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Building Material Selection Criteria in Türkiye and the Role of Sustainability

Türkiye'de Yapı Malzemesi Seçim Kriterleri ve Sürdürülebilirliğin Rolü

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ÖZ

Yapılar, yaşam döngüleri boyunca başta malzeme ve enerji olmak üzere büyük miktarlarda doğal kaynak tüketmeleri ve atık üretmeleri nedeniyle sürdürülebilirliğin odak noktası haline gelmişlerdir. Yapıları sürdürülebilir hale getirme çabaları yapım yönetim sürecinin büyük kısmını yöneten malzemelerin sürdürülebilirliğiyle başlamaktadır. Bu çalışmada Türkiye'de yapı malzemelerinin sürdürülebilirliğinde dikkate alınacak kriterlerin önem seviyelerinin belirlenmesine çalışılmıştır. Bu maksatla çevresel, sosyal ve ekonomik kriterler başlıkları altında toplanmış 25 kriterin sürdürülebilirlik açısından öneminin değerlendirildiği bir anket çalışması gerçekleştirilmiştir. Anket farklı mesleklerden ve farklı demografik özelliklerde 50 kişinin katılımı ile gerçekleştirilmiş, katılımcı görüşlerinin demografik özelliklere göre farklılaştığı çıkarımsal analizlerle incelenmiştir. Çıkarımsal analizlerde sadece iş deneyim süresi için ekonomik kriterlere ilişkin görüşlerin farklılaştığı; cinsiyet, yaş, eğitim seviyesi ve mesleğe göre bir farklılaşma olmadığı tespit edilmiştir. Bu nedenle sonuçların genellenebileceğine karar verilmiş ve kriterlerin göreli önem değerleri belirlenmiştir. Suyun korunumu çevresel dahil tüm kriterler içerisinde ilk sırada yer alırken, sosyal kriterler içerisinde erişilebilirlik ve ekonomik kriterler içerisinde uzun vadeli tasarruf en önemli kriterler olarak tespit edilmiştir. Sonuçlar inşaat sektörünü daha sürdürülebilir hale getirmek için yapı malzemelerinin sürdürülebilirliğinde hangi kriterlere dikkat edilmesi gerektiğini ortaya koymuştur. Bu açıdan çalışmanın hükümetler, yerel yönetimler, yapı malzemesi üreticileri, tasarımcılar, yükleniciler ve en nihayetinde kullanıcılar için yol gösterici olacağı değerlendirilmektedir. Çalışmanın Türkiye'de yapı malzemelerinin sürdürülebilirliğinin değerlendirilmesine yönelik literatürdeki boşluğu doldurması beklenmektedir.

Anahtar Kelimeler: Su Çıkarımı, Sürdürülebilirlik, Sürdürülebilir Malzeme Yönetimi, Yapı Malzemesi, Yaşam döngüsü

ABSTRACT

Buildings have become the focal point of sustainability because they consume large amounts of natural resources, especially materials and energy, and produce waste throughout their life cycle. Efforts to make buildings sustainable begin with the sustainability of the materials that govern most of the construction management process. In this study, an attempt was made to determine the importance levels of the criteria to be considered in the sustainability of building materials in Türkiye. To achieve this, a survey was conducted to assess the significance of 25 criteria, grouped under environmental, social, and economic categories, in terms of sustainability. The survey was conducted with the participation of 50 people from different professions and with different demographic characteristics, and whether participant opinions differed according to demographic characteristics was examined through inferential analyses. The inferential analyses revealed that the views differed for the work experience and only on economic criteria, and that there was no differentiation according to gender, age, education

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level and profession. Therefore, it was concluded that the results could be generalized, and the relative importance values of the criteria were established. While water conservation ranks first among all criteria, including environmental, accessibility among social criteria and long-term savings among economic criteria have been determined to be the most important criteria. The results revealed which criteria should be taken into consideration in the sustainability of building materials in order to make the construction industry more sustainable. In this context, the study is anticipated to serve as a valuable resource for governments, local authorities, producers, designers, and end users. It aims to address the existing gap in the literature regarding the sustainability assessment of building materials in Türkiye.

Keywords: Life cycle, Building Material, Sustainability, Water Extraction, Sustainable Material Management

INTRODUCTION:

Within the span of 1500 years from 0 to 1500 AD, the world population doubled to reach 600 million, while in the subsequent 150 years from 1750 to 1900 AD, it doubled again. The next doubling occurred in just 30 years between 1950 and 1980 (Clayton and Radcliffe, 1996). Currently, there are over 8 billion people living on Earth (Worldometers, 2023). By 2050, it is expected that the global population will increase by 27% to reach 9.8 billion, and by 2060, the global building floor area is projected to double, indicating that all environmental, social, and economic impacts related to the built environment will increase (World Green Building Council, 2023). The rapid urbanization accompanying unchecked population growth, capitalist/technological/industrial development, and consumption-driven development processes (Özmehmet, 2008) have exposed humanity to various problems such as ecological imbalance, overpopulation, depletion of natural resources and water sources, air pollution, dispersion of chemicals and heavy metals into the environment, global warming, deforestation, acid rains, desertification, and ozone depletion (Low, 2000; Hoşkara & Sey, 2009). These problems have been accompanied by many economic and social issues such as poverty, unemployment, unhealthy urbanization, international inequality, and increasing crime rates (Emrealp, 2005). All these developments have led humanity to start remembering the Native American proverb, “the frog does not drink up the pond it lives in”, and to accelerate the search for balance between the environment and development. In this process, the concept of sustainable development, a long-term development model that considers human and other living factors affecting life and focuses on using resources as efficiently as possible, has emerged (Tıraş, 2012). The report “Our Common Future”, published by the World Commission on Environment and Development (WCED) in 1987, is significant in terms of discussing social, economic, and environmental factors in development. The report, also known as the Brundtland Report, presented the definition of sustainable development used today (WCED, 1987). Initially emphasizing the environmental dimension, sustainability is fundamentally built upon three dimensions: environmental, economic, and social, and it is considered critical to give importance to each dimension and evaluate each one separately to achieve balance (Rogers et al., 2008). In general, elements of sustainable built environment comprise a range of issues including climate, urban design, building design, and building management. The holistic connection between these themes is depicted in Figure 1. Therefore, it is evident that particularly in sustainable building design, consideration of building lifecycle & material selection and renewable energy issues is crucial.

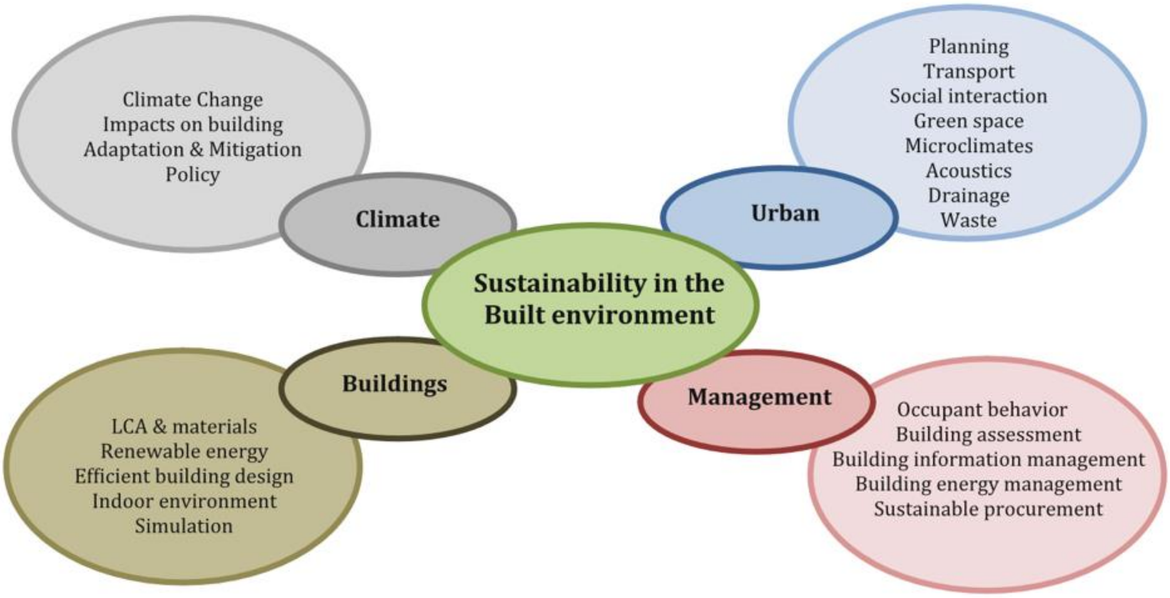

Figure 1. Relationship Between Sustainability and Built Environment (Yao, 2013)

The intense migration to cities has created a need for housing, accelerating the construction of buildings as a fundamental factor. Additionally, the number of households living in buildings is decreasing day by day, while demand for the construction of new buildings is increasing. In Türkiye, it is observed that the number of households has been decreasing every year. The average household size, which was 4 people in 2008, has decreased to 3.17 as of 2022 (TURKSTAT, 2023). Therefore, there is an increase in building stock every day. Throughout the life cycle of buildings, including design, construction, use, and demolition, their consumption of natural resources, primarily materials and energy, and the generation of waste, have had significant negative impacts on the environment, making the construction sector one of the focal points of sustainability. The construction of buildings requires the consumption of natural materials such as wood, stone, brick, clay, cement, gravel, and sand, while also generating large amounts of waste (Pappu et al., 2007). Buildings consume large amounts of energy both during construction and use, with approximately 40% of the European Union's total primary energy consumption attributed to the construction sector (European Commission, 2020). The buildings and construction sector plays a major role in global climate change, contributing approximately 21% of worldwide greenhouse gas emissions. In 2022, buildings were responsible for 34% of the global energy demand and accounted for 37% of energy and process-related CO_2 emissions (United Nations Environment Programme, 2024). Energy consumption and CFC production are recognized as key drivers of climate change, posing a threat to the planet (Bulkeley & Betsill, 2005). All of these factors have led stakeholders in the sector to increase efforts to make their activities environmentally friendly.

The efforts to make the construction sector sustainable start with building materials. A significant portion of the construction process is governed by materials, highlighting the importance of material selection as a crucial factor that can influence the sustainability of a building (Nassar et al., 2003; Treloar et al., 2001; Alibaba & Özdeniz, 2004). For instance, proper selection of construction materials can reduce CO_2 emissions by up to 30% (Wang et al., 2005), while unsuitable materials lead to ineffective sustainable constructions (Nassar et al., 2003; Van Kesteren, 2008; González and Navarro, 2006). Consequently, selecting building materials sustainably is stated to be the easiest way for designers to incorporate sustainable principles into building projects (John et al., 2005). On the other hand, due to its association with various criteria such as safety, cost-effectiveness, durability, aesthetics, and functionality, the process of selecting building materials is already challenging and complex. With the addition of sustainability into the equation, the selection of building materials becomes even more challenging. From this perspective, sustainable material selection is considered one of the most difficult tasks to undertake in a building project (Kibert, 2016).

This study aims to determine the importance levels of sustainable material selection criteria in Türkiye. Additionally, the research question has been formulated to examine whether there are differences among demographic groups in these criteria. For this purpose, the research hypothesis is formulated as follows:

H0: The importance of sustainable material selection criteria does not differ by demographic characteristics in Türkiye.

H1: The importance of sustainable material selection criteria differs by demographic characteristics in Türkiye.

Through a survey, data were collected from 50 participants, including engineers, architects, contractors, and real estate professionals from the construction sector, as well as faculty members from relevant academic fields, all with varied demographic profiles. The study examined 25 criteria across environmental, social, and economic sustainability categories, emphasizing their relative importance within the context of Türkiye. T-tests and Analysis of Variance (ANOVA) were employed to conduct inferential analyses. The study then calculated the relative importance index (Index of Relative Importance - IRI) for each criterion. Academic research on sustainable material selection is scarce, with no known studies specifically conducted in Türkiye. This research is significant for its ranking of criteria critical to sustainable material selection in Türkiye and for identifying similarities and differences in criterion selection across participants with varied demographic profiles. Therefore, this study aims to contribute to the literature by incorporating participants from Türkiye.

The paper's structure is as follows: Chapter 1 explores the connection between sustainable architectural design and the use of sustainable materials, along with a review of previous studies in the literature. Chapter 2 presents the methodology of the study, and the findings, followed by the discussion of the results in Chapter 3. Finally, Chapter 4 presents the implications of the findings. The study's findings are expected to provide valuable guidance for initiatives aimed at enhancing the sustainability of the construction sector.

1. The Theoretical Framework for the Construction Sector and The Need for Sustainability

The primary goal of sustainability in buildings is to achieve energy efficiency. This is because both the embodied energy, which can account for up to 40% of a building's life cycle energy consumption (Sartori & Hestnes, 2007), and the energy expended during their use can reach significant levels. Studies have shown that energy efficiency measures in buildings have the potential to achieve energy savings of 20-40% (Chirarattananon & Taveekun, 2004). While the share of embodied emissions in life cycle emissions can reach up to 68% (Ozawa-Meida et al., 2013), the construction sector is responsible for more than 30% of greenhouse gas emissions (Castro et al., 2009; Yang et al., 2014; Huo et al., 2018). Buildings, which also contribute significantly to environmental pollution, have direct effects on the health and comfort of their users (Melchert, 2007; Franzoni, 2011). Sustainable buildings are considered the most suitable solution for reducing natural resource consumption, energy consumption, minimizing environmental damage, and waste (Aye, 2003), and are evaluated as an important long-term strategy for reducing life cycle costs and passive environmental impacts of buildings (Baharetha et al., 2013).

Sustainability, while universal, is closely related to local conditions and is fundamentally shaped by local problems, needs, and resources. In this regard, it is essential to understand the situation where the research is conducted. Türkiye, which meets 77% of its energy needs through imports, ranks fifth among 39 European countries in energy import dependence (Euronews, 2019). High per capita energy consumption in a country indicates the welfare level of its citizens, while low energy intensity implies more value creation with the same energy use (Narin & Akdemir, 2006). Compared to Japan, Türkiye's energy consumption is one-fourth, but its energy intensity is 3.5 times higher. Efficient energy consumption is crucial for Türkiye due to its significant environmental impacts and the economic burden it imposes. The annual amount of usable water per capita was 1,652 cubic meters in 2000, 1,544 cubic meters in 2009, and 1,346 cubic meters in 2020. When considering the usable water potential per capita, Türkiye is among the countries experiencing water stress (DSİ, 2024). Approximately 60% of nearly 300 natural lakes, which are essential freshwater sources, have dried up in the country. Furthermore, lakes like Akşehir, once the fifth-largest freshwater lake in the country, have lost their natural lake characteristics, and water levels in Beyşehir and Eğirdir lakes have significantly decreased (Yıldız et al., 2021). Due to the increasing warming of Türkiye's climate, drought and heat waves have become major threats. The temperature has risen by more than 1.5°C, and more extreme weather conditions are now observed (Aksu, 2021). Excessive energy and water consumption lead to ecological problems such as the depletion of the country's material resources, pollution of air, soil, and water, degradation of the natural environment, and endangerment of biodiversity. All these factors necessitate Türkiye's emphasis on sustainability in all sectors, especially in the construction sector.

The selection of building materials is crucial for increasing the sustainability of buildings and contributing to economic, environmental, and social well-being. However, it is observed that sufficient attention is not given to studies focusing on sustainable material selection. The literature offers limited resources on building material selection and the prioritization of sustainability criteria. Danso (2018) examined building materials through the lens of economic, social, and environmental sustainability, defining relevant criteria in his research. Dinh et al. (2020) prioritized 18 criteria by importance, finding material cost to be the highest priority. Al-Atesh et al. (2023) evaluated sustainable building material criteria, ranking 29 criteria by importance through the Analytic Hierarchy Process (AHP). This study highlighted that environmental and economic criteria outweighed social ones in importance. A review of these studies indicates a lack of consensus on sustainable building material selection criteria, emphasizing the need for country-specific reevaluation of criteria and their significance levels.

2. Material and Methodology

2.1. Analysis Techniques

In this study, inferential analyses were conducted using T-tests and ANOVA. Ultimately, the relative importance levels of all criteria were established through the Index of Relative Importance (IRI). ANOVA comprises a set of statistical models designed to assess differences in means among groups and related procedures, such as evaluating the "variation" between groups. This method, developed by Ronald Fisher, decomposes the observed variance in a given variable into components attributed to various sources of variation (Purnama, 2023). In its most basic form, ANOVA provides a statistical test to determine whether the means of multiple groups are equivalent, effectively serving as a generalized t-test for scenarios involving more than two groups (LaMotte, 2017; Wang & Sun, 2013). Given that conducting multiple two-sample t-tests can increase the likelihood of a Type-I statistical error, ANOVA is particularly valuable for comparing three or more means (groups or variables) to determine statistical significance.

The Relative Importance Index (IRI) was applied to identify the most critical criteria in the scope of this research. The IRI values for each criterion were calculated using the formula provided below:

$$IRI = \Sigma W / A * N$$

IRI: Index of Relative Importance coefficient

W: Ratings assigned by each participant on a scale

A: Maximum possible rating

N: Total number of participants

2.1. Research Design

The criteria identified in the study conducted by Danso (2018) have been utilized as the basis for sustainable material selection research. Danso (2018) assessed building materials in terms of economic, social, and environmental sustainability, selecting relevant criteria based on these dimensions. Each criterion selection was compiled from sources in the literature. Therefore, Danso's study is comprehensive in terms of criterion selection. Twenty-five criteria related to material selection were evaluated under three main headings: environmental, economic, and social. In this study, the criteria under the environmental dimension were identified as "climate change, ozone layer depletion, human toxicity, ecotoxicity, acidification, fossil fuel depletion, solid waste, mineral extraction, water extraction, freight transport, and photochemical oxidation." Under the social dimension, the criteria included "cultural heritage preservation, aesthetic quality, choice and security of tenure, housing for all, empowerment and participation, adaptability, accessibility, and thermal comfort." For the economic dimension, the criteria were "initial cost, maintenance cost, operational cost, job creation, long-term savings, and tourism." Participants were grouped into five categories based on their occupations in their workplaces, including architects and engineers, real estate sector employees, contractors, academic staff, freelance professionals, and healthcare sector employees. Participants in the study were carefully selected to represent a diverse range of professionals involved in the building and construction industry. They were chosen for their expertise and roles that influence material selection decisions, ensuring a well-rounded evaluation of sustainability criteria. A questionnaire was administered to participants as a data collection tool, asking them to rate the importance of each criterion for sustainability on a 5-point Likert scale. The survey included 50 participants with varied demographic backgrounds, and data were analyzed using the Statistical Package for Social Sciences (SPSS 29.0). Statistical methods such as descriptive analysis, reliability analysis, independent sample t-tests, and ANOVA were performed, and the relative importance index (IRI) of each criterion was calculated.

3. Discussion of Findings

3.1. Results of Descriptive Statistics and Reliability Analysis

Descriptive analysis was used to obtain the demographic data of the participants, summarizing numerical values or counts in a descriptive or graphical format (Mann, 1995). The demographic characteristics are shown in Table 1, showing that 62% of the participants are women. All participants in the 30-40 age group, which comprises 38% of the sample, were selected from individuals with bachelor's degree (B.Sc.) level education or higher, as they were deemed to have a better understanding of sustainability issues. In terms of years of work experience, participants were roughly evenly distributed across the categories of less than 5 years, 5-10 years, 10-20 years, and over 20 years. Approximately half of the participants were professionals directly related to the construction industry, such as engineers, architects, contractors, and real estate professionals, while the other half consisted of individuals from other professions.

Table 1. Demographic Data Related to the Participants.

Variable	N	%
Gender		
Male	19	38.0
Female	31	62.0
Age Group		
20-30	12	24.0
30-39	19	38.0
40-49	10	20.0
50 and over	9	18.0
Education Status		
B.Sc.	33	66.0
M.Sc.-Ph.D.	17	34.0
Work Experience Period		
5 years and below	13	26.0
5-10 years	13	26.0
10-15 years	6	12.0
15-20 years	6	12.0
20 years and over	12	24.0
Profession		
Civil Eng.	6	12.0
Electrical Eng.	4	8.0
Architect	6	8.0
Real Estate Sect.	9	18.0
Contractor	6	6.0
Lecturer	5	10.0
Health Sect.	4	14.0
Self-employment	6	18.0
Officer	4	6.0
Total	50	100.0

Table 2 presents the descriptive statistics and reliability coefficients for the scales utilized in the study. The mean scores for the responses to the questions were 3.74, 3.89, and 4.02 for the environmental, social, and economic criteria, respectively. The table shows that the reliability values of the scales surpassed the threshold values recommended by Cronbach (1951) at 0.5 and by Bowling and Ebrahim (2005) at 0.7, demonstrating that the scales were reliable.

Table 2. Reliability Values and Descriptive Statistics

Variable	N	N of Criteria	Mean of Criteria	Min.	Max.	C.Alpha
Environmental Criteria	50	11	3.747	3.200	4.380	0.712
Social Criteria	50	8	3.893	3.620	4.300	0.771

Economic Criteria	50	6	4.020	3.620	4.300	0.711

3.2. Relationships Between Demographic Variables and Material Selection and Sustainability Criteria

The aim of the study is to determine the importance levels of sustainable criteria for building materials. Initially, it was deemed appropriate to conduct inferential analyses to determine whether participant views differed. For this purpose, the normality of the data was checked to decide whether parametric or non-parametric tests should be applied in inferential analyses.

3.2.1. Normality Test

Data normality can be assessed through various methods, with one of the most common being an examination of Skewness and Kurtosis values. Based on the values shown in Table 3, the largest value is 1.695 and the smallest is -0.920. Since George (2011) reported that Skewness and Kurtosis values between +2 and -2 are sufficient for data to be considered normal, it is assumed that the data for all three groups are normally distributed. Therefore, it was decided to conduct inferential analyses using parametric tests for all data showing normal distribution.

Table 3. Mean, Kurtosis and Skewness Values of the Scales.

		Statistic	Std. Error
Environmental Criteria	Mean	3.7473	.07100
	Skewness	-.920	.337
	Kurtosis	1.695	.662
Social Criteria	Mean	3.8925	.09807
	Skewness	-.922	.337
	Kurtosis	.393	.662
Economic Criteria	Mean	4.0200	.09614
	Skewness	-.731	.337
	Kurtosis	.027	.662

3.2.2. Inferential Analysis Results

Inferential statistics is a field of statistics focused on deriving analytical expressions for estimating or testing hypotheses about the characteristics of a statistical population (Dodge, 2003). Inferential analysis tests are used to determine whether the difference between the means of two or more groups is random or statistically significant by comparing them. Independent sample t-tests are used when there are two groups to assess whether participants' opinions differ according to different characteristics, while ANOVA tests are used when there are more than two groups.

In this section, the possible significant differences between the opinions of participants based on their genders have been investigated. Table 4 presents the means according to the participants' genders. It can be observed that the means of both groups for environmental, social, and economic criteria are quite close to each other.

Table 4. Descriptive Statistics by Participants' Genders.

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Environmental Criteria	Male	19	3.7799	.52163	.11967
	Female	31	3.7273	.49738	.08933
Social Criteria	Male	19	3.9539	.67470	.15479
	Female	31	3.8548	.71305	.12807
Economic Criteria	Male	19	4.0526	.69178	.15870
	Female	31	4.0000	.68313	.12269

An independent samples t-test was performed for gender-based comparisons. In this test, if the significance (p) value from Levene's test is greater than 0.05, it indicates no variance difference between the groups, and the value in the first row is used. For each of the three criteria, the first row was examined, and it was observed that the significance (p) values were greater than 0.05 (0.723; 0.629, and 0.794), indicating no significant difference between genders (Table 5).

Table 5. Test Results of T-Test According to Participants' Genders.

		Levene's Test for Eq. of Var.		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Environmental Criteria	Equal var. as.	.173	.680	.357	48	.723
	Equal var.not as.			.352	36.794	.727
Social Criteria	Equal var. as.	.406	.527	.487	48	.629
	Equal var.not as.			.493	39.869	.624
Economic Criteria	Equal var. as.	.000	.986	.263	48	.794
	Equal var.not as.			.262	37.837	.794

In the inferential analysis conducted based on age groups, an ANOVA test was applied. The test result yielded a significance (p) value greater than 0.05 for all three categories (0.498; 0.118, and 0.851), indicating no significant difference between the groups (Table 6).

Table 6. ANOVA Test Results According to Participants' Age Groups.

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	.615	3	.205	.803	.498

Environmental Criteria	Within Groups	11.737	46	.255		
	Total	12.352	49			
Social Criteria	Between Groups	2.793	3	.931	2.062	.118
	Within Groups	20.770	46	.452		
	Total	23.563	49			
Economic Criteria	Between Groups	.383	3	.128	.264	.851
	Within Groups	22.264	46	.484		
	Total	22.647	49			

Since there were two groups based on participants' education levels, independent samples T-test was conducted to examine whether there were differences in participants' opinions. Levene test results indicated significance for environmental and social criteria, thus the values from the second row were considered, while for economic criteria, values from the first row were considered. As the mentioned values were greater than 0.05, it was concluded that there were no significant differences among participants based on their education levels (Table 7).

Table 7. T-Test Results are Based on Participants' Education Levels.

		Levene's Test for Eq. of Var.		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Environmental Criteria	Equal var. as.	14.656	<.001	1.929	48	.060
	Equal var.not as.			1.554	19.588	.136
Social Criteria	Equal var. as.	14.412	<.001	2.451	48	.018
	Equal var.not as.			2.047	21.004	.053
Economic Criteria	Equal var. as.	1.183	.282	1.879	48	.066
	Equal var.not as.			1.725	25.923	.096

In the analysis conducted based on participants' years of work experience, a significant difference was observed in the means of economic criteria (sig (p) = 0.035) (Table 8). An examination of the means revealed a significant difference between the group with 15-20 years of experience (mean = 4.42) and the group with 5-10 years of experience (mean = 3.76).

Table 8. ANOVA Test Results Based on Participants' Work Experience Durations.

		Sum of Squares	df	Mean Square	F	Sig.
Environmental Criteria	Between Groups	1.163	4	.291	1.170	.337
	Within Groups	11.188	45	.249		

	Total	12.352	49			
Social Criteria	Between Groups	3.904	4	.976	2.486	.057
	Within Groups	17.666	45	.393		
	Total	21.570	49			
Economic Criteria	Between Groups	3.971	4	.993	2.832	.035
	Within Groups	15.775	45	.351		
	Total	19.747	49			

An ANOVA was conducted, and the results showed that the significance (p) values for all three categories were greater than 0.05 (0.192, 0.395, and 0.694) as presented in Table 9, indicating no significant differences among the groups.

Table 9. ANOVA Test Results Based on Participants' Occupation.

		Sum of Squares	df	Mean Square	F	Sig.
Environmental Criteria	Between Groups	1.536	4	.384	1.597	.192
	Within Groups	10.816	45	.240		
	Total	12.352	49			
Social Criteria	Between Groups	2.003	4	.501	1.045	.395
	Within Groups	21.560	45	.479		
	Total	23.563	49			
Economic Criteria	Between Groups	1.071	4	.268	.558	.694
	Within Groups	21.576	45	.479		
	Total	22.647	49			

3.3. Selection of Sustainable Building Materials Criteria

Inferential analyses revealed significant differences in participants' views on economic criteria based on their work experience, supporting the generalizability of the findings. Additionally, IRI coefficients for the criteria were calculated based on the formula provided in the methodology section, where the highest possible weight is 5, and the participant total is 50. Table 10 presents the IRI values and rankings for criteria in selecting sustainable building materials. Water extraction, accessibility, and long-term savings emerged as the most critical criteria, while environmental criteria ranked lowest, with freight transport and photochemical oxidation occupying the final two positions.

Table 10. IRI Coefficients of Criteria to be Considered in the Selection of Sustainable Building Materials.

Rank	Criteria	Mean	IRI
EN9	Water Extraction	4.380	0.876

S18	Accessibility	4.300	0.860
E24	Long-term Savings	4.300	0.860
S15	Housing for All	4.220	0.844
E20	Initial Cost	4.200	0.840
EN8	Mineral Extraction	4.160	0.832
S17	Adaptability	4.020	0.804
E23	Job Creation	4.020	0.804
E21	Maintenance Cost	4.000	0.800
E22	Operational Cost	3.980	0.796
EN1	Climate Change	3.920	0.784
S19	Thermal Comfort	3.880	0.776
EN4	Ecotoxicity	3.860	0.772
EN6	Fossil Fuel Depletion	3.800	0.760
EN7	Solid Waste	3.760	0.752
S14	Choice and Use Safety	3.760	0.752
S12	Cultural Heritage Preservation	3.720	0.744
EN5	Acidification	3.660	0.732
S13	Aesthetic Quality	3.620	0.724
S16	Empowerment and Participation	3.620	0.724
E25	Tourism	3.620	0.724
EN3	Human Toxicity	3.600	0.720
EN2	Ozone Layer Depletion	3.560	0.712
EN10	Freight Transport	3.320	0.664
EN11	Photochemical Oxidation	3.200	0.640

4. Implications of The Findings

The study was conducted with participants from different genders, ages, occupations, and work experience groups; however, only individuals with a university-level education or higher were included in the study, considering their presumed greater familiarity with the concept of sustainability. Inferential analyses indicated that participants' opinions varied little across demographic characteristics. This result suggests a consensus on sustainability among individuals with a certain level of education. The averages for environmental, social, and economic criteria were 3.74, 3.89, and 4.02, respectively. Although the averages are close to "very important", it is evident that economic criteria are more prominent. In terms of the relative importance rankings of the criteria, the top five include one environmental, two social, and two economic criteria: water extraction, accessibility, long-term savings, housing for everyone, and initial cost. When very few studies in the literature are evaluated, it is seen that the results of the research give similar results with Al-Atesh et al. (2023) and Dinh et al. (2020). The results of the research conclude that economic criteria are more important, just like Al-Atesh et al. (2023), and that costs are becoming more important, like Dinh et al. (2020) research. However, considering that the other results of studies differ, it is thought that the number of studies involving different regional or national stakeholders should be increased.

The freshwater resources worldwide are increasingly under greater pressure due to population growth, rising per capita water usage, urbanization, increasing industrial activities, and the impacts of climate change (Anderson & Thornback, 2012). One of the criteria for material assessment in the program created by Building Research Establishment (BRE) to provide independent, third-party assessment and certification of the environmental performance of materials and products is water extraction. Water extraction refers to the water used throughout the processes of raw material cultivation and extraction, product manufacturing, transportation, and construction—in other words, embedded water. Studies show that the majority of this (92% of the total) is related to material production (Bleby, 2023). Considering that the embedded water is 11 tons for 1 m3 of concrete, 3.4 tons for 1 m2 of 4 mm thick glass, and 20.1 tons for 1 m3 of timber (Fuller et al., 2009), the importance of water extraction in the sustainability of building materials will be better understood. Due to the importance of the issue, the 'ISO 14046 - Water Footprint Standard" has been developed, which is an international standard that allows for the assessment of the potential environmental impacts related to water of products, processes, and organizations as part of their life cycle assessment (Turkish Standards Institute, 2023).

In the relative importance ranking, accessibility has taken the second position. Accessible construction involves creating or modifying spaces in a way that considers the diverse and unique needs of everyone who will use the area, regardless of their age or abilities. Ultimately, the result will be an inclusive environment that promotes safety and helps everyone enjoy it (Home Solutions, 2024). It is evident that this is important from a social sustainability perspective. It is also observed that the selected building materials can both enhance and reduce accessibility. For example, floor coverings must have a certain level of slip resistance. Particularly, polished shiny surfaces lacking sufficient slip resistance pose a serious threat to users, especially people with disabilities and the elderly (Latham, 2024; AHRC, 2008). It is vital for visually impaired individuals to have "Tactile Ground Surface Indicators" made of brass or stainless steel installed in necessary locations (Latham, 2024). Similarly, permeable pavement blocks can be used in landscaping to increase water infiltration into the ground; however, if the installation of these blocks results in wide gaps or an uneven surface, accessibility is adversely affected (WBDG, 2022). Based on these, we can infer that accessibility is increasingly becoming a significant criterion in construction and urban planning in Türkiye. This involves creating spaces that cater to diverse needs, ensuring safety and inclusivity for all users, regardless of age or ability.

At the core of any housing policy lies the provision of affordable and adequate housing for all individuals, regardless of their financial status. In almost all countries, the unmet demand for housing contributes to an imbalanced housing market, financially unattainable housing, and overcrowding, resulting in various social and health problems, including informal settlements lacking infrastructure, sanitation, clean energy, and access to fresh water (Golubchikov & Badyina, 2012). Even in the European Union, the growing housing prices and decreasing availability of affordable housing have exacerbated the issue of housing accessibility. According to Eurostat data, 8.7% of the European Union's population, equivalent to more than 40.8 million people, allocate more than 40% of their income to housing, and there has been a worrying increase in homelessness in most member states over the past decade (Spanish Presidency, 2023). The same situation applies to Türkiye. Particularly between 2018 and 2022, the significant increase in rental and sale prices of housing has made homeownership or renting increasingly difficult not only for the poor and low-income groups but also for lower-middle and middle-income households (Kutsal & Polatoğlu, 2023). Studies indicate that materials account for approximately 50-60% of construction costs and are involved in 80% of the construction process (Caldas, 2015), underscoring the importance of economical building materials in meeting housing needs. Many studies have shown that providing housing for everyone is achievable with affordable housing, necessitating the use of cost-effective building materials (Bredenoord, 2016; Arun et al., 2021; Alabi & Fapohunda, 2021).

In terms of sustainability, the opportunity for long-term savings is also a crucial consideration. Sustainable housing offers significant economic advantages in terms of energy savings during use, making sustainable housing more cost-effective in the long run compared to traditional housing (UN Habitat, 2011a). While the initial cost of sustainable design may be higher than traditional methods, long-term operational savings can be realized during use (Wilson & Tagaza, 2006). Furthermore, the long-term performance of materials is important, and it is evident that materials with longer lifespans and requiring less frequent maintenance can offer significant savings (UN Habitat, 2011b). For example, the lifespan of stainless-steel lighting poles is approximately 70 years, whereas traditional galvanized poles, despite being cheaper initially, have a lifespan of only about 25-30 years (Zhou et al., 2008). Therefore, careful consideration should be given to the use of cheaper and less environmentally impactful traditional materials over durable and long-lasting modern materials (UN Habitat, 2012)., Based on this result, there is a growing recognition of the economic benefits of sustainable housing in Türkiye. While the initial costs of sustainable design may be higher, the long-term operational savings in energy consumption are substantial compared to traditional housing methods.

Economic sustainability is the dimension of sustainability aimed at promoting the efficient, responsible, and long-term use of resources (Tatum, 2023). Furthermore, economic sustainability is also concerned with generating and sustaining the necessary financial resources for achieving environmental and social sustainability (Gilbert et al., 2013). A significant portion of costs in a construction project is associated with building materials, and it is essential for the economic sustainability of a project that the initial cost of materials is reasonable. Additionally, the limited availability of sustainable materials, the need for custom orders and production, and sometimes the necessity of imports due to the underdeveloped sustainable material market can result in high initial costs (Shari & Soerbarto, 2012; Zaini, 2016; Hwang et al., 2017). There are studies in the literature indicating that the cost of sustainable materials is 3% to 4% higher compared to traditional construction materials (Zhang et al., 2011). However, as demand for sustainable materials increases and technology advances, prices become more competitive (The Build Chain, 2023). Conversely, certain materials that are appealing due to low initial costs may negatively impact quality, reliability, and performance over the building's lifespan and may even harm the environment (Ashraf et al., 2015). It should also be considered that efforts to minimize initial costs may not necessarily affect the lifetime performance of buildings, and a higher initial cost could reduce the overall life cycle cost (LCC) (Fulford & Standing, 2014).

The criteria ranking lowest in terms of relative importance are oxidation, freight transport, and ozone depletion, which are among the photolytic environmental criteria. However, environmental problems in Türkiye are worsening day by day. For instance, according to the Clean Air Right Platform report, air pollution in Türkiye ranks fifth among the risks leading to death, following tobacco, obesity, high blood pressure, and high blood sugar. The top five diseases causing deaths due to air pollution include cardiovascular diseases, chronic respiratory diseases, various cancers, diabetes, chronic kidney disease, respiratory infections, and tuberculosis (Clean Air Right Platform, 2022). Furthermore, a report prepared by the Ministry of Environment and Urbanization states that water and soil pollution are significant issues in Türkiye. Data collected from 81 provinces in Türkiye reveals that water pollution is the biggest problem in 30 provinces. The quality control of 158 surface water sources in these provinces revealed that the water was polluted in 33 points (21% of the sources) and very polluted in 52 points (33% of the sources) (Ministry of Environment and Urbanization, 2018). Therefore, it is considered essential to attribute greater importance to environmental sustainability in Türkiye.

The least attributed importance in the study is to photolytic oxidation, also known as summertime smog, which is a form of secondary air pollution. It occurs in the troposphere primarily as a result of sunlight reacting with emissions from the combustion of fossil fuels to form other chemicals (Baumann & Tillman, 2004). Photolytic oxidation leads to respiratory problems, eye irritation, and damage to certain materials and crops (Adeeb & Shooter, 2002). The service life of building exterior materials, especially wood and plastic construction materials, is determined by deterioration caused by weather conditions, with photolytic oxidation playing a significant role in this degradation process (Andrady et al., 2015).

Unsustainable freight transportation constitutes a significant portion of the environmental damage caused by construction activities. Various assessments in the field of climate change suggest that transportation will account for approximately 60% of emissions by 2050 (IPCC, 2014). European Union (EU) transport data estimate that construction material transportation contributes to about 50% of European freight transportation (Balm & Ploos van Amstel, 2017), while another estimate indicates that construction transportation accounts for approximately 30% of urban freight transportation (Guerlain et al., 2019; Muerza & Guerlain, 2021). Sustainable freight transportation in the construction sector generally refers to transportation that is conducive to reducing greenhouse gas emissions, pollution, and climate-related disruptions (UN ESCAP, 2021). A freight transport system must meet two very important efficiency requirements: providing just-in-time supply and ensuring technological integration and high sustainability (Sala et al., 2015; Anschütz et al., 2004).

The main gases responsible for ozone depletion are CFCs, HCFCs, and halons. It is known that many materials used in the construction sector have a high ozone-depleting potential (Park et al., 2020). Changes in the intensity of solar UV radiation due to stratospheric ozone depletion have significant effects on all organisms on the planet. Biological and ecological responses to increases in UV-B radiation can cause significant harm to humans, especially in terms of the frequency of skin cancers such as cataracts and malignant melanoma (Solomon, 2008). In the construction materials industry, steps are being taken to replace ozone-depleting insulation and foam materials with gases that do not harm the ozone layer, such as HFCs (Anderson & Thornback, 2012).

CONCLUSION:

Sustainability in all its dimensions - environmental, social, and economic - is an important issue not only globally but also within Türkiye. As a country with limited natural resources such as energy and water, facing increasing pressure on water, air, and soil pollution, as well as urbanization encroaching on agricultural/forest lands, Türkiye is experiencing rapid growth of problems such as inequality, unemployment, poverty, inadequate infrastructure and services, traffic congestion, violence, crime, and disease, particularly in major cities. It is imperative for every sector to do its part in sustainability. Sustainability in the construction sector begins with the sustainability of building materials. For this reason, the study evaluated the importance of various sustainability criteria in the selection of building materials in Türkiye, emphasizing the environmental, social, and economic dimensions of sustainability. This comprehensive approach highlighted critical areas for consideration in the construction sector, aiming to enhance sustainability practices across the board.

The study assessed 25 criteria categorized under environmental, social, and economic sustainability in terms of their importance in Türkiye, using T-tests and ANOVA analyses. Also to find the most important criteria IRI is used, and research findings are discussed. The research study is considered to guide efforts aimed at selecting sustainable building materials. It is expected that the results of the research will contribute to different stakeholders. In conclusion, the findings of this study highlight the critical importance of sustainability criteria in building material selection. By prioritizing environmental, social, and economic dimensions, stakeholders in the construction sector can make significant strides towards a more sustainable future, ultimately contributing to the well-being of society and the environment.

Within the research, it is recommended to designers and architects to prioritize materials that minimize water consumption and have low environmental impacts, incorporate accessibility features in all designs to promote inclusivity and consider long-term savings and lifecycle costs in material selection to enhance economic sustainability. Besides this the other vital issue will be utilizing innovative technologies that improve energy efficiency and sustainability. The results of the research are also essential for policy makers. Accordingly, in terms of future regulations, it is recommended to develop and implement regulations that promote sustainable building practices and materials and provide incentives for the use of sustainable technologies in the construction sector.

In the future, more comprehensive studies can be conducted to determine the weight of criteria in the sustainability of materials and to certify materials based on concrete data. Future research should explore regional variations in sustainability priorities, the long-term impacts of sustainable materials, and the role of emerging technologies in optimizing material selection for sustainability. By addressing these areas, the construction sector can further advance its sustainability goals.

Conflict of İnterest

The author(s) declare that they do not have a conflict of interest with themselves and/or other third parties and institutions, or if so, how this conflict of interest arose and will be resolved, and author contribution declaration forms are added to the article process files with wet signatures.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study**.**

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