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Research Article

Determining the importance levels of criteria in selection of sustainable building materials and obstacles in their use

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ABSTRACT

The construction industry has become the focal point of sustainability as one of the largest consumers of natural resources and waste producers. A sustainable construction industry is possible with the sustainability of building materials, which is the main factor controlling the construction management process. In this research, the importance levels of a total of 17 criteria under the headings of economic, environmental, and social sustainability in terms of sustainability of building materials and the importance levels of 11 obstacles to the use of sustainable materials were investigated through a survey conducted with the participation of 60 people. Whether there were differences between the participants' opinions was investigated through inferential analysis. In ranking criteria according to their importance level, the health of workers and citizens, safety in construction and operation, and toxic emissions took the first three places. The risks of higher initial cost, total cost, and extra time are the biggest obstacles to using sustainable materials. In addition, the obstacles were subjected to factor analysis, and a model consisting of four factors was created. The study revealed the criteria for sustainable material selection and the barriers to sustainable material use in a holistic manner. In this respect, it is evaluated that it will be a guide for governments, local governments, building material manufacturers, designers, contractors, and ultimately users to achieve a more sustainable construction sector.

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1. INTRODUCTION

The world population, estimated to be around 600 million in the 1700s [1], today exceeds 8 billion. This insane population growth and the accompanying industrial revolution have led to an uncontrolled development process focused on unlimited production and consumption. This process has put significant pressure on the environment. It has created major environmental problems such as the rapid depletion of natural resources, pollution of air, water, and soil, the spread of chemicals and heavy metals throughout the environment, the destruction of forests and agricultural areas, global warming and acid rain, desertification, and the destruction of the ozone layer [2, 3]. In addition to these environmental problems, the rapidly increasing population, which cannot be satisfied in the countryside, has piled up in cities to work. This has led to unmanageable and unplanned urban growth [4]. Cities have become potential centers for many social, environmental, and economic problems, such as inequality, unemployment, poverty, inadequate infrastructure and services, traffic chaos, violence, crime, and disease [5, 6]. This economic development model has been based on people's desire to continuously raise their living standards without limits, on a policy

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of unlimited production and overconsumption of natural resources, and on destroying the basis of life of living beings. The World Commission on Environment and Development (WCED) report "Our Common Future," published in 1987, emphasized the need to change this model. The report contended that sustainable development should encompass apparent consideration and definition of the social, economic, and ecological facets, defining it as fulfilling present needs while safeguarding the capacity of future generations to fulfill their own [7].

Buildings, particularly in urban areas, are significant consumers of energy and natural resources, contributing to air, water, and soil pollution through waste generation [8]. The statistics reveal that buildings account for 45% of global energy consumption and 50% of water usage. Additionally, they are responsible for 23% of urban air pollution, 50% of greenhouse gas emissions, 40% of water pollution, and 40% of solid waste generation [9]. These alarming figures have prompted initiatives to enhance the sustainability of the construction industry as a whole and individual buildings. "sustainable design" and "sustainable architecture" have emerged to systematically solve the environmental, social, and economic problems associated with our built environment and buildings. Sustainable design is defined as the design of products, services, and the built environment by the principles of social, economic, and environmental sustainability, that is, in a way that serves both present and future generations to achieve a healthy and quality life [10]. On the other hand, sustainable architecture is designing sustainable buildings to reduce the total environmental impact during the entire life cycle, from the production of building materials to the construction, use, and demolition of the building [11]. The goal of sustainable architecture is to create buildings that are sensitive to their environment, minimize the destruction of nature, use all-natural resources such as energy, materials, water, and land most economically and efficiently [12] and expresses an approach that adapts to the surrounding nature, climate, society, and culture [13].

The first and essential condition for producing sustainable architectural works is the selection of sustainable materials [14–16]. Research shows that by selecting construction materials compatible with sustainability principles, for example, CO_2 emissions can be reduced by up to 30% [17]. Otherwise, efforts to build sustainable buildings will be ineffective [14, 18, 19]. On the other hand, the material selection process is very challenging and complex since building materials are the main factor affecting many criteria expected from a building, such as being safe, economical, durable, aesthetic, and functional. With the addition of sustainability in this process, sustainable material selection becomes one of the most challenging tasks in a building project [20]. This situation necessitates a good understanding of the relationship between sustainability and building materials, and this study was carried out to serve this purpose.

The study highlights the significance of environmental, social, and economic factors impacting building material sustainability alongside barriers to their adoption. It assessed 17 criteria covering these sustainability aspects and identified 11 obstacles to material use in Türkiye. Furthermore, factor analysis categorized these barriers into common groups. The data collected through the questionnaire study were obtained from 60 people with different demographic characteristics, including engineers and architects, real estate workers and contractors operating in the construction sector, and faculty members working in related faculties. In the research, inferential analyses were obtained with T and Anova Tests, and the barriers in selecting sustainable materials were tested by factor analysis. In the last stage, all criteria' Index of Relative Importance (IRI) was determined. This research is vital in ranking the requirements for sustainable material selection in Türkiye, identifying the barriers, and selecting the similarities or differences between the criteria choices of participants with different demographic characteristics. Unlike previous studies that only focused on criteria selection or barriers, a holistic approach was used by including the participants' demographic characteristics. It also aims to fill the gap in the literature by conducting research with participants in Türkiye.

Within the scope of the study's design, the relationship between sustainable architectural design and sustainable materials is examined in section 2, and previous studies in the literature are reviewed. In section 3, the study materials and methods are presented, the findings are evaluated, and the results are discussed in section 4. Considering that sustainability is closely related to the local, the study is critical primarily because it was conducted in Türkiye. On the other hand, unlike the literature, the study analyzed the participants' views according to their demographic characteristics and created a model for the barriers to using sustainable materials. In these respects, the study will make a significant contribution to the literature, and the results of the study will be a guide for efforts to make the construction sector more sustainable.

2. THEORETICAL FRAMEWORK AND STUDIES IN THE LITERATURE

As hybrid and electric cars are changing the automobile industry, sustainable architecture is changing the construction industry [21]. According to Bourdeau (1999), the main characteristics of a sustainable architectural product are meeting human health and comfort at the highest level, aiming to improve the quality of human life, being energy and resource-efficient, protecting biodiversity, minimizing waste production, longevity, and using recycled and recyclable materials [22]. Sustainable housing offers many benefits, such as improving quality of life and property value, ensuring affordability, fostering human development, reducing natural disaster risks, and encouraging sustainable urban growth [23]. In the framework developed by Kim and Rigdon (1998) as a guideline for sustainable design, three basic principles of "Economy of Resources, Life Cycle Design, and Humane Design" and strategies and methods related to these principles have been developed. The relationship between sustainability and building materials has been examined through these principles (Table 1) [24].

Table 1. Sustainable design framework [24]

Principles		
Economy of resources	Life cycle design	Humane design
Strategies		
Energy conservation	Prebuilding phase	Preservation of natural conditions
Water conservation	Building phase	Urban design / Site planning
Material conservation	Post building phase	Design for human comfort
Methods		

2.1. The Principle of the Economy of Resources

Covering only 2% of the world's landmass, cities consume 75% of resources, producing greenhouse gas clouds and billions of tons of solid and toxic waste. For example, 125 times the area of London is required to re-supply the resources consumed [25]. The principle of resource conservation, which was developed in response to this excessive human consumption, aims to reduce the use of non-renewable resources and ensure their conservation throughout the life cycles of buildings consisting of design, construction, construction, and demolition. The objectives of sustainable building design include reducing resource inputs, recycling resource outputs, and reducing environmental pollution through effective waste management [26].

The principle of resource conservation consists of methods related to energy, water, and material conservation strategies [24]. The energy conservation strategy aims to use more renewable energy throughout the building life cycle [27]. When the relationship between energy conservation and building materials is examined, it is seen that both the energy consumed during the production, transportation, and transformation of building materials and the contribution of materials to energy saving during the use of the building should be addressed. Energy is inevitably used to process all building materials [28]. There is a vast difference between the energy used to build a house made of locally available material, such as adobe or rammed earth, and the energy used to create a steel construction house. In sustainable design, it is essential to use materials that require less energy to produce and transport [29]. Within the framework of energy conservation, Kim and Rigdon (1998) recommend the use of materials with low embodied energy; the selection of materials that require little energy for their production, transportation, maintenance, and repair and are obtained from local sources; attention to insulation materials used to reduce heat gains and losses; and the use of energy-saving materials in systems such as heating, cooling, air conditioning, and lighting [24].

In addition to the increase in world population, per capita water use, industrial and production activities, and urbanization, the decrease in precipitation and change in precipitation regimes due to climate change put the world's freshwater resources under tremendous pressure [30]. For example, Türkiye's water per capita has decreased from 4,000 m^3 to 1,500 m^3 in the last 20 years. Türkiye's population is expected to reach 100 million in 2030. With the decrease in precipitation, Türkiye is expected to approach the category of water-poor countries with a per capita water amount of 1100 m^3 [31]. The water conservation strategy aims to reduce the amount of water buildings use throughout their life cycle. Just like in energy, there is also embedded water for building materials. It is possible to define embodied water as water consumed during the cultivation and extraction of raw materials for building materials, manufacturing and transportation of products, and construction. Research shows that most of this water (92%) is consumed for material production [32]. For 1 m^3 of concrete, the embedded water reaches 11 tons; for 1 m^2 of glass with a thickness of 4 mm, 3.4 tons; and for 1 m^3 of timber, 20.1 tons [33]. These figures indicate the importance of water conservation in selecting building materials.

Material conservation is crucial to ensure that the design meets sustainability criteria. It is vital for sustainability that building materials are durable, easy to maintain and maintain, recycled, and recyclable [34]. According to Stahel (1990), materials should be recyclable, reusable, locally sourced, produced outside extensive centralized facilities, and positively impact user health and comfort level [29]. They prefer materials that have a long lifetime and are easy to maintain, resulting in less need for renovation. In this way, problems such as the embedded energy and water required to produce the new material, carbon dioxide emissions during manufacturing, local environmental impact due to raw material extraction, and pollution during the transportation and processing of the material are avoided [28].

2.2. The Principle of Life Cycle Design

The principle of life cycle design is based on the transformation of resources from one form in which they are helpful to another in which they can be useful so that their useful life continues without ever ending. Materials are considered one of the most critical inputs to the life cycle process. All stakeholders, from owners to designers, contractors to users, should seek assurance that the materials used in buildings are the best materials for the environment on a "cradle to grave" basis. Under ideal conditions, it is part of the process that buildings are built with materials from recycling other buildings and are recyclable. However, it is naturally impossible to design an utterly closed building life cycle that eliminates the need for new materials. However, adhering to life cycle principles means reducing the consumption of energy, water, and resources required to produce new materials and reducing the production of solid waste and harmful emissions. The life cycle design principle comprises pre-building, building, and post-building phases [24]. The building design is realized in the pre-building phase, and the selected materials are evaluated regarding their environmental impact. In this phase, the raw materials should consist of renewable resources, environmentally harmless materials with low embodied energy and water, and long-lasting and durable materials requiring less replacement and maintenance. The building phase is concerned with the environmental, social, and economic impacts that arise during the transformation of materials into manufacturing using labor. This phase aims to establish a waste management system that includes collecting and recycling material waste. Care is also taken to ensure that building materials and materials used during manufacturing, such as adhesives and binders, do not contain toxins that could harm the health of construction workers and users. In the post-building phase, the aim is to recycle materials after the end of the useful life of the building, thus reducing the use of new natural resources and energy.

2.3. The Principle of Humane Design

The first two principles prioritize efficiency and conservation, while the design principle for people encompasses the entire ecosystem, including individuals, plants, and wildlife [24]. Research indicates that the quality of the environment influences people's health, well-being, economic prosperity, and lifestyle [35]. Making sustainability viable involves aligning it with people's needs and cultural values [36]. The strategies within this principle involve conserving natural environments, urban design, and designing for human comfort [24]. Sustainable selection of building materials can help preserve the natural ecosystem and protect vulnerable areas [37]. Designing buildings in harmony with their environment, considering topography, climatic data, and natural and artificial elements aids in selecting materials correctly, prolonging their service life, using them effectively, and avoiding unnecessary labor and costs [38]. Urban design and land planning strategies involve transitioning from building to city scale, requiring materials that respect local characteristics [24]. The design strategy for human comfort focuses on interior spaces, where people spend 70% of their lives selecting materials to enhance thermal, visual, and auditory comfort. Proper thermal insulation materials reduce mechanical heating and cooling systems, while utilizing natural light reduces the need for additional lighting, promoting healthy biorhythms [39]. Additionally, materials used in door, window, and wall systems play a crucial role in providing auditory comfort by mitigating noise.

2.4. Studies in the Literature

Studies in the literature reveal that more importance should be given to selecting sustainable materials. A study conducted in Türkiye concluded that using sustainable materials and building elements is insufficient even in LEED-certified projects [40]. Therefore, it seems appropriate to investigate the crucial factors in using sustainable materials and their barriers. There are a limited number of studies on this issue in the literature. Akadiri (2015) examined the main barriers to selecting sustainable building materials in Nigeria. A survey conducted among professionals in the construction sector showed that the most critical barriers to selecting sustainable materials are the perception of extra cost and the need for knowledge of sustainable materials [41]. Kuppusamy et al. [42] concluded that the main barriers to using green building materials in Malaysia are high cost, lack of awareness, and lack of rules and regulations. The solutions are reducing the cost of green building materials and organizing education and training campaigns. In a similar study, Mohsin and Ellk (2018) found problems between designers' environmental awareness in building construction and realistic implementation due to administrative and technical reasons [43]. Dinh et al. [44] identified 11 obstacles to integrating sustainability criteria into material selection in Vietnam, one of the developing country examples. They concluded that four are of "high" importance. Mewomo et al. [45] evaluated sustainable building materials through 25 barriers they created. In the study, lack of awareness and knowledge, lack of local authority and government involvement, insufficient funding for research and development and education and training, lack of understanding of the net benefit, lack of qualified personnel or practitioners, and lack of building codes and regulations on innovation were considered as the most critical barriers. In their study, Gounder et al. [46] aimed to identify the main barriers to using sustainable materials in Australia. Using the relative importance index, exploratory factor analysis, and multinomial logistic regression analysis as research methods, the study reveals that the critical barriers to the use of sustainable materials are related to cost and profit considerations, the reluctance of key stakeholders to include these materials in construction projects, lack of incentives and government policies. In another study conducted in Nigeria, Eze et al. [47] identified resistance and information barriers, regulation and financing challenges in research and development, cost and market hurdles, insufficient government incentives, limited supplier availability, and barriers to expertise and labor as the primary obstacles hindering the adoption of sustainable materials.

Danso (2018), in his study on the determination of sustainability criteria, determined criteria by evaluating building materials based on their economic, social, and environmental sustainability [48]. Dinh et al. [44] ranked 18 criteria according to their importance. As a result of the research, it was concluded that the most crucial criterion is material price. Al-Atesh et al. [49] evaluated the criteria for sustainable building materials. Within the scope of the study, 29 criteria were ranked according to their importance with AHP. As a result of the research, it was concluded that environmental and economic criteria are more important than social criteria. When previous academic studies are evaluated, there has yet to be a consensus on the criteria for sustainable building materials selection and the barriers in this regard. It is seen that the barriers to the selection of sustainable materials vary from country to country and can also differ according to the opinions of the participants. In all these respects, there is a need for much more studies on the subject, especially on a national scale.

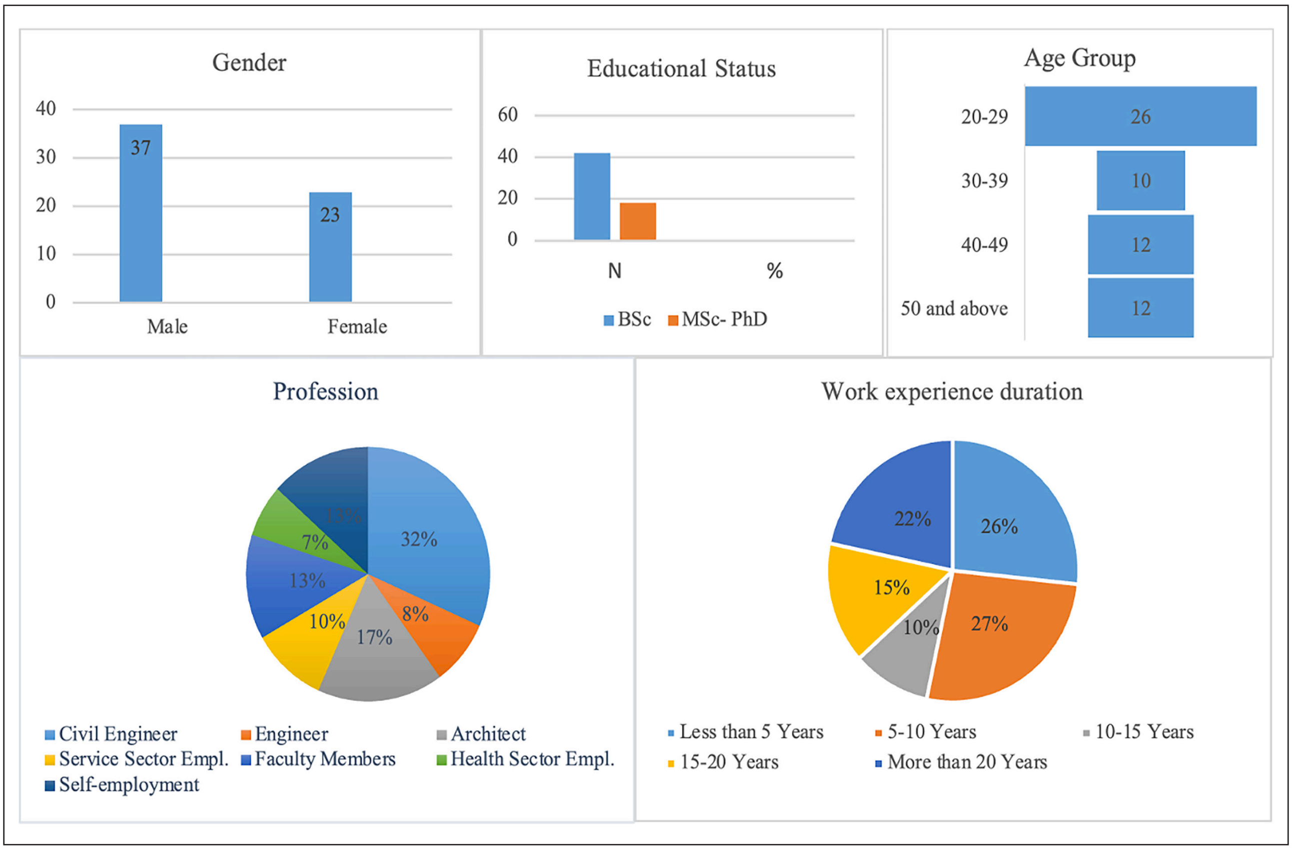

Figure 1. Demographic features of the participants.

3. MATERIAL AND METHODS

Dinh et al. [44] examined sustainable material selection and barriers to sustainable material use in Vietnam. In the study, it was seen that the criteria were determined based on a comprehensive literature study and existing criteria related to sustainability. Since Vietnam is a developing country, Vietnam has economic characteristics similar to Türkiye, so the scale used by Dinh et al. [44] was utilized in this study. Participants were asked to evaluate the importance levels of 17 criteria under the headings of environmental, social, and economic sustainability in terms of sustainability of building materials and the importance levels of 11 barriers to using sustainable materials. The evaluations used a 5-point Likert scale (1- Not important, 2- Slightly important, 3- Average important, 4- Very important, and 5- Very important). The survey was conducted with 60 participants with different demographic characteristics, and the collected data were analyzed using SPSS 29.0 (Statistical Package for Social Sciences) (SPSS, 2023). Descriptive analyses were made about the scales according to the characteristics of the participants. In the study, the reliability of the scales was also tested, and inferential analyses were made with independent sample T-Tests andT-testsTests after checking the normality of the data. The Index of Relative Importance (IRI) of all criteria was determined. In the last stage, to better understand the barriers to sustainable material selection, factor analysis was performed, factor weights were determined, and a model was created.

4. RESULTS

4.1. Demographic Findings

Demographic findings of the participants were obtained through descriptive analysis. Descriptive analysis expresses and summarizes a data set in quantitative numerical values or counting or ranking values in quantitative or graphic form [50]. Demographic findings of the participants are given in Figure 1. Accordingly, 62% of the participants were male. All the participants, who were predominantly (43%) between the ages of 20 and 29, were selected from those with a university education level or higher, as it was thought that they could better evaluate the issue of sustainability. In terms of work experience, more than half of the respondents have 0–10 years of experience, while 22% have more than 20 years of experience. When engineers and architects, real estate sector employees and contractors included in the service sector employees and self-employed, and faculty members working in related faculties are evaluated together, it is possible to say that almost all the participants are related to the construction sector.

4.2. Descriptive Statistics and Reliability Analysis Results of the Scales Used

The results of descriptive statistics and reliability coefficients of the scales used in the research are given in Table 2. The questions were 3.65, 3.86, 3.90, and 3.65 for economic, environmental, and social criteria and barriers to sustainable material use, respectively. As can be seen in the table, the reliability values of the scales were above the 0.5 limit

Table 2. Descriptive statistics and reliability values of the scales

Variable	N	Item number	Item mean	Item min.	Item max.	C. Alpha
Economic criteria	60	5	3.653	3.067	4.100	0.649
Environmental criteria	60	8	3.867	3.483	4.300	0.813
Social criteria	60	6	3.904	3.317	4.367	0.552
Barriers	60	11	3.652	3.100	4.033	0.789

Table 3. Mean and standard deviation values of the criteria

No	Criteria	N	Mean	SD
Ec1	Material price	60	4.1000	0.72952
Ec2	Material handling cost	60	3.7667	0.87074
Ec3	Cost during the construction phase	60	3.6000	1.21013
Ec4	Cost in operation and maintenance phase	60	3.7333	1.05552
Ec5	Cost further ing demolition phase	60	3.0667	1.19131
Econmean		60	3.6533	0.65062
En1	Energy consumption	60	3.6667	1.14487
En2	Water consumption	60	3.4833	1.15702
En3	Global warming	60	3.6500	1.20486
En4	Waste production management	60	3.8667	1.06511
En5	Toxic emissions	60	4.3000	0.94421
En6	Depletion of natural resources	60	4.0667	0.95432
En7	Acidification of soil and water	60	4.1167	0.99305
En8	Potential for recycling and reuse	60	3.7833	1.13633
Envmean		60	3.8667	0.70481
Sc1	Safety in construction and operation	60	4.3167	0.79173
Sc2	The health of workers and citizens	60	4.3667	0.78041
Sc3	LabLaborailability	60	3.6167	0.99305
Sc4	Aesthetics	60	3.3167	1.29525
Socialmean		60	3.9042	0.63127

SD: Standard deviation.

value suggested by Cronbach and Helmstater, indicating that the scales were reliable [51, 52]. While the reliability values are pretty high for environmental criteria, they are relatively low for social criteria.

The average scores of the criteria are presented in Table 3. Among the economic criteria, the criterion of the initial price of the material explained in the questionnaire as "The price that the contractor orders from the suppliers" has reached the highest average score, and the cost during the demolition phase has reached the lowest average score. Among the environmental criteria, the toxic emission criterion, "emission of poisons into the environment during the use of construction material," has the highest average, and water consumption has the lowest average. Among the social criteria, "Health of workers and citizens" and "aesthetics" received the highest and lowest average scores, respectively.

The average scores of the criteria related to the barriers to the use of sustainable materials are presented in Table 4. Among this criterion, "Risks of higher initial cost, total cost and extra time" has the highest mean score and "Refusal to change traditional criteria in material selection and construction methods" has the lowest mean score.

4.3. Inferential Analyses

Inferential analyses were conducted to determine whether participant evaluations changed according to demographic characteristics. For this purpose, it was first checked whether the data were usually distributed to decide whether parametric or nonparametric tests would be applied in inferential analyses. Different methods can be used to determine this. The most used of these methods is to check the Skewness and Kurtosis values of the data. The skewness and kurtosis values in Table 5 vary between –0.922 and 0.244. Hair et al. [53] reported that the data are considered customarily distributed if the skewness and kurtosis values are between +1 and –1. Therefore, it was accepted that the data were normally distributed for all four criteria, and inferential analyses with parametric tests were conducted.

Inferential statistics are statistics that obtain analytic expressions for estimation or hypothesis testing about the character of the statistical main population [54]. Inferential analysis tests compare the means of two or more groups and decide whether the difference between means is random or statistically significant. Since the data were normally distributed, the independent sample T-test was used for

Table 4. Mean and standard deviation values of barriers to sustainable material use

No	Criteria	N	Mean	SD
BAR1	Lack of database on environmental and social impacts of the material	60	3.8000	1.0051
BAR2	Limited availability of sustainable materials in the construction sector	60	3.7167	0.9223
BAR3	Lack of education, awareness, and knowledge of sustainable materials	60	3.8167	0.8335
BAR4	Lack of cost-effective software or toolkits for material selection	60	3.5167	1.0655
BAR5	Stakeholders focus only on economic criteria	60	3.9667	0.9382
BAR6	Lack of government support	60	3.4833	1.4081
BAR7	Lack of customer demand and awareness	60	3.8333	1.1956
BAR8	Lack of sustainable construction culture	60	3.5833	1.1541
BAR9	Refusal to change traditional criteria in the selection of materials and construction methods	60	3.1000	1.2171
BAR10	The evaluation process is too complex	60	3.3167	1.0655
BAR11	Higher initial cost, total cost, and extra time risks	60	4.0333	1.0571
Barmean		60	3.6515	0.6137

SD: Standard deviation.

cases with two groups in inferential analyses, and the Anova test was used for cases with more than two groups. The test results for the cases where the difference between the participants' opinions is significant are as follows:

The independent sample T-test was used to investigate whether there was a significant difference between the participants' opinions according to their gender. As a result of the test, a significant difference was found only for environmental criteria (Table 6). In this test, Levene's test sig (p) value greater than 0.05 indicates no difference between the groups, in which case the value in the first row is considered. The sig. The value in the first row is 0.035, meaning the difference is significant ($p<0.05$). For environmental criteria, men's average was 3.7, while women's average was 4.1.

The analysis, according to the age groups of the participants, was carried out using the ANOVA test. As a result of the test, the sig (p) value was less than 0.05, i.e., significant, for the economic, environmental, and sustainable material selection barriers criteria (Table 7). The averages of the participants according to age groups are presented in Table 8. Accordingly, the lowest mean for economic criteria was 3.31 for the age group above 50 years, and the highest mean was 3.88 for the age group 20–29 years. For environmental criteria, the lowest mean was 3.13 for those over 50, and the highest was 4.27 for the 20–29 age group. For the barriers to using sustainable materials, the lowest average was realized for those over 50 and the highest for the 30–39 age group.

The independent sample T-test was used to investigate whether there was a significant difference between the participants' opinions according to their education level. As a result of the test, a significant difference was found only for economic criteria and barriers to using sustainable materials (Table 9). For both criteria groups, the averages of those with master's and doctorate level education were higher than those with university degrees. The averages were 3.50 and 4.01 for economic criteria and 3.48 4.04 for barriers.

Table 5. Mean, kurtosis, and skewness values of the scales

	Statistic	SE
Economic mean		
Mean	3.8667	0.091
Skewness	-0.362	0.309
Kurtosis	-0.524	0.608
Environmentalmean		
Mean	3.8925	0.098
Skewness	-0.922	0.337
Kurtosis	0.393	0.662
Socialmean		
Mean	3.9042	0.08150
Skewness	-0.537	0.309
Kurtosis	0.244	0.608
Barriermean		
Mean	3.6515	0.079
Skewness	-0.117	0.309
Kurtosis	-0.705	0.608

SE: Standard error.

Table 6. T-test results according to the gender of the participants

	Levene's Test for equality of var.		T-test for equality of means		
	F	Sig.	t	df	Sig. (2-tailed)
Envmean					
Equal var. as.	1.809	0.184	-2.161	58	0.035
Equal var. not as.			-2.319	56.193	0.024

df: Degrees of freedom.

Table 7. Anova test results according to age groups of participants

	Sum of squares	df	Mean square	F	Sig.
Econmean					
Between groups	3.498	3	1.166	2.893	0.043
Within groups	22.571	56	0.403		
Total	26.069	59			
Envmean					
Between groups	10.896	3	3.632	11.047	0.000
Within groups	18.412	56	0.329		
Total	29.308	59			
Barmean					
Between groups	3.878	3	1.293	3.947	0.013
Within groups	18.340	56	0.328		
Total	22.218	59			

df: Degrees of freedom.

Table 8. Mean criteria scores of participants according to age groups

Criteria	Age group	N	Mean	SD
Econmean	20–29	26	3.8846	0.70011
	30–39	10	3.7400	0.55817
	40–49	12	3.4167	0.64079
	>50	12	3.3167	0.52194
	Total	60	3.6533	0.66472
Envmean	20–29	26	4.2740	0.50747
	30–39	10	3.8125	0.74594
	40–49	12	3.7604	0.51802
	>50	12	3.1354	0.60410
	Total	60	3.8667	0.70481
Barmean	20–29	26	3.8217	0.56538
	30–39	10	3.9273	0.44906
	40–49	12	3.4470	0.65608
	>50	12	3.2576	0.58767
	Total	60	3.6515	0.61365

SD: Standard deviation

Inferential analyses of the participants, according to the duration of work experience, were conducted using the ANOVA test. As a result of the research, a significant difference was found for economic and environmental criteria ($p<0.05$) (Table 10). Looking at the averages, the average of the group with 16–20 years of experience (3.11) was found to be the lowest, and the average of the group with 6–10 years of experience (3.90) was found to be the highest for economic criteria (Table 11).

Anova test was used to analyze whether the differences in the participants' opinions according to their professions were significant [55]. The test showed that the result was significant for economic criteria (Table 12). When the averages of the groups were analyzed, it was seen that the lowest average was found for engineers (3.28), and the highest average was found for faculty members (4.13). When the inferential analyses are analyzed in general, it is seen that there are differences in the opinions in general for economic criteria and, in some cases, for environmental criteria and barriers. For social criteria, there is a consensus.

4.4. Criteria to be Considered in the Selection of Sustainable Building Materials

As a result of inferential analyses, it was determined that the results, especially the economic criteria, differed signifi-

Table 9. T-test results according to the education level of the participants

	Levene's Test for equality of var.		T-test for equality of means		
	F	Sig.	t	df	Sig. (2-tailed)
Econmean					
Equal var. as.	0.550	0.461	-2.895	58	0.005
Equal var. not as.			-3.034	35.976	0.004
Barmean					
Equal var. as.	1.068	0.306	-3.563	58	0.001
Equal var. not as.			-3.793	37.371	0.001

df: Degrees of freedom.

Table 10. Anova test results according to participants' duration of work experience

	Sum of squares	df	Mean square	F	Sig.
Econmean					
Between groups	5.453	4	1.363	3.637	0.011
Within groups	20.617	55	0.375		
Total	26.069	59			
Envmean					
Between groups	7.474	4	1.868	4.706	0.002
Within groups	21.835	55	0.397		
Total	29.308	59			

df: Degrees of freedom.

cantly according to the demographic characteristics of the participants. In this case, the results can't be generalized. However, to obtain a general view, the relative importance indexes of the criteria were determined according to the formula below. Table 13 presents the relative importance of economic, environmental, and social criteria. Accordingly, the criterion with the highest relative importance is "S2 - Health of workers and citizens," and the barrier with the highest relative importance is "BAR11 - Higher initial cost, total cost, and extra time risks".

$$IRI = \Sigma W/A*N \quad (1)$$

IRI: Index of Relative Importance

W: The weights given by each participant for that proposition are 1- Not important, 2- Somewhat important, 3- Average important, 4- Very important, and 5- Very important.

A: The highest weight value. In this case, it is 5.

N: Total number of participants (60)

The relative importance indexes of the criteria to be considered in selecting sustainable building materials and their ranking accordingly are presented in Table 13. The top three criteria were the health of workers and citizens, safety in construction and operation, and toxic emissions. At the same time, water consumption, aesthetics, and cost during the demolition phase were the bottom three criteria.

The ranking of the barriers to using sustainable building materials according to their relative importance indexes is given in Table 14. The criterion "Risks of higher initial cost, total cost and extra time" has the highest relative importance, and "Refusal to change traditional criteria in material selection and construction methods" has the lowest relative importance.

4.5. Factor Analysis

In the last stage of the study, factor analysis was conducted to determine the barriers to using sustainable building materials. Factor analysis is the general name of a group of multivariate analysis techniques that aim to reduce many variables that are thought to be related to each other to a smaller number of basic dimensions to orotate the understanding and interpretation of these relationships [56].

Table 11. Averages of the participants according to the duration of their work experience

Criteria	N	Mean	SD
Econmean			
≤5	16	3.8625	0.75089
6–10	16	3.9000	0.61536
11–15	6	3.8333	0.46332
16–20	9	3.1111	0.44845
>20	13	3.3846	0.56250
Total	60	3.6533	0.66472
Envmean			
≤5	16	4.2813	0.56734
6–10	16	4.0391	0.52185
11–15	6	3.8333	0.83915
16–20	9	3.6111	0.51707
>20	13	3.3365	0.77793
Total	60	3.8667	0.70481

SD: Standard deviation.

In factor analysis, the first step is to examine the suitability of the data for factor analysis, that is, to check the factorability of the items. The most well-known method for this is to conduct sample suitability tests. The tests for the suitability of factor analysis are Bartlett's test of sphericity and Kaiser-Methe yer-Olkin (KMO) test. The results of the

Table 12. Anova test results according to participants' professions

	Sum of squares	df	Mean square	F	Sig.
Econmean					
Between groups	5.685	6	0.948	2.464	0.036
Within groups	20.384	53	0.385		
Total	26.069	59			

df: Degrees of freedom.

Table 13. Ranking of sustainable building material selection criteria according to their IRI

No	Criteria	IRI
Sc2	The health of workers and citizens	0.873
Sc1	Safety in construction and operation	0.863
Env5	Toxic emissions	0.860
Env7	Acidification of soil and water	0.823
Ec1	Material price	0.820
Env6	Depletion of natural resources	0.813
	Social	0.781
Env4	Waste production management	0.773
	Environmental	0.773
Env8	Potential for recycling and reuse	0.757
Ec2	Material handling cost	0.753
Ec4	Cost in operation and maintenance phase	0.747
Env1	Energy consumption	0.733
	Economic	0.731
Env3	Global warming	0.730
Sc3	Labor availability	0.723
Ec3	Cost during the construction phase	0.720
Env2	Water consumption	0.697
Sc4	Aesthetics	0.663
Ec5	Cost during the demolition phase	0.613

IRI: Index of Relative Importance.

sample suitability tests are given.MO that is used to test the suitability of the sample size in factor a. The KMO value must be higher than 0.50 to proceed with factor analysis. In this test, the KMO value was found to be 0.590. Bartlett's test tests the null hypothesis that "the original correlation matrix is the same as the identity matrix (all correlation coefficients are zero)" [56]. The Table 15 shows that this test is significant, meaning that it is suitable for factor analysis.

According to the commonalities table, each variable (item) has a common variance between 0 and 1. While items with commonalities above 0.50 explain more of the variance, items with commonalities lower than 0.50 may lead to more complex factors to interpret, or these items need to be eliminated. In Table 16, only one item with a commonality below 0.5 was identified (BAR4–0.484). Still, since the value was close to 0.5, it was decided to include all items in the analysis.

A good factor analysis is expected to explain the highest variance with the least number of factors. An analysis that explains 50–75% of the total variance is considered a good result in factor analysis. The table below shows the eigenvalues before and after factor extraction and after rotation (Table 17). These values roughly indicate the correlation between two variables. Also, there are four factors with eigenvalues greater than 1; the first factor explains 32% of the variance. The relative importance of the factors is equalized by rotation. The four factors explain 74% of the total variance (Table 17).

Interpreting factor loadings without rotation presents challenges. Rotating the matrix aids in achieving a more interpretable factor structure and optimizes the items in terms of explained variance post-rotation. Upon examination of the factor loading matrix rotated using the Varimax method, no instance was observed where an item exhibited strong loadings from multiple factors. In such cases, a minimum load difference of 0.1 is preferred, and items explaining multiple factors are systematically removed from the scale, one item at a time, with the matrix reassessed accordingly. However, such a scenario did not occur in this instance (Table 18).

An essential stage of factor analysis is naming the factors. Factors are named by examining the variables loading on the factors and determining the common point between the variables. In naming, care is taken to give the name that best expresses the meaning the variables loading on the factor want to emphasize. By naming the factors, the model shown in Figure 2 was obtained.

5. DISCUSSION

The research was conducted with 60 participants with different demographic characteristics. The participants were asked to evaluate the importance of 17 criteria under the headings of economic, environmental, and social sustainability in terms of sustainability of building materials. Participants also reported how important they found the barriers to using sustainable materials. Inferential analyses showed that participant opinions differed according to different demographic characteristics. This differenti-

Table 14. Ranking of the barriers to the use of sustainable building materials according to their IRI

No	Criteria	IRI
BAR11	Higher initial cost, total cost, and extra time risks	0.807
BAR5	Stakeholders focus only on economic criteria	0.793
BAR7	Lack of customer demand and awareness	0.767
BAR3	Lack of education, awareness, and knowledge of sustainable materials	0.763
BAR1	Lack of database on environmental and social impacts of the material	0.760
BAR2	Limited availability of sustainable materials in the construction sector	0.743
BAR8	Lack of sustainable construction culture	0.717
BAR4	Lack of cost-effective software or toolkits for material selection	0.703
BAR6	Lack of government support	0.697
BAR10	The evaluation process is too complex	0.663
BAR9	Refusal to change traditional criteria in the selection of materials and construction methods	0.620

Table 15. KMO and Bartlett tests' results

Kaiser-Meyer-Olkin measure of sampling adequacy.	0.590
Bartlett's test of sphericity	
Approx. Chi-Square	270.539
df	55
Sig.	0.000

KMO: Kaiser-Methe yer-Olkin; df: Degrees of freedom.

ation was most pronounced for economic criteria, whereas no significant differences emerged for social criteria. It was observed that female respondents attributed greater importance to environmental criteria than male respondents. Another result is that as the age of the participants increases, the level of importance they attribute to the criteria decreases. The most significant difference emerged for environmental criteria, with the average for the 20–29 age group being well above very important (4.27).

Table 16. Communalities

Criteria	Extraction
BAR1	0.815
BAR2	0.759
BAR3	0.773
BAR4	0.484
BAR5	0.782
BAR6	0.852
BAR7	0.815
BAR8	0.775
BAR9	0.575
BAR10	0.730
BAR11	0.719

Extraction Method: Principal Component Analysis.

Table 17. Total variance explained

Comp.	Initial eigenvalues			Extraction sums of Sq. loadings			Rotation sums of Sq. loadings		
	Total	% of var.	cum. %	Total	% of var.	cum. %	Total	% of var.	cum. %
1	3.734	33.949	33.949	3.734	33.949	33.949	2.623	23.845	23.845
2	1.745	15.861	49.809	1.745	15.861	49.809	2.072	18.838	42.683
3	1.526	13.877	63.686	1.526	13.877	63.686	1.860	16.910	59.594
4	1.076	9.781	73.467	1.076	9.781	73.467	1.526	13.873	73.467
5	0.700	6.364	79.831						
6	0.676	6.147	85.978						
7	0.579	5.265	91.243						
8	0.333	3.028	94.270						
9	0.299	2.715	96.985						
10	0.225	2.049	99.034						
11	0.106	0.966	100.000						

Extraction Method: Principal Component Analysis.

Table 18. Rotated factor loadings matrix

		Component			
		1	2	3	4
BAR1	Lack of database on environmental and social impacts of the material	0.288	-0.105	0.809	0.258
BAR2	Limited availability of sustainable materials in the construction sector	0.061	0.763	0.390	0.147
BAR3	Lack of education, awareness, and knowledge on sustainable materials	0.387	0.389	0.166	0.667
BAR4	Lack of cost-effective software or toolkits for material selection	0.610	0.164	0.255	0.141
BAR5	Stakeholders focus only on economic criteria	0.053	-0.082	-0.008	0.879
BAR6	Lack of government support	0.387	0.642	-0.380	0.383
BAR7	Lack of customer demand and awareness	0.864	-0.107	-0.214	0.107
BAR8	Lack of sustainable construction culture	0.862	0.086	0.118	0.109
BAR9	Refusal to change traditional criteria in the selection of materials and construction methods	0.610	0.315	0.321	0.028
BAR10	The evaluation process is too complex	0.048	0.846	0.006	-0.113
BAR11	Higher initial and total cost and risk of extra time	0.004	0.222	0.809	-0.127

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 5 iterations.

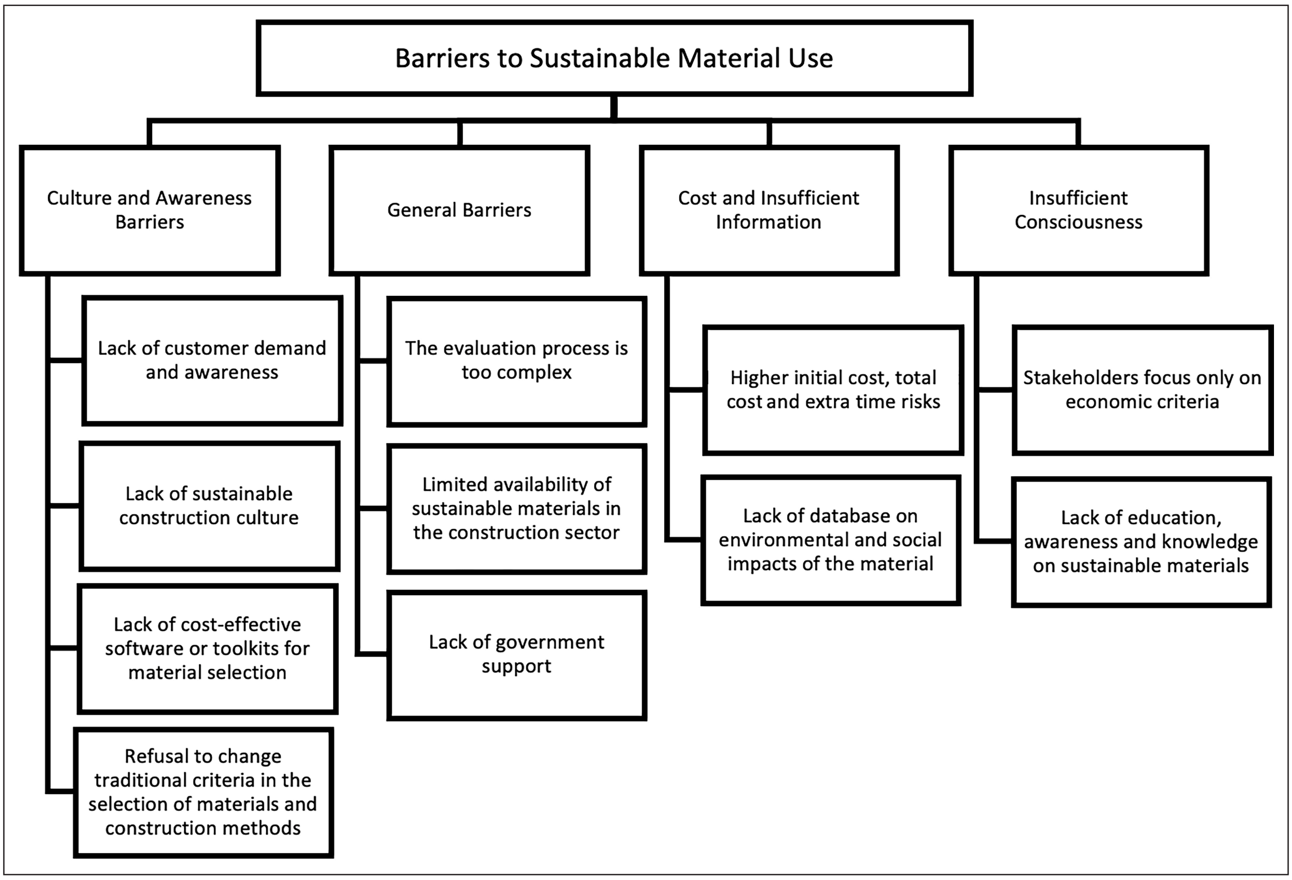

Figure 2. Model of barriers to sustainable material use (Source: Created by the authors).

In comparison, it was almost only necessary (3.14) for the over-50 age group. Since work experience is directly proportional to age, a similar pattern was observed for work experience. Respondents with a master's degree and higher education attributed greater importance to economic criteria. While there was a significant difference by occupation only for economic criteria, faculty members were the occupational group that attributed the highest importance. This differentiation between the participants' views identified by inferential analysis indicates that it would be helpful to conduct studies with a more significant number of participants.

On the other hand, it is pleasing that young people are more sensitive to sustainability. Nevertheless, conducting cross-sectional studies to see whether participants' views have changed over time would be helpful. There is always the possibility that other challenges participants face over time may have pushed sustainability to the background. The significant differences in participants' opinions on economic criteria, in general, maybe because the financial difficulties experienced by our country in recent years have affected different segments of society at various levels. A general conclusion is that people whose tasks are linked to sustainability should be carefully selected, as they can reflect their views on practice.

Although there were differences of opinion among the participants for some criteria, the relative importance of the criteria was found to get a general idea. The requirements with the highest relative importance were:

- The health of workers and citizens.
- Safety in construction and operation.
- Toxic emissions.

In this respect, the study conducted in Türkiye differs from other studies in the literature. This means that the country's dynamics should re-examine the study's structure. As a result, all three of the top three most important criteria are related to health and safety. This situation in the construction sector is quite alarming. The fact that building materials carry serious health risks increases the importance of this awareness. The following factors are considered influential in prioritizing criteria in this manner:

- With industrialization, the number of occupational accidents and diseases has increased significantly, and protecting workers' health and safety has been one of the most critical problems of working life since then. Occupational accidents affect the health and safety of everyone in the construction industry, including designers, architects, structural engineers, and construction site workers [57]. The construction sector ranks first in terms of the frequency of accidents causing death and permanent incapacity for work in Türkiye [58].
- The construction sector faces numerous risk factors that contribute to accidents. These include outdoor work under varying weather conditions, high turnover rates, work conducted at different elevations, constant movement of workers and materials, and a dispersed workforce with varying education levels [59]. These

factors, often intertwined with material selection, influence safety measures. For instance, opting for prefabricated materials reduces time spent at heights, while choosing easier-to-assemble materials minimizes on-site labor requirements.
- The link between occupational diseases and construction materials is significant, surpassing that of occupational accidents. Various materials used in construction, including cement, adhesives, wood and plaster dust, solvent and glue vapors, asbestos, heavy metals, and welding fumes, pose health risks to workers and users of completed structures. Exposure to these substances can result in severe conditions such as cancer, silicosis, asbestosis, skin allergies, bronchitis, nervous system disorders, and lead poisoning [60].

The last three ranked criteria were water consumption, aesthetics, and cost of demolition, with relative importance levels below 0.7. The conclusions reached regarding these are provided below:
- Water is one of the world's most precious natural resources. In Türkiye, projections indicate that per capita water availability may classify the country as water-poor [31]. Climate change simulations further forecast a rise in temperatures by up to 5 degrees Celsius nationwide, accompanied by a precipitation decline of up to 30% in the southern and western regions [61]. Given these forecasts, addressing water consumption is deemed crucial, necessitating heightened awareness and emphasis on conservation efforts
- Architectural beauty is more than just a visual delight. It's defined as "the harmony of everything and a certain harmony between all the elements of the building so that no part can be added, removed or changed without damaging the design" or "an impressive photograph of any relationship between lines, colors, and volumes" [62]. In this respect, aesthetics, like water consumption, is a criterion that should be given higher importance, as it's the architects' and urban planners' role to create functional, visually appealing, and harmonious structures.
- Demolition costs encompass various factors. However, compared to construction costs, demolition expenses are relatively low. Hence, it's common practice to assign minimal importance to demolition costs as a criterion in decision-making processes.

In ranking the barriers to using sustainable building materials according to the relative importance indexes, the criterion "Higher initial cost, total cost, and extra time risks" has reached the highest relative importance. "Refusal to change traditional criteria in material selection and construction methods" had the lowest relative importance. The results of the study are in line with the literature. In parallel with [41, 42, 46], "cost" factors are among the most critical barriers to the use of sustainable materials. The initial cost of sustainable materials is often higher than conventional ones, but a prevalent misconception is that sustainability always entails significantly higher expenses.

Additionally, uncertainty about future costs and availability can deter stakeholders from adopting sustainable materials. However, in the long term, buildings constructed with sustainable materials are more cost-effective due to the savings they provide. Transition difficulties are cited as barriers to the widespread adoption of sustainable materials. On the other hand, in this study, the participants attributed little importance to rejecting the traditional approach.

In the last stage of the study, the barriers to using sustainable building materials were subjected to factor analysis. Four factors explaining 73.5% of the total variance were identified. The factors were named cultural and awareness barriers, general barriers, cost, insufficient knowledge, and insufficient awareness by paying attention to the common points between the variables. It is evaluated that the model obtained will contribute to the literature in this regard.

6. CONCLUSIONS

While Türkiye's environmental pollution pressure is increasing, the bill resulting from its external dependence on energy is steadily rising. If this trend continues, the country is expected to become one of the water-stressed countries shortly. These three fundamental problems alone point to the need for Türkiye to make significant strides in sustainability. Like the rest of the world, the construction sector is one of the sectors where the need for sustainability is most evident. The first and most crucial step in achieving sustainability in the industry is the sustainable selection and use of materials that significantly affect construction management. The study is expected to make the construction industry sustainable by providing essential data to stakeholders on sustainable material selection and barriers to sustainable material use. It is thought that it would be beneficial to enrich the literature by conducting more extensive research in the future.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

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REFERENCES

[1] Klein Goldewijk, K., Beusen, A., Van Drecht, G., & De Vos, M. (2011). The HYDE 3.1 spatially explicit database of human-induced global land-use change over the past 12,000 years. *Glob Ecol Biogeogr, 20*(1), 73–86. [CrossRef]

[2] Elander, I., Gleeson, B., Lidskog, R., & Low, N. (2002). *Consuming cities—The urban environment in the global economy after the Rio Declaration* (1st ed.). Rutledge.

[3] Hoşkara, E., & Sey, Y. (2009). Ülkesel koşullar bağlamında sürdürülebilir yapım. *İtüderg/a, 7*(1), 50–61.

[4] Yazar, K. H. (2006). *Sürdürülebilir kentsel gelişme çerçevesinde orta ölçekli kentlere dönük kent planlama yöntem önerisi* [Doktora Tezi, Ankara Üniversitesi].

[5] Jian, Z., De-nong, Z., & Yu-kun, Z. (23–26 January, 1999). Opening a new epoch of architecture and culture in the 21st century. *Sub-theme Reports of the 20th UIA Congress: Architecture of the 21st Century*. Beijing, China.

[6] Blowers, A., & Pain, K. (1999). *The unsustainable city. Unruly Cities?* Order/Disorder.

[7] WCED. (1987). *Our common future. World commission on environment and development*. Sustainable Development.

[8] Vyas, S., Ahmed, S., & Parashar, A. (2014). BEE (Bureau of energy efficiency) and Green Buildings. *Int J Res, 1*(3), 23–32.

[9] Dixon, W. (2010). *The impacts of construction and the built environment*. Willmott-Dixon Group.

[10] McLennan, J.F. (2004). *The philosophy of sustainable design: The future of architecture*. Ecotone Publishing.

[11] Ji, Y., & Plainiotis, S. (2006). *Design for Sustainability*. Architecture and Building Press.

[12] Gür, N. V., & Aygün, M. (2008). Mimaride sürdürülebilirlik kapsamında değişken yapı kabukları için bir tasarım destek sistemi. *İtüderg/a, 7*(1), 74–82.

[13] Karslı, H. (2008). *Sürdürülebilir mimarlık çerçevesinde ofis yapılarının değerlendirilmesi ve çevresel performans analizi için bir model önerisi* [Yayımlanmamış Doktora Tezi]. Mimar Sinan Güzel Sanatlar Üniversitesi.

[14] Nassar, K., Thabet, W., & Beliveau, Y. (2003). A procedure for multi-criteria selection of building assemblies. *Autom Constr 12*(5), 543–560. [CrossRef]

[15] Treloar, G., Fay, R., Ilozor, B., & Love, P. (2001). Building materials selection: greenhouse strategies for built facilities. *Fac, 19*(3–4), 139–150. [CrossRef]

[16] Alibaba, H. Z., & Özdeniz, M. B. (2004). A building elements selection system for architects. *Build Environ, 39*(3), 307–316. [CrossRef]

[17] Wang, W., Zmeureanu, R., & Rivard, H. (2005). Applying multi-objective genetic algorithms in green building design optimization. *Build Environ, 40*(11), 1512–1525. [CrossRef]

[18] Van Kesteren, I. E. H. (2008). Product designers' information needs in materials selection. *Mater Design, 29*(1), 133–145. [CrossRef]

[19] González, M. J., & Navarro, J. G. (2006). Assessment of the decrease of CO2 emissions in the construction field through the selection of materials: Practical case study of three houses of low environmental impact. *Build Environ, 41*(7), 902–909. [CrossRef]

[20] Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*. John Wiley & Sons. [CrossRef]

[21] Wang, N., & Adeli, H. (2014). Sustainable building design. *J Civ Eng Manag 20*(1), 1–10. [CrossRef]

[22] Bourdeau, L. (1999). Sustainable development and the future of construction: A comparison of visions from various countries. *Build Res Inf J, 27*(6), 354–366. [CrossRef]

[23] UN-Habitat. (2012). Going green: *A handbook of sustainable housing practice in developing countries*. UN-Habitat Publishing.

[24] Kim, J. J., & Rigdon, B. (1998). *Sustainable architecture module: Introduction to sustainable design*. National Pollution Prevention Center for Higher Education.

[25] Pearce, F. Eco-cities special: Ecopolis now. https://www.newscientist.com/article/mg19025561-600-eco-cities-special-ecopolis-now/.

[26] Özek Karadeniz, Y. (2010). *Geleneksel Afyonkarahisar evlerinin sürdürülebilir mimarlık ilkeleri bağlamında değerlendirilmesi* [Yüksek Lisans Tezi, Mimar Sinan Güzel Sanatlar Üniversitesi].

[27] Yellamraju, V. (2004). *Evaluation and design of double-skin facades for office buildings in hot climates* [Doctoral dissertation, Texas A&M University].

[28] Roaf, S., Fuentes, M., & Thomas, S. (2003). *Ecohouse 2: a design guide*. Architectural Press.

[29] Stahel, H. P. (1990). *Baukunst & Gesundheit*. AT Verlag.

[30] Anderson, J., & Thornback, J. (2012). *A guide to understanding the embodied impacts of construction products*. Construction Products Association.

[31] Bal, E. (2012, February 24). Su Hayattır, Hayatınızı Koruyun. https://web.archive.org/web/20161005163326/http://www.yesiloji.com/yesilhaber/su-hayattir-hayatinizi-koruyun/

[32] Bleby, M. "Embodied water" is the latest challenge for the building industry. https://www.afr.com/property/commercial/construction-s-next-cost-challenge-embodied-water-20230328-p5cvvm.

[33] Fuller, R. J., Crawford, R. H., & Leonard, D. (January, 2009). What is wrong with a big house. *Performative ecologies in the built environment: Sustainable research across disciplines: Proceedings of the 43rd Annual Conference of the Australian and New Zealand Architectural Science Association ANZAScA*. Launceston, Tasmania.

[34] Tönük, S. (2001). *Bina tasarımında ekoloji*. Yıldız Teknik Üniversitesi Basım-Yayın Merkezi.

[35] Toofan, S. (2014). Importance of humane design for sustainable landscape. *Int J Eng Technol, 6*(6), 508–511. [CrossRef]

[36] Oktay B., & Hoşkara, Ş. Ö. (2009). A model for measuring the sustainability level of historic urban quarters. *Eur Plan Stud, 17*(5), 715–739. [CrossRef]

[37] Jones, D. L. (1998). *Architecture and the environment: bioclimatic building design*. Laurence King Publication.

[38] Aktuna, M. (2007). *Geleneksel mimaride binaların sürdürülebilir tasarım kriterleri bağlamında değerlendirilmesi Antalya Kaleiçi evleri örneği* [Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi].

[39] Atabay, B. (2010). *Doğal ve yapay ışığın mekanı anlamlandırma gücü ve bir arada bulunma dinamikleri* [Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi].

[40] Hashi, M. N., & Kasapoğlu, E. (2023). Türkiye'de Leed Belgesi almış büro binalarının sürdürülebilir malzeme ve kaynak kullanımı bağlamında değerlendirilmesi. *Eksen Dokuz Eylül Üniv Mimar Fak Derg, 4*(1), 170–188. [CrossRef]

[41] Akadiri, P. O. (2015). Understanding barriers affecting the selection of sustainable materials in building projects. *J Build Eng, 4*, 86–93. [CrossRef]

[42] Kuppusamy, S., Chew, H. Y., Mari, T. S., & Chai, C. S. (2019). Implementation of green building materials in construction industry in Johor Bahru, Malaysia. *IOP Conf Ser Earth Environ Sci, 268*(1), 012006. [CrossRef]

[43] Mohsin, A. H., & Ellk, D. S. (2018). Identifying barriers to the use of sustainable building materials in building construction. *J Eng Sustain Dev, 22*(2), 107–115. [CrossRef]

[44] Dinh, T. H., Dinh, T. H., & Götze, U. (2020). Integration of sustainability criteria and life cycle sustainability assessment method into construction material selection in developing countries: The case of Vietnam. *Int J Sustain Dev Plan, 15*, 1145–1156. [CrossRef]

[45] Mewomo, M. C., Mogaji, I. J., Iruka, A., & Makanjuola, S. A. (2022). Barriers to the successful adoption of innovative building materials for sustainable construction: A review. *In Construction Industry Development Board Postgraduate Research Conference*. (pp. 103–112). Springer. [CrossRef]

[46] Gounder, S., Hasan, A., Shrestha, A., & Elmualim, A. (2023). Barriers to the use of sustainable materials in Australian building projects. *Eng Constr Archit Manag, 30*(1), 189–209. [CrossRef]

[47] Eze, E. C., Sofolahan, O., & Omoboye, O. G. (2023). Assessment of barriers to the adoption of sustainable building materials (SBM) in the construction industry of a developing country. *Front Eng Built Environ, 3*(3), 153–166. [CrossRef]

[48] Danso, H. (2018). Dimensions and indicators for sustainable construction materials: A review. *Res Dev Mater Sci, 3*(4), 286–294. [CrossRef]

[49] Al-Atesh, E. A., Rahmawati, Y., Zawawi, N. A. W. A., & Utomo, C. (2023). A decision-making model for supporting selection of green building materials. *Int J Constr Manag, 23*(5), 922–933. [CrossRef]

[50] Mann, P. S. (1995). *Introductory statistics*. Wiley. [CrossRef]

[51] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334. [CrossRef]

[52] Helmstadter, G. C. (1964). *Principles of psychological measurement*. Appleton-Century-Crofts.

[53] Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. (2010). *Multivariate data analysis*. Pearson.

[54] Dodge, Y. (2003). *The Oxford dictionary of statistical terms* (6^{th} ed.). Oxford University Press. [CrossRef]

[55] Hair, J.F., Anderson, R.E., Tatham, R.L., & Black, W.C. (1995). *Multivariate data analysis* (4^{th} ed.). Prentice Hall.

[56] Kline, P. (2014). *An easy guide to factor analysis*. Routledge. [CrossRef]

[57] Gambatese, J. A., Behm, M., & Hinze, J. W. (2005). Viability of designing for construction worker safety. *J Constr Eng Manag, 131*(9), 1029–1036. [CrossRef]

[58] SSK. (n.d.) İstatistik yıllıkları. https://www.sgk.gov.tr/Istatistik/Yillik/fcd5e59b-6af9-4d90-a451-ee7500eb1cb4/

[59] Müngen, U. (2011). İnşaat sektörümüzdeki başlıca iş kazası tipleri. *Türk Müh Haber Derg, 469*(5), 32–39.

[60] Adisesh, A., Rawbone, R., Foxlow, J., & Harris-Roberts, J. Occupational health standards in the construction industry. https://www.researchgate.net/profile/Anil-Adisesh/publication/274700436_Occupational_Health_Standards_in_the_Construction_Industry/links/5aa40fe4aca272d448b8e7ab/Occupational-Health-Standards-in-the-Construction-Industry.pdf

[61] Şen, Ö. L., Bozkurt, D., Göktürk, O. M., Dündar, B., & Altürk, B. Türkiye'de iklim değişikliği ve olası etkileri. https://www.researchgate.net/profile/Bahadir-Altuerk/publication/322099836_Turkiye'de_Iklim_Degisikligi_ve_Olasi_Etkileri/links/5a44e280458515f6b0531a0e/Tuerkiyede-Iklim-Degisikligi-ve-Olasi-Etkileri.pdf

[62] Attia, M. M. (2000). *Aesthetic values in plastic arts*. Dar al-Faker al-Arabi.