materials
			Internal environment
			Urban & social integration
			Character & innovation

Utah in 1960s. In these studies, satisfaction of users in university dormitories was determined in terms of quality and performance levels (Preiser & Nasar, 2008).

2.3 Housing quality indicator (HQI)

Studies carried out in Europe and USA, are rapidly flourishing in order to determine criteria for assessing abode quality. Developing countries also take these criteria as basis and try to adapt them to assessment systems in themselves. HQI comes to the fore in our day. HQI has been developed by The Housing Corporation and the Office of the Deputy Prime Minister (ODPM) since 1996 (Le et al., 2016). It is a quality measurement tool developed for the purpose of obtainment of higher-quality abodes based on the problems of existing abode stock in England. Its main objective is to determine the existing good and bad samples and to increase building quality correspondingly. The assessment tool, developed with the aim of easy use, encompasses usage process of buildings. The HQI covers ten indicators: 1. Location 2. Master plan of the building, 3. Open space 4. Traffic 5. Unit (Apartment)'s size, 6. Unit (Apartment)'s layout, 7. Noise and light manipulation, 8. Accessibility, 9. Sustainability, 10. Vision for life (Cook, 2008; Le et al., 2016; Malakouti, 2019; Sanni-Anibire et al., 2016) (Table 2). HQI, location, design and performance can be grouped within basic criteria. Specific parts of the survey, which is asked to users with questions and mostly assessed through yes/no answers, are filled out by professional auditors. In the assessment, not only is the general score of the building obtained but also the plan schema is assessed. The assessment is carried out through contemplation of quality, crucial properties of the housing project without being dependent on the cost. The system has been developed in a way that it is based on assessment of quality in many different aspects.

Similarly, the U.S. Housing Quality Standards (HQS) provide a 19-page survey of 13 indicators that ask users questions about housing for residential supervision. Standard conditions and minimum quality criteria are given in the same form as the residential unit examined and the units examined are evaluated according to these criteria. Diagnostics are used in the inspection of new sites and in special inspections resulting from complaints to ensure the quality of the delivered homes. Therefore, these audits will serve several purposes. Such assessment-based data play an important role in documenting, informing and controlling processes in the residential sector, thereby providing assurance for achieving, developing and sustaining the optimum quality level for all residential areas (Dinc et al., 2014; Mast, 2009).

The criteria of DQI, HQI, and HQS methods, chosen as samples, are based on Vitruvian triplet, the basis for architectural design quality and on sustainable principles. These general criteria are positive for the sake of being agreed on and of delineating a common framework in assessment processes. If we are to summarize all these criteria specified, it can be stated that they are assessed through a broad perspective encompassing building design quality, intended cost, duration, physical performance criteria, functional expectations, aesthetic expectations and appropriateness for environment and laws, constructability, production of efficacious solutions in terms of energy conservation. Complications and uncertainty rise in a process full of so many multi-dimensional criteria. Diversity is the biggest cause of complications and uncertainty regarding the determination of quality criteria in the design process. For this reason, it is necessary to benefit from Multiple Criteria Decision Making (MCDM) methods to systematize these criteria and determine priority order.

Table 2 HQI: Housing quality indicators

Sanni-Anibire et al. (2016)		Malakouti et al. (2019)		Le et al. (2016)
Location	Location	Visual impact	Location	Master plan of the building,
		Layout and landscaping		
Design	Site	Open space	Site	Open space
		Routes and movement		
	Unit	Size	Unit	Size
		Layout		Layout
		Noise control		Noise and light manipulation,
Performance	Performance in use	Light quality and services	Performance in use	Accessibility
		Accessibility within the unit Energy		Sustainability
		Green and sustainability issues		Vision for life

2.4 Multiple criteria decision making (MCDM)

MCDM methods are analytical methods providing the opportunity to assess measurable/tangible and imponderable/intangible strategic and operational factors simultaneously, able to incorporate many persons into decision-making processes. Yau (2011) proposed a multi-criteria decision-making method for high-rise residential buildings, where conflicts exist among various users because of varied interests. Alanne et al. (2007) considered the selection of a residential energy supply system as a multi-criteria decision-making problem, which involved both financial and environmental issues.

The primary goal of this paper is to assess design quality of buildings and to create awareness regarding the production of design knowledge for preferences through comparison of the criteria. For this reason, some highlights coming to the fore from among the criteria adopted across the world were exemplified on a mass housing area produced after the earthquake in Turkey and which criteria the stakeholders prioritized more during the production of mass housing in this area was determined. It was observed that productive usage of knowledge was secured and that knowledge was directly communicated to the stakeholders, thereby supporting the decision-makers through analytical analyses carried out.

There are three basic steps that all MCDM systems follow (Mulliner et al., 2013; Triantaphyllou, 2000).

1. Determine relevant criteria and alternatives,
2. Attach numerical measures to the relative importance of the criteria and to the impacts of the alternative on these criteria,
3. Process the numerical values to determine a ranking of each alternative.

In order to process the numerical values, there are various different MCDM methods available, each with their own varying characteristics. Some of the most commonly used methods include the AHP, TOPSIS, PROMETHEE and ELECTRE etc. (Mulliner et al., 2013; Sabaei et al., 2015). AHP technique was opted for being able to make a choice from among the criteria oriented toward developing building design quality.

3 Research methodology: analytic hierarchy process (AHP)

AHP is a multi-criteria decision-making technique developed by Saaty for the purpose of assessing and choosing alternatives in the selected criteria group (Saaty, 1990). The objective of AHP usage is to organize tangible and intangible factors systematically and to provide a structured, simple solution toward decision-making process for problems (Awasthi & Chauhan, 2012).

Sarathy (2013) has defined AHP as the opportunity for decision-makers to model a complicated problem in the way of a hierarchical structure showing relations between objectives, criteria and alternatives. The objective is specified at the top of the hierarchical structure produced within the method; sub-objectives and alternatives are specified below the objective. In addition to structuring complex problems, the AHP allows the inclusion of objective and subjective considerations into the decision process. In AHP applications, all parts of the hierarchy are related to each other and how the change in a factor affects other factors can be seen easily. The reasons why AHP method was opted for in the study are primarily that it can be organized hierarchically and it can help to make a choice from among alternatives by enabling assessment of calculable, tangible criteria and subjective, incalculable, intangible criteria (Abdel-Basset, 2018; Svahnberg, 2003); that it can be used for consistency analysis (Razavi et al., 2011); that it can be used both in individual decision-making processes and in decision-making processes by a group; that it ensures implementation of data collection easily and in a short time (Deng, 1999); that it can be used in each phase of building production; that it has a flexible and improvable structure; that it presents the opportunity to alter criteria, etc.

AHP-based approach aims to serve as a support system for stakeholders oriented toward the choice of alternatives within the framework of determined criteria and sub-criteria mainly for the purpose of assessment of quality. The subsequent step to production of hierarchical table belonging to the problem for decision-making is to determine weight of the criteria with the same level of significance in comparison with each other (Thanki et al., 2016). In this stage, in the part of weighting in comparison with each other, the scale of preference scored from 1 to 9 by Saaty is benefited from (Saaty, 1987) (Table 5). The efficaciousness of this scale was detected as the result of implementations carried out in different fields and theoretical comparisons with other scales (Kuruüzüm & Atsan, 2001; Uzun & Kazan, 2016).

The pairwise comparison matrix indicates the significance levels of criteria in comparison with each other within a certain logic (Gass & Rapcsák, 2004). Criteria are converted into a matrix through pairwise comparisons. Different units measure each criterion so they should to be normalized to obtain appropriate classifications, as used the scale by Saaty here, to reach the results for a final score. Thus, data normalization is an essential part of any decision making process because it transforms the input data into numerical data (Vafaei et al., 2016). After data normalization process, the significant priorities are determined using either Eigen vectors method or a simplified version with weighted $\sum$ method Simple Additive Weighting (SAW) (Tables 3, 4).

The pairwise comparison matrix has some attributes. These are listed below:

1. All elements of the matrix are positive numbers and the matrix is a square matrix.
2. If the matrix is fully consistent, the equation of $a_{ij}.a_{jk} = a_{ik}$ is produced.
3. If the matrix is fully consistent, all other factors of the matrix are obtained through any of its lines.
4. The eigenvector corresponding to the greatest eigenvalue of the matrix is defined in AHP matrix as the weight or *relative importance vector*.
5. The diagonals of matrix A are equal to 1(Saaty, 1987, 1990).

Table 3 Development of pairwise comparison matrix

Criteria	C_1	C_2	C_3	……	C_n
C_1	1	a_{12}	a_{13}	……	a_{1n}
C_2	$1/a_{12}$	1	a_{23}	……	a_{2n}
C_3	$1/a_{13}$	$1/a_{23}$	1	……	a_{3n}
………	………	…………	………	1	…….
C_n	$1/a_{1n}$	$1/a_{2n}$	$1/a_{3n}$	……	1
	$\sum Column_1$	$\sum Column_2$	$\sum Column_3$	……	$\sum Column_n$

Table 4 Development of normalized matrix

Criteria	C_1	C_2	C_3	……	C_n
C_1	$1/\sum Column_1$	$(a_{12})/\sum Column_2$	$(a_{13})/\sum Column_3$	……	$(a_{1n})/\sum Column_n$
C_2	$(1/a_{12})/\sum Column_1$	$1/\sum Column_2$	$(a_{23})/\sum Column_3$	……	$(a_{2n})/\sum Column_n$
C_3	$(1/a_{13})/\sum Column_1$	$(1/a_{23})/\sum Column_2$	$1/\sum Column_3$	……	$(a_{3n})/\sum Column_n$
………	…….	………	…….	……	…….
C_n	$(1/a_{1n})/\sum Column_1$	$(1/a_{2n})/\sum Column_2$	$(1/a_{3n})/\sum Column_3$	……	$1/\sum Column_n$

Row average	Weights
$\sum Row_1/n =$	w_1
$\sum Row_2/n =$	w_2
$\sum Row_3/n =$	w_3
…….	…….
$\sum Row_n/n =$	w_n

W the purpose of determining the significance of criteria and/or alternatives in comparison with each other in Analytical Hierarchy Process, each alternative is scored through examination of its weight in AHP Pairwise Comparison Scale table with other alternatives. These weights and their significance are shown in Table 5.

Through AHP, the priorities showing the relative importance of the parameters by additive normalization method. The priorities are interpreted to resişpect decision parameters used to set up the comparison processes. Additive normaliztion method helped to get the priority vector by dividing sum of each column to the each values on each column called the normalization of columns. Then, the elements in each resulting row are added and divided by the number of values shown in the corresponding row. Priority vector is also called as the normalized Eigenvector of the matrix.The next step is to find out a consistency ratio to check how consistent the judgements are (Bhatia & Singh, 2015).

The factor related to the reliability of the ultimate decision in AHP models is the consistent behaviour of the decision-maker during pairwise comparisons. For this, a method of determining the ratio of consistency was developed. For pairwise comparison matrices in the AHP method, the consistency ratio is calculated (Formula 1, 2, Table 6). If the value of Consistency Ratio is lower than 0.10, this indicates that comparisons by the decision-maker are consistent (Razavi et al., 2011; Saaty, 1987). AHP calculations are based on the assumption of all decision maker rational on their choices so if they choose X is selected over Y and Y is preferred to Z, as a result X is selected over Z as well. This property is vital for AHP and called transitive property. Saaty (1980) defined the consistent reciprocal matrix as th largest eigenvalue (λ_{max}) is equal to the number of comparisons.

Consistency Ratio is calculated as follows;

$$\text{Consistency Index} = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

$$\text{Consistency Ratio}(CR) = \frac{\text{Consistency Index(CI)}}{\text{Random consistency Index(RI)}} \tag{2}$$

Note that if the AHP hierarchy has multiple levels of criteria and sub-criteria, the above-mentioned computations must be done for each sub-criteria (leaf node of the hierarchy)

Table 5 Saaty's 1–9 scale for pairwise comparison

Weight intensity	Definition	Explanation
1	Equally important	Two activities contribute equally to the objective
3	Moderately important	Experience and judgment slightly favour one over another
5	Strongly important	Experience and judgment strongly favour one over another
7	Very strongly important	An activity is strongly favoured and its dominance is demonstrated in practice
9	Extremely important	The importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate weights	Used to represent compromise between the priorities listed above

Table 6 Random consistency index values (RI) (Saaty, 1987)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

and then the priority vectors of the alternatives according to each sub-criteria are synthesized into one priority vector (Razavi et al., 2011).

4 Case study

In this study, four (4) main criteria and some sub-criteria related to these main criteria were determined by adding "green and sustainability issues" to the "functionality", "build quality" and "impact" triplet determined by Vitruvius for the development of architectural design quality. The sub-criteria below these four criteria were produced from among the criteria compiled from among BQI, HQI, and HQS quality assessment methods (Table 7).

In this study, comparison of the criteria determined that are oriented toward quality assessment in building production process and priority assessment of the criteria have been exemplified in mass housing projects. The majority of mass housing production in Turkey is actualized by Housing Development Administration (TOKI). The study was restricted to mass housing projects for low-income and middle-income groups within the framework of revenue sharing model of TOKI, taking the variety in customer profile in housing industry into account. The reasons why mass housing projects were preferred in the study for the implementation of the method can be listed as follows:

1. The fact that the place of mass housing sectors in national economies is significant,
2. Necessity of true solutions where each stage of the abode life cycle is taken into account,

Table 7 Building Design Quality indicators (BDQIs) compiled from the literature

BDQIs		
F: Functionality	B: Build quality	I: Impact
F.1: Location and transport	B.1: Performance	I.1: Design
F.2: Regional priority	B.2: Indoor environmental quality	I.2: Form & materials
F.3: Accessibility	B.3: Light quality and services	I.3: Visual impact
F.4: Flexibility	B.4: Noise control	I.4: Layout & Size
F.5: Traffic	B.5: Health and wellbeing	I.5: Routes and movement
F.6: Space	B.6: Engineering Systems	I.6: Character & innovation
	B.7: Construction	I.7: Urban & social integration
	G: Green and sustainability issues	
	G.1: CO_2 emission/energy consumption	
	G.2: Material and resources	
	G.3: Water efficiency	
	G.4: Land use and ecology	
	G.5: Pollution	
	G.6: Waste management	

3. Necessity of developing methods oriented toward determining the expectations of the target market,
4. Necessity of determined customer expectations and needs being handled from a holistic standpoint within the framework of life cycle of projects

The method within the scope of the study took as the basis mass housing production actualized by various contractor companies within the framework of the revenue sharing model of TOKI. For this reason, mass housing areas in the province of Bingöl produced after the earthquake of 2003 were focused on. These residential areas are made up of various residential sections. There are two types of abode projects in these residential sections and users of these abodes consist of low-income and middle-income groups. The housings located in area are the Toki housing projects are often used in many provinces of Turkey. The projects used in practice have a compact form similar to a square or a rectangle (Fig. 1). They are applied in each climatic region of Turkey. Designed as an 8-storey housing, each floor has four apartments. Floor height of the apartments is 2.80 m and the height of the basement is 0.50 m.

For assessments, a technical team of five (5) persons made up of architects and engineers, a focus group of twelve (12) persons made up of mass housing clients as users and a focus group of three (3) persons made up of building production firms were selected. The most important reason for the conduction of this study in Turkey is to assess and demonstrate the results of the quality criteria entered into the literature in countries with different cultures and environments.

Both in Turkey and in other countries of the world, designs developed as one-type in public housing and made without regard to demographic structure and environmental relations prevent building production from achieving its intended use. These structures arise as a problem of living spaces that are incompatible with their users and do not respond to needs. Case studies from different parts of the world should be included in the literature in order to identify this problem and develop solutions. As the diversity in

Building form	Building material	Number of stories	Number of rooms	Heating System	Orientation	Flexibility	Accessibility	Social infrastructure
Rectangle and Compact	Reinforced concrete	8	3+1 4+1	Natural gas	The orientation criteria have been partially taken into account.	the buildings are not flexible	in the city center disabled access partially provided	Public facilities Open spaces Children's activity areas Storage, parking and waste services

Fig. 1 Mass housing produced in Bingol after the earthquake in 2003

the literature increases, the applicability and performance of the determined criteria will be tested.

5 Results and discussions

The criteria determined after the literature review, the method of pairwise comparison via AHP was implemented and consistency analyses were calculated. Through this method, different evaluations of each criterion and sub criterion have been determined by distinct type of stakeholders.

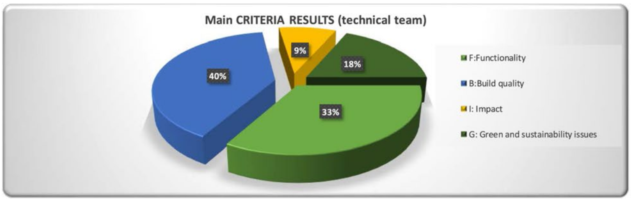
Main criteria and their sub-criteria were subjected to pairwise comparison one by one and the results were tabulated. The comparison matrix demonstrates the assessment of all criteria in comparison within a particular logic. Even though, AHP has a consistent systematics, so accuracy of the results will naturally depend on the consistency to be made by the decision-makers.

Consistency values (CR) were calculated separately for comparison of each main criteria and sub-criteria. If CR value is lower than 0.10 ($CR \leq 0.10$) for a comparison matrix, this indicates that evaluations by the decision-maker are consistent. If CR value is greater than 0.10 ($CR \geq 10$), this shows either a miscalculation in AHP or an inconsistency in comparisons by the decision-maker. The CR values have been determined for main criteria as 0.0406 evaluated by technical team (Fig. 2), as 0.0931 evaluated by managers of facilities (Fig. 3) and as 0.0971 evaluated by mass housing clients (Fig. 4). Consistency of the sub-criteria was also calculated, and all evaluations are consistent as shown in Table 8.

First group of building process stakeholder is technical team including five individuals as architectures and engineers. The technical team has made comparison for main criteria and sub criteria separately as a single person. After they finished their comparisons separately, to show the group decision results, final comparison matrix has been gathered by using geometric mean method. Likewise, for second group stakeholder which are twelve individual occupiers as mass housing clients and third group of stakeholders which are three authorized officers from building production company, the same step has been applied and then the group decision matrixes created. When the comparative results of the main criteria are examined by technical team firstly, it is observed that "build quality" with weight of 0.3943 is ranked first, then "functionality" with weight of

Main CRITERIA RESULTS (technical team)

	F	B	I	G	N_{max}		F	B	I	G	Row Averages
F:Functionality	1,00000	1,00000	3,00000	2,00000	**1,3630**	**F:Functionality**	0,3529	0,3871	0,2727	0,3158	**0,3321**
B:Build quality	1,00000	1,00000	4,00000	3,00000	**1,6365**	**B:Build quality**	0,3529	0,3871	0,3636	0,4737	**0,3943**
I: Impact	0,33333	0,25000	1,00000	0,33333	**0,3601**	**I: Impact**	0,1176	0,0968	0,0909	0,0526	**0,0895**
G: Green and sustainability issues	0,50000	0,33333	3,00000	1,00000	**0,7500**	**G: Green and sustainability issues**	0,1765	0,1290	0,2727	0,1579	**0,1840**
Column Total	**2,83333**	**2,58333**	**11,00000**	**6,33333**	**4,1097**	**Total**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**



n	4	Consistency	
n_{max}	**4,1097**	$n_{max \geq n}$	eligible
CI	**0,0366**		
RI	**0,9000**		
CR	**0,0406**	0,1	consistent

N	RI
1	0,00
2	0,00
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

Fig. 2 Main criteria consistency calculation for technical team

MAIN CRITERIA RESULTS (Facilities managers)

	F	B	I	G	N_{max}		F	B	I	G	Row Averages
F:Functionality	1,00000	3,00000	3,00000	5,00000	2,1515	F:Functionality	0,5357	0,4091	0,6429	0,4167	0,5011
B:Build quality	0,33333	1,00000	0,33333	3,00000	0,6443	B:Build quality	0,1786	0,1364	0,0714	0,2500	0,1591
I: Impact	0,33333	3,00000	1,00000	3,00000	1,1378	I: Impact	0,1786	0,4091	0,2143	0,2500	0,2630
G: Green and sustainability issues	0,20000	0,33333	0,33333	1,00000	0,3177	G: Green and sustainability issues	0,1071	0,0455	0,0714	0,0833	0,0768
Total	1,86667	7,33333	4,66667	12,00000	4,2514	Total	1,0000	1,0000	1,0000	1,0000	1,0000

n	4	Consistency
n_{max}	4,2514	$n_{max \geq n}$ eligible
CI	0,0838	
RI	0,9000	
CR	0,0931	0,1consistent

N	RI
1	0,00
2	0,00
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

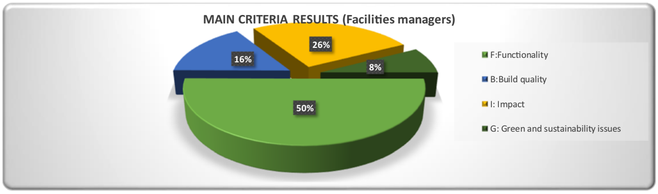


Fig. 3 Main criteria consistency calculation for facilities managers

MAIN CRITERIA RESULTS (Mass housing clients)

	F	B	I	G	N_{max}		F	B	I	G	Row Averages
F:Functionality	1,00000	3,00000	2,00000	3,00000	1,9160	F:Functionality	0,4615	0,6207	0,3750	0,3000	0,4393
B:Build quality	0,33333	1,00000	2,00000	3,00000	1,1052	B:Build quality	0,1538	0,2069	0,3750	0,3000	0,2589
I: Impact	0,50000	0,50000	1,00000	3,00000	0,8435	I: Impact	0,2308	0,1034	0,1875	0,3000	0,2054
G: Green and sustainability issues	0,33333	0,33333	0,33333	1,00000	0,3976	G: Green and sustainability issues	0,1538	0,0690	0,0625	0,1000	0,0963
Total	2,16667	4,83333	5,33333	10,00000	4,2623	Total	1,0000	1,0000	1,0000	1,0000	1,0000

n	4	Consistency
n_{max}	4,2623	$n_{max \geq n}$ eligible
CI	0,0874	
RI	0,9000	
CR	0,0971	0,1 consistent

N	RI
1	0,00
2	0,00
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

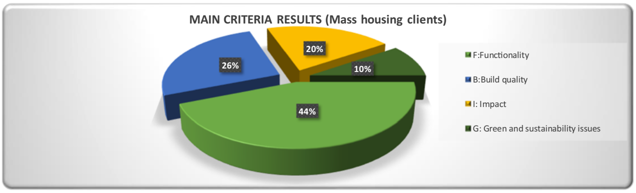


Fig. 4 Main criteria consistency calculation for mass housing clients

0.3321 is ranked secondly, “green and sustainability issues” is ranked third with weight of 0.1840 and “impact” is ranked last with weight of 0.0895. Therefore, technical team considers that most important issue is quality of the build. Furthermore, they do not see “impact” as a vital issue.

Secondly, the weights of main criteria have been defined by firm executives as “functionality” with 0.5011, “impact” with 0.2630, “build quality” with 0.1591 and “green and sustainability issues” with 0.0768 respectively (Table 8) As is seen, managers of the building company consider that the most important criteria are functionality. Moreover, this group does not believe that green and sustainability issues are important.

Thirdly, mass housing clients ranked “functionality” as first main criteria with weight of 0.4340, “build quality” as second with 0.2536, “impact” as third with 0.2221 and “green and sustainability issues” as the last one with 0.0903 (Table 8). Therefore, also occupiers considers build quality as the most important issue, too. However, they do not see green and sustainability criteria as a vital issue.

Table 8 Comparative results of main and sub criteria

Criteria/sub-criteria	Technical team (Architects/engineers)			Facilities managers			Mass housing clients		
	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)
F: Functionality	0.0996	2.83	0.3321	0.0977	1.87	0.5011	0.0963	2.17	0.4393
F.1: Location and transport		8.67	0.1200		3.28	0.2946		3.33	0.2874
F.2: Regional priority		21.00	0.0462		10.50	0.0927		12.00	0.0785
F.3: Accessibility		2.98	0.3179		3.58	0.2564		4.00	0.2345
F.4: Flexibility		4.23	0.3209		7.33	0.1826		6.17	0.2227
F.5: Traffic		8.83	0.1375		11.50	0.1107		13.00	0.0910
F.6: Space		19.00	0.0574		18.00	0.0631		14.00	0.0859
B: Build quality	0.0955	2.58	0.3943	0.0974	7.33	0.1591	0.0861	4.83	0.2589
B.1: Performance		11.33	0.1245		3.75	0.2898		4.92	0.2684
B.2: Indoor environmental quality		2.65	0.3732		7.92	0.2112		9.17	0.1707
B.3: Light quality and services		13.00	0.0760		12.00	0.0901		15.00	0.0668
B.4: Noise control		11.50	0.0579		6.83	0.0763		8.17	0.0648
B.5: Health and wellbeing		11.20	0.1470		10.92	0.1291		6.95	0.1938
B.6: Engineering systems		13.20	0.1103		13.45	0.1019		10.45	0.1379
B.7: Construction		5.40	0.1110		6.20	0.1016		4.90	0.0976

Table 8 (continued)

Criteria/sub-criteria	Technical team (Architects/engineers)			Facilities managers			Mass housing clients		
	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)
I: Impact	0.0712	11.00	0.0895	0.0981	4.67	0.2630	0.0908	5.33	0.2054
I.1: Design		4.50	0.2283		4.78	0.2275		3.83	0.2746
I.2: Form & materials		9.50	0.1136		7.33	0.1674		8.75	0.1476
I.3: Visual impact		15.00	0.0630		4.33	0.2241		9.00	0.1243
I.4: Layout & size		10.50	0.1122		10.50	0.1030		10.00	0.0983
I.5: Routes and movement		9.83	0.1245		17.00	0.0545		9.50	0.1080
I.6: Character &innovation		7.33	0.1514		12.50	0.0794		7.00	0.1438
I.7: Urban & social integration		4.83	0.2071		10.33	0.1440		12.00	0.1034

Table 8 (continued)

Criteria/sub-criteria	Technical team (Architects/engineers)			Facilities managers			Mass housing clients		
	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)	consistency ratio (CR) < 0.1	Pairwise comparison matrix (column total)	Weights (normalized)
G: Green and sustainability issues	0.0789	6.33	0.1840	0.0811	12.00	0.0768	0.0934	10.00	0.0963
G.1: CO_2 emission/energy consumption		4.83	0.2153		3.92	0.2492		2.50	0.3637
G.2: Material and resources		10.00	0.1151		14.00	0.0689		12.50	0.0809
G.3: Water efficiency		6.33	0.1717		15.50	0.0739		18.00	0.0509
G.4: Land use and ecology		5.00	0.2005		11.67	0.1201		11.67	0.1168
G.5: Pollution		9.00	0.1214		5.08	0.2094		7.08	0.1677
G.6: Waste management		6.33	0.1760		3.42	0.2785		5.42	0.2199

According to these results, stakeholders generally prioritize different main criteria, while the "functionality" criterion has a first level rank of importance for managers of facilities and occupiers. Technical team has a different view on the main criteria ranking. There are also distinct evaluations for defining the priority order of sub-criteria.

As shown in Table 8, considering "functionality" main criteria, according to the prioritization of the technical team, the first three sub-criteria are "flexibility (0.3209)", "accessibility (0.3179)", and "traffic (0.1375)" respectively. So on, facility managers have evaluated "location and transport (0.2946)" as first rank, "accessibility (0.2564)" as second rank and "flexibility (0,1826)" as third rank. Finally, mass housing clients thinks that the first three sub-criteria are "flexibility (0,2874)", "accessibility (0.2345)", and "location and transport (0.2227)" respectively.

When the "build quality" main criteria results are analysed, according to the technical team, the first three sub-criteria are "indoor environmental quality (0.3732)", "health and well-being (0.1470)", and "performance (0.1245)" respectively. Second group which are facility managers have evaluated "performance (0.2898)" as first rank, "indoor environmental quality (0.2112)", as second rank and "health and well-being (0.1291)", as third rank. So on, the final group which are mass housing clients thinks that the first three sub-criteria are "performance (0.2684)", "health and well-being (0.1938)", and "indoor environmental quality (0.1707)" respectively.

As reflecting the results of third main criteria "impact", according to the technical team, the first three sub-criteria are "design (0.2283)", "character & innovation (0.2071)", and "urban & social integration (0.1514)" respectively. So on, facility managers have evaluated "design (0.2275)" as first rank, "visual impact (0.2241)" as second rank and "form & materials (0.1674)" as third rank. Finally, mass housing clients thinks that the first three sub-criteria are "design (0.2746)", "form & materials (0.1476)", and "character & innovation (0.1438)" respectively.

When interpreting the results of "green and sustainability issues" main criteria, according to the prioritization of the technical team, the first three sub-criteria are "CO_2 emission/energy consumption (0.2153)", "land use and ecology (0.2005)", and "waste management (0.1760)" respectively. So on, facility managers have evaluated "waste management (0.2785)" as first rank, "CO_2 emission/energy consumption (0.2492)" as second rank and "pollution (0.2094)" as third rank. Finally, mass housing clients thinks that the first three sub-criteria are "CO_2 emission/energy consumption (0.3637)", "waste management (0.2199)", and "pollution (0.1677)" respectively.

The "flexibility", "accessibility", "performance", "indoor environmental quality", "health and well-being", "design", "CO_2 emission/energy consumption" and "waste management" sub-criteria have high importance scores by all stakeholders. In order to keep in view with energy efficiency in mass housing production; space organization, material use and construction techniques should be developed depending on the social characteristics of the users and the climatic characteristics of regions. In order to ensure the satisfaction of the residents whose family sizes differ according to the regions, the housing designs should be given flexible features. Involving stakeholders in all stages of housing designs will significantly affect satisfaction.

According to these results, it is revealed that common goals should be defined considering common priorities of criteria among stakeholders in order to get total success in the building production process. For this reason, the determinations made by the stakeholders involved in the use of existing buildings are discussed and evaluated. At this point, the group targets should be determined based on the evaluations, comments and determinations of each subgroup. The group goals can be achieved in terms of priorities and preferences of criteria discussed in this study. As a result of this analysis, with this approach, now it is possible and much more clear to determine the criteria and sub-criteria that will direct the new design process.

In accordance with this, in scheduling process, based on predefined priorities, different aspects of needs can be defined and physically can be prepared in the earliest stages of building production.

In this study, an adaptation that will represent an example was implemented in order for AHP methodology to be employed in building production. The method was assessed during usage process of mass housing. Here, the criteria on mass housing samples in a single area have been listed. Nonetheless, the criteria can also be compared between various samples in various areas. Also in the study, not only were group decisions by various stakeholders compared between themselves but also selection priorities dependent on mutual assessment could be revealed. Criteria determined during usage stage must be communicated to design teams of mass housing to be newly designed in the area and strategic plans must be prepared in accordance with these results.

6 Conclusion

In the study, criteria oriented toward assessment and improvement of building design quality has been assessed through a case study implemented in Turkey via the usage of Analytic Hierarchy Process (AHP) method.

When all four main criteria are evaluated, it is seen that "technical team" (architects and engineers) gives priority to "build quality" main criteria, while "managers of facilities" and "mass housing clients" give priority to "functionality" main criteria.

When all stakeholders are considered, more emphasis is placed on the main criterion of "functionality". The main criteria of "green and sustainability issues" are less preferred by stakeholders because "green building certification systems" are not yet adequately known and implemented in the region. Awareness raising activities are required on this subject. When the benchmarking results are examined, "managers of facilities" and "mass housing clients" have reached similar results unlike "technical team". Therefore, not only "architects and engineers" should be the decision makers in building designs, but also the opinions of other stakeholders should be taken into account. While a system to support decision making by considering the opinions of all stakeholders is recommended in the study, it is also recommended to transfer the data obtained to the design processes.

When sub-criteria are evaluated, it can be said that "flexibility" and "accessibility" are common important sub-criteria of "functionality" for all three groups. "Performance", "indoor environmental quality", and "health and well-being" are also exactly very important sub-criteria of "build quality" for all three groups as well. "Design" is only common important sub-criteria of "impact" for three groups at the same time. So on, "CO_2 emission/energy consumption" and, "waste management" sub-criteria are have high importance scores by all stakeholders in "green and sustainability issues".

Hence, the decision-making processes in mass housing production are profoundly affected by the fact that there are various stakeholders in the process, by lack of communication between stakeholders and by external factors such as user variety and social, economic and political factors. However, traditional methods based on individual efforts are employed during design making. A mutual assessment cannot be made by these methods and decisions wrongfully made cause dissatisfaction between stakeholders. Therefore, the use of decision support systems has been recommended in the study implemented. What has been intended via AHP, the preferred one among decision support systems, is to eliminate the lack of communication between stakeholders, to collect various stakeholders' opinions under one roof. Some highlights emerging from among the criteria determined in various places around the world have been exemplified on mass housing production in Turkey and the significance levels of the criteria have been revealed.

By the proposed assessment methodology;

- Focus groups have been formed in order for stakeholders needing to be present in building production processes to be determined.
- Weighting through pairwise comparison method has ensured the determination of the significance levels of the stakeholders in quality assessment. Hence, the criteria with the highest priority among many others have been determined through contemplation of stakeholders' assessments.
- Tangible results have been obtained through integration of conceptual data with quantitative methods.
- Information has been used productively and directly communicated to stakeholders via analytical analyses, supporting decision-makers.
- The data has been contemplated on in different aspects; prioritization of the required criteria has been secured and decision-making processes have become easier.

In housing designs, it is important to use accurate quality indicators in terms of the success of the design. Quality indicators to be used should be adapted to the preparation, construction and use stages of housing projects.

Socio-demographic data, living conditions, cultural characteristics, climatic data and user experiences in old houses should be brought together in the pre-design preparation phase, and should be used as a guide for the decisions to be taken during the design phase. By adding stakeholder experiences in the design process and post-use evaluations to the information obtained during the preparation phase, an extremely useful guide will be obtained for the following processes.

Data about the expectations, tastes and preferences of residential users should be collected through surveys and transferred to design guides. These design guides will include information on flexible design, correct structural system selection, appropriate use of space/size and the desired spatial quality in order to produce houses that are compatible with the living conditions and cultural characteristics of different regions. Design guides, which will be questioned and updated after each experience, will be an important reference for the designer to be used in the next design process. It is thought that more liveable buildings, built environments and cities can be created in the future with the studies to be carried out and their implementation.

References

Abdel-Basset, M., et al. (2018). Three-way decisions based on neutrosophic sets and AHP-QFD framework for supplier selection problem. *Future Generation Computer Systems, 89*, 19–30

Abdirad, H., & Nazari, A. (2015). Barriers to effective implementation of quality management systems in public design projects in Iran. *Architectural Engineering and Design Management, 11*(6), 457–474

Adinyira, E., Kwofie, T., & Quarcoo, F. (2018). Stakeholder requirements for building energy efficiency in mass housing delivery: The House of Quality approach. *Environment, development and sustainability, 20*(3), 1115–1131

Alanne, K., et al. (2007). Multi-criteria evaluation of residential energy supply systems. *Energy and buildings, 39*(12), 1218–1226
ASCE. (2012). *Quality in the constructed project: A guide for owners, designers, and constructors*. VA: ASCE Reston.
Awasthi, A., & Chauhan, S. S. (2012). A hybrid approach integrating affinity diagram, AHP and fuzzy TOPSIS for sustainable city logistics planning. *Applied Mathematical Modelling, 36*(2), 573–584
Baird, G. (1996). *Building evaluation techniques*. McGraw-Hill Professional Publishing.
Bernus, P., Nemes, L., & Schmidt, G. (2012). *Handbook on enterprise architecture*. Springer Science & Business Media.
Beynon, M. J. (2006). The role of the DS/AHP in identifying inter-group alliances and majority rule within group decision making. *Group decision and negotiation, 15*(1), 21–42
Bhatia, R., & Singh, M. (2015). Preserving privacy in healthcare web services paradigm through hippocratic databases. *Intelligent Computing, Communication and Devices.* (pp. 177–188). Springer.
Blyth, A., & Worthington, J. (2002). *Managing the brief for better design*. Taylor & Francis.
Boschi, N. (2002). Quality of life: Meditations on people and architecture. Monterey (CA). In: Levin, H. (Ed.), *Proceedings of Indoor Air '02*. ISBN 0-9721832-0-5.
Brophy, V., & Lewis, J. O. (2012). *A green vitruviu principles and practice of sustainable architectural design*. Routledge.
Cook, M. (2008). *The design quality manual improving building performance*. Wiley.
Cornick, T. (2006). *Construction quality and management—its delivery and discipline in housing and other building sectors*. (p. 471). Management, Quality Economics in Building.
Deming, W. E. (1952). *Elementary principles of the statistical control of quality*. UK: Oxford Press.
Deng, H. (1999). Multicriteria analysis with fuzzy pairwise comparison. *International Journal of Approximate Reasoning, 21*(3), 215–231
Dinc, P., Özbilen, E., & Bilir, M. B. (2014). A multi-dimensional scale for measuring residential satisfaction (rs) in mass housing projects. *Indoor and Built Environment, 23*(6), 864–880
Gann, D., Salter, A., & Whyte, J. (2003). Design quality indicator as a tool for thinking. *Building research & information, 31*(5), 318–333
Gass, S. I., & Rapcsák, T. (2004). Singular value decomposition in AHP. *European Journal of Operational Research, 154*(3), 573–584
Gibson, E., & Gebken, R. (2003). Design quality in pre-project planning: Applications of the project definition rating index. *Building Research & Information, 31*(5), 346–356
Harputlugil, T., Gültekin, A.T., Prins, M., & Topcu, Y.I. (2016). Architectural design quality assessment based on analytic hierarchy process: A case study. *METU Journal of the Faculty of Architecture*, *31*(2).
Ho, W., & Ma, X. (2018). The state-of-the-art integrations and applications of the analytic hierarchy process. *European Journal of Operational Research, 267*(2), 399–414
Hsieh, T.-Y., Lu, S.-T., & Tzeng, G.-H. (2004). Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *International journal of project management, 22*(7), 573–584
Juran, J. M. (1974). *Quality Control Handbook*. McGraw-Hill.
Kamaruzzaman, S. N., et al. (2018). Developing weighting system for refurbishment building assessment scheme in Malaysia through analytic hierarchy process (AHP) approach. *Energy Policy, 112*, 280–290
Kazaz, A., & Birgonul, M. T. (2005). Determination of quality level in mass housing projects in Turkey. *Journal of construction engineering and management, 131*(2), 195–202
Kondo, Y. (2000). Attractive quality: its importance and the points of remark. *Total Quality Management, 11*(4–6), 647–651
Kowaltowski, D. C., et al. (2019). A critical analysis of research of a mass-housing programme. *Building Research & Information, 47*(6), 716–733
Kuruüzüm, A., & Atsan, N. (2001). Analitik Hiyerarşi Yöntemi ve İşletmecilik Alanındaki Uygulamaları. *Akdeniz University Faculty of Economics & Administrative Sciences Faculty Journal, 1*(1), 83–105
Lang, J. T. (1974). *Designing for human behavior: Architecture and the behavioral sciences*. (Vol. 6) Dowden, Hutchinson & Ross.
Le, L. H., Ta, A. D., & Dang, H. Q. (2016). Building up a system of indicators to measure social housing quality in Vietnam. *Procedia engineering, 142*, 116–123
Li, T. H., Ng, S. T., & Skitmore, M. (2012). Conflict or consensus: An investigation of stakeholder concerns during the participation process of major infrastructure and construction projects in Hong Kong. *Habitat International, 36*(2), 333–342

Li, T. H., Thomas Ng, S., & Skitmore, M. (2016). Modeling multi-stakeholder multi-objective decisions during public participation in major infrastructure and construction projects: A decision rule approach. *Journal of Construction Engineering and Management, 142*(3), 04015087
Malakouti, M., et al. (2019). Evaluation of flexibility components for improving housing quality using fuzzy TOPSIS method. *Journal of Building Engineering, 22*, 154–160
Mareschal, B. (1988). Weight stability intervals in multicriteria decision aid. *European Journal of Operational Research, 33*(1), 54–64
Mast, B. D. (2009). Measuring housing quality in the housing choice voucher program with customer satisfaction survey data. *A Journal of Policy Development and Research*, *11*(2), 101–112.
Mlecnik, E., Visscher, H., & Van Hal, A. (2010). Barriers and opportunities for labels for highly energy-efficient houses. *Energy Policy, 38*(8), 4592–4603
Mulliner, E., Smallbone, K., & Maliene, V. (2013). An assessment of sustainable housing affordability using a multiple criteria decision making method. *Omega, 41*(2), 270–279
Pekuri, A., Haapasalo, H., & Herrala, M. (2011). Productivity and performance management–managerial practices in the construction industry. *International Journal of Performance Measurement, 1*(1), 39–58
Preiser, W. F., & Nasar, J. L. (2008). Assessing building performance: Its evolution from post-occupancy evaluation. *International Journal of Architectural Research: ArchNet-IJAR, 2*(1), 84–99
Preiser, W., & Vischer, J. (Eds.). (2006).*Assessing building performance*. Oxford: Elsevier.
Razavi, M., Aliee, F. S., & Badie, K. (2011). An AHP-based approach toward enterprise architecture analysis based on enterprise architecture quality attributes. *Knowledge and information systems, 28*(2), 449–472
Rounce, G. (1998). Quality, waste and cost considerations in architectural building design management. *International Journal of Project Management, 16*(2), 123–127
Rowland, I. D., & Howe, T. N. (2001). *Vitruvius: 'Ten books on architecture.'* Cambridge University Press.
Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical modelling, 9*(3–5), 161–176
Saaty, T. L. (1990). How to make a decision: the analytic hierarchy process. *European journal of operational research, 48*(1), 9–26
Sabaei, D., Erkoyuncu, J., & Roy, R. (2015). A review of multi-criteria decision making methods for enhanced maintenance delivery. *Procedia CIRP, 37*, 30–35
Safapour, E., et al. (2019). Identifying effective project-based communication indicators within primary and secondary stakeholders in construction projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 11*(4), 04519028
Sanni-Anibire, M. O., Hassanain, M. A., & Al-Hammad, A.-M. (2016). Post-occupancy evaluation of housing facilities: Overview and summary of methods. *Journal of Performance of Constructed Facilities, 30*(5), 04016009
Sarathy, P. S. (2013). TQM practice in real-estate industry using AHP. *Quality & Quantity, 47*(4), 2049–2063
Sikorsky, C. S. (1990). *Product and process integration for the US design-construction industry*. Texas A & M University.
Simon, H., A. (1962). The architecture of complexity. In *Proceedings of the American philosophical society*, vol **106**(6), pp 467–482
Svahnberg, M., et al. (2003). A quality-driven decision-support method for identifying software architecture candidates. *International Journal of Software Engineering and Knowledge Engineering, 13*(05), 547–573
Thanki, S., Govindan, K., & Thakkar, J. (2016). An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach. *Journal of Cleaner Production, 135*, 284–298
Thomson, D. S., et al. (2003). Managing value and quality in design. *Building Research & Information, 31*(5), 334–345
Triantaphyllou, E. (2000). Multi-criteria decision making methods. *Multi-criteria decision making methods: A comparative study.* (pp. 5–21). Springer.
Uzun, S., & Kazan, H. (2016). Çok kriterli karar verme yöntemlerinden AHP TOPSIS ve PROMETHEE karşılaştırılması: Gemi inşada ana makine seçimi uygulaması. *Journal of Transportation and Logistics, 1*(1), 99–113
Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2016). *Normalization techniques for multi-criteria decision making analytical hierarchy process case study*. Doctoral conference on computing electrical and industrial systems (pp. 261–269). Springer.

Volker, L., et al. (2008). Deciding about design quality: Design perception during a European tendering procedure. *Design Studies, 29*(4), 387–409

Yau, Y. (2011). Multicriteria decision making for homeowners' participation in building maintenance. *Journal of Urban Planning and Development, 138*(2), 110–120

Yudelson, J. (2010). *Greening existing buildings (McGraw-Hill's Greensource)*. New York, NY: McGraw-Hill.

Zavadskas, E. K., et al. (2018). Sustainable decision-making in civil engineering, construction and building technology. *Sustainability, 10*(1), 14

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