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The relationship between building design and environmental sustainability at the facility management stage in the construction sector

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Abstract

Buildings exert a variety of environmental impacts throughout every stage of their life cycle. A structure designed and constructed with environmental sustainability in mind not only reflects the design team's awareness but also influences the environmental sustainability awareness of multiple stakeholders involved in the post-design phases of the building life cycle. This study explores the impact of constructing production buildings (facilities) in accordance with environmental sustainability principles on the awareness of environmental sustainability among companies and managers during the facility management phase. A survey was conducted with 38 companies operating in the Turkish construction sector, all of which are currently in the facility management stage of the building life cycle. The collected data were analyzed using cluster analysis, factor analysis, and the Relative Importance Index (RII). The cluster analysis classified the facilities into two distinct groups based on environmental sustainability criteria: Group 1 includes facilities not constructed in line with environmental sustainability principles, whereas Group 2 comprises facilities that were built in accordance with such principles. Subsequently, the environmental sustainability awareness of the institutions and managers within each group, along with the key influencing factors, were examined. The results reveal that institutions and managers in Group 2 demonstrate significantly higher awareness levels and RII scores compared to those in Group 1. These findings highlight the importance of incorporating environmental sustainability considerations at the early stages of the building life cycle, particularly during the design phase, in order to ensure full adoption of sustainability by companies and managers.

1. Introduction

The construction industry is one of the sectors contributing to economic growth. However, activities in this sector have adverse effects on the environment, such as the excessive consumption of global resources, increased carbon emissions, and pollution [1, 2]. Worldwide, 25% of water, 30% of raw materials, and 20% of land are used by the construction sector, while 30% of stored waste originates from this sector [3-6]. Furthermore, studies show that buildings account for 21% of global greenhouse gas emissions [7]. A significant portion of the greenhouse gas emissions in the construction sector consists of CO_2, and approximately 40% of the world's annual CO_2 emissions come from buildings and infrastructure [7, 8].

Environmental sustainability is not only related to the natural environment but also to the built environment, which encompasses the activities within construction projects. If these activities are not effectively managed, they can lead to substantial negative environmental impacts [9]. Currently, sustainable construction methods, such as green building design, are being researched to mitigate the adverse environmental effects caused by the construction sector [10].

For sustainable construction selection, environmental protection, efficient water usage, reuse of wastewater, the use of eco-friendly materials, carbon footprint reduction, heating and cooling systems utilizing natural resources, ensuring appropriate indoor air quality, energy conservation, solar energy production, hot water heating, high-quality insulation, comfort, and enhancing quality of life must all be considered, taking advantage of nature's power. The development and widespread adoption of infrastructure for sustainable buildings, roads, dams, etc., is essential to ensure sustainability for both human life and the planet [11].

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Resource and energy management are of paramount importance for environmental sustainability in the construction industry [12]. Nair and Nayar [12] emphasize the importance of water conservation and recycling, particularly stressing that water-saving measures should be implemented during the design phase of buildings. Generally, while the use of sustainable construction methods may increase construction costs, it provides savings in operational costs and carbon emissions for buildings [13].

The most significant factor in the advancement and implementation of sustainable construction is the lack of awareness and understanding [1, 14]. Companies with insufficient awareness will fall significantly behind in market conditions as technology continues to evolve [14].

This study aims to assess the environmental sustainability awareness of institutions operating in the construction sector and the managers working within these institutions who are involved in the facility management phase of the building life cycle. The evaluation was conducted by grouping the institutions based on whether their production buildings (facilities) were constructed within or outside the framework of environmental sustainability, using cluster analysis. The main research question of the study is whether constructing production buildings (facilities) in line with environmental sustainability principles affects the environmental sustainability awareness of institutions and managers during the facility management phase.

2. Research Background

Ding [15], in his 2004 study, developed a multi-criteria project evaluation model integrating economic, social, and environmental values. The model aimed to combine economic, social, and environmental factors with a sustainability index, measuring environmental issues and integrating them into this index. Zhong and Wu [16] conducted a comprehensive study on the economic sustainability, environmental sustainability, and constructability performance of reinforced concrete and steel-frame structures in Singapore. As a result, they presented a guide that considers economic, environmental, and constructability factors in structural material selection. Nair and Nayar [12] investigated performance indicators for the economic, social, and environmental dimensions of sustainability in the construction industry in India. Dobrucali et al. [17] explored the critical success factors for economic, social, and environmental sustainability in the construction sector and identified five factors for each system.

Ortiz et al. [18], Ingrao et al. [19] and Shuvo and Sharmin [20] conducted sustainability assessments considering the life cycle processes of construction projects. Ortiz et al. [18] examined the differences between life cycle assessment (LCA) of construction materials and processes. The study concluded that the operational phase is the most critical phase in terms of environmental burdens in Europe. It was also emphasized that sustainable construction practices should be promoted to enhance sustainability in the construction sector. Ingrao et al. [19] investigated the importance of Life Cycle Assessment (LCA) and Life Cycle Technology (LCT) applications. LCA contributes to quality, energy efficiency, and sustainability in buildings, while the implementation of LCT plays a fundamental role in achieving high-quality and environmentally healthy buildings. The study also found that LCA results support environmental planning and increase stakeholder awareness by encouraging environmental product declarations related to the building life cycle. Shuvo and Sharmin [20] reported that commercial buildings consume more energy and generate higher emissions compared to residential and educational buildings.

Vivian and Zeng [21], through Relative Importance Index (RII) analysis, ranked 62 sustainability performance indicators for buildings used for residential purposes. O'Connor et al. [22] identified 54 indicators for sustainability actions during the construction phase of buildings. Abidin [9], considering project developers, investigated the awareness and application levels of sustainability practices. He identified the lack of experience and knowledge as one of the reasons for the weaknesses of these practices.

Özustaoğlu [23] conducted a study examining the factors affecting the sustainable building production process in the Turkish construction sector. In this study, a survey was administered, and the relationship between the participant characteristics and the factors influencing sustainable building production was analyzed in detail. Zulu et al. [24] investigated the extent to which environmental sustainability was integrated by designers in infrastructure designs in developing countries. The study concluded that, unlike developed countries, environmental sustainability is not considered as a design philosophy in developing countries. Dzeraviaha [25], in his study, examined the impact of company size on environmental sustainability. Based on the company's cost structure, the study found that smaller companies were more successful in environmental sustainability in production, construction, and related activities, while larger companies were more successful in resource-intensive activities, particularly energy and material-based operations.

3. Research Methodology

Given the positive effects of environmental sustainability on the planet, sustainability awareness is becoming increasingly important in the construction industry, as in many other sectors. In this context, the main research problem considered in the design of this study is the relationship between the environmental sustainability awareness of companies and managers in the construction sector and the sustainability of the buildings in which they operate. Specifically, this study explores the impact of constructing a facility (production building) in accordance with environmental sustainability criteria on the environmental sustainability awareness of the company and its managers. The Marmara Region, where industrial buildings are densely concentrated, was selected to obtain the data required for the study. Six organized industrial zones in which companies operating in the construction sector are highly concentrated were identified by the authors. Clustering analysis was selected to determine whether buildings constructed in accordance with environmental sustainability and those that are not form meaningful clusters within the survey data. To identify, evaluate, and compare the relationships between these clusters and the survey questions (variables), commonly used statistical analysis methods (factor analysis and the relative importance index) were selected. The steps constituting the methodology and design of this study are presented in Fig. 1.

The first phase of the methodology involved the preparation of questions for the survey. The questions in the survey were determined through expert opinions and a literature review. Four expert opinions were obtained during the preparation of the questions. Two of the experts were representatives of companies operating in the field of sustainability, while the other two were academic members of the civil engineering faculty. Based on these expert opinions and the literature review, a comprehensive list of questions was created. The consulted experts evaluated the questions derived from the literature in terms of the regulations and other provisions related to the construction sector and environmental sustainability in Türkiye. Additionally, due to the limited number of management studies on the topic in the literature, the general information obtained from the literature was adapted to management-related questions with the assistance of the experts. The list of survey questions and the corresponding table are shown in Table 1.

In the second phase of the study, the survey was designed. This survey consists of four sections. The first section gathers general information about the participants, leaders, and institutions. The second section collects general information about the design and construction characteristics (project) of the buildings in the facility management phase and the company's approach to environmental sustainability in order to create clusters.

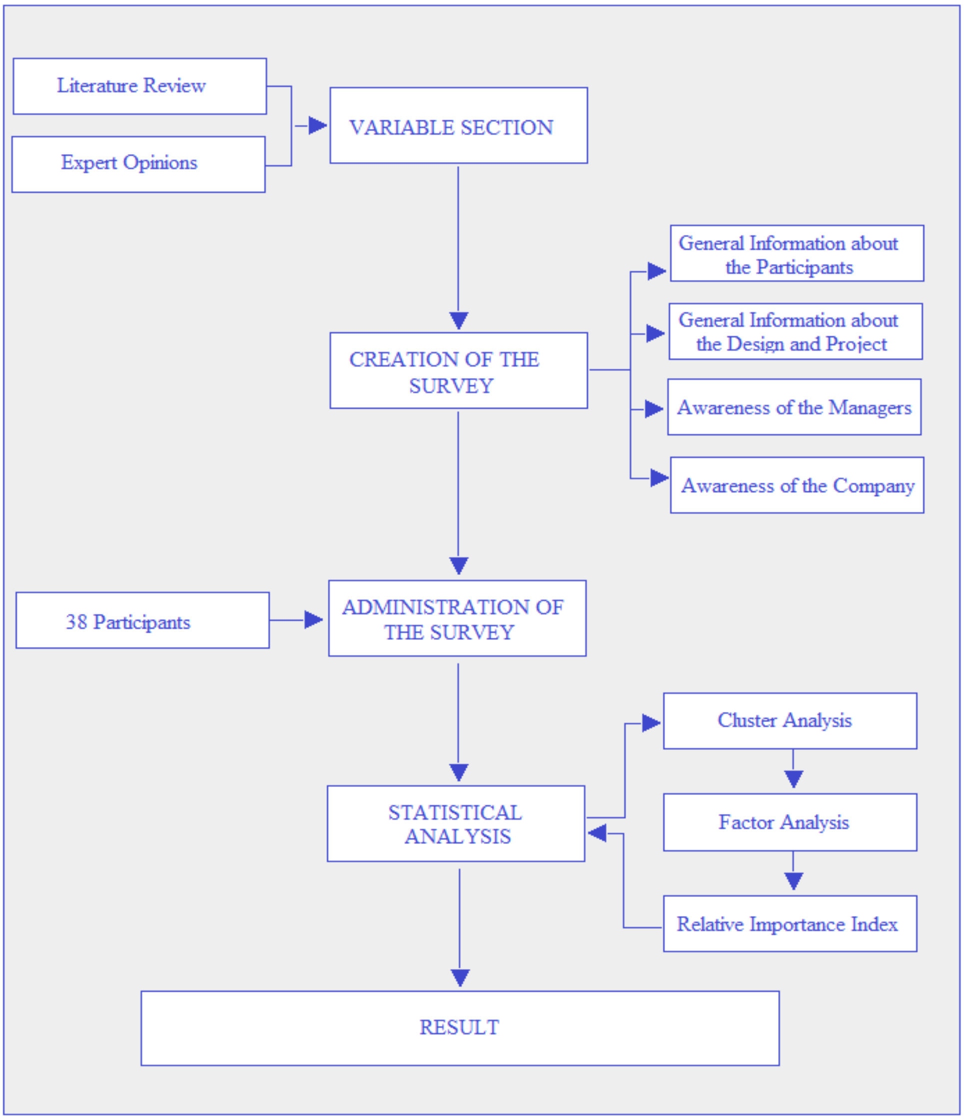


Fig. 1. Research methodology

Table 1. The list of the survey questions (Edited by [29])

	Survey Questions	Reference
Cluster	K1 The company has sufficient knowledge about the concept of sustainability	[14, 23]
	K2 The company conducts preliminary research for environmental sustainability	[14, 23]
	K3 Sustainability criteria were considered during the construction of the production facility	[14, 23]
	K4 The production facility is structurally suitable for environmental sustainability	[14, 23]
Company	C1 Knowledge about renewable energy sources	[30, 31]
	C2 Suitability for solar panel installation	[31, 32]
	C3 Investment in solar energy systems	[27]
	C4 Initiatives for clean energy	[33]
	C5 Appropriate infrastructure for collecting and utilizing rainwater	[34, 35, 36]
	C6 Sufficient knowledge about rainwater collection and utilization	[34, 35, 36]
	C7 Knowledge about rainwater and its potential areas of use	[34, 35, 36]
	C8 Availability of technical personnel for proper rainwater collection and use	[34, 35, 36]
	C9 Knowledge about the costs of collecting and utilizing rainwater	[34, 35, 36]
	C10 Economic contribution of rainwater harvesting	[34, 35, 36]
	C11 Knowledge about the applications of rainwater use	[34, 35, 36]
	C12 Knowledge about regulations related to rainwater collection, storage, and discharge systems	[34, 35, 36]
Manager	M1 Knowledge about procedures for installing solar panels	[33]
	M2 Cost–benefit and return on investment for sustainable systems	[27, 37]
	M3 Knowledge about the costs of renewable energy	[38]
	M4 Renewable energy is included in current investment plans	[27, 39]
	M5 Clean energy has positive environmental impacts	[27]
	M6 Clean energy has positive economic contributions	[30, 31]
	M7 Clean energy helps reduce carbon emissions	[30, 31]
	M8 Knowledge about the payback period of sustainable systems	[30, 31]
	M9 Knowledge about energy savings	[30, 31]
	M10 Knowledge about the design stages and duration of sustainable systems (e.g., solar panels)	[40]
	M11 Knowledge about the advantages and disadvantages of rainwater harvesting	[34, 35, 36]

The third section of the survey includes questions about the environmental sustainability awareness of the managers, and the fourth section focuses on the company's environmental sustainability awareness. The questions in the third and fourth sections particularly focus on rainwater harvesting and the use of renewable energy (especially solar panels). This is because, globally, the largest share of investment in renewable energy is directed toward solar energy, which accounts for 57% of total investments in renewable energy sources [26, 27]. Furthermore, recent changes to Türkiye's "Regulation on the Amendment of the Zoning Law for Planned Areas" [28] have introduced new obligations regarding rainwater harvesting, which will become effective in 2026. A five-point Likert scale was used in sections two, three, and four of the survey. In this scale, 1 represents the lowest value, and 5 represents the highest value.

In the third phase of the study, a survey was conducted with 38 companies and their managers operating in the construction sector in six different organized industrial zones in the Marmara region of Türkiye. The survey included participation from civil engineers, architects, and other managers (e.g., mechanical and environmental engineers).

Finally, the data obtained from the survey were evaluated using cluster analysis, frequency analysis, and the Relative Importance Index (RII) analysis. Detailed information regarding the analysis process is provided in the "4. Data Analysis" section.

4. Data Analysis

4.1. General information

In the first section of the survey, information was gathered regarding the educational background, education level, and industry experience of the managers. Of the managers, 65.8% have a degree in civil engineering, 15.8% in architecture, and 18.4% in other fields. In terms of educational qualifications, 68.4% of the managers hold a bachelor's degree, 18.4% have a master's degree, and 13.2% possess an associate degree. In terms of industry experience, 26.3% of the managers have 0-5 years, 18.4% have 6-10 years, 34.2% have 11-15 years, 15.8% have 16-20 years, and 5.3% have more than 20 years of experience in the construction sector. The survey also asked about the duration of the companies' activities in the construction sector. According to the results, 21.1% of the companies have been active for 0-5 years, 15.8% for 6-10 years, 28.9% for 11-15 years, 5.3% for 16-20 years, and 28.9% have been operating for more than 20 years. The detailed information of this section is shown in Table 2.

4.2. Cluster analysis

In this study, cluster analysis was performed to assess whether the clusters were classified properly.

Table 2. The properties of the manager and corporation

	Categories	Percentage (%)
Departments where participants received training	Civil Engineering	65.8
	Architecture	15.8
	Others	18.4
Educational status of manager	Master’s degree	18.4
	Bachelor’s degree	68.4
	Associate's degree	13.2
Working periods of manager	more than 20 years	5.3
	16-20 years	15.8
	11-15 years	34.2
	6-10 years	18.4
	0-5 years	26.3
Working periods of	more than 20 years	28.9
	16-20 years	5.3
	11-15 years	28.9
	6-10 years	15.8
	0-5 years	21.1

One of the tools used to evaluate the validity of clustering is the Silhouette value, which can determine the separation distance between clusters. The Silhouette value ranges from −1 to +1 [41]. For example, when this value is +1, it suggests that the clusters are well-separated, 0 indicates that the data point lies on the decision boundary between two neighboring clusters, and negative values may imply that a data point has been assigned to the wrong cluster [42, 43].

In this study, cluster analysis was performed using the TwoStep algorithm in SPSS 30.0.0 [44], based on the four variables listed under the cluster heading in Table 1. The results showed that the data were grouped into two clusters, and the Silhouette Coefficient was between 0.5 and 1.0, indicating a "good" level of clustering.

Fig. 2 illustrates the sizes and quality of the clusters formed as a result of the cluster analysis. As shown in the figure, the size ratio between the largest and smallest clusters is 1.71, indicating a balanced distribution. The cluster quality assessment is slightly above 0.5, falling within the “Good” category. This suggests that the clustering solution provides a clear and reliable separation between the two groups. Overall, these findings support the validity of the clustering approach used.

According to the analysis results, 36.8% of the data belong to Group 1, while 63.2% belong to Group 2 (Fig. 2).

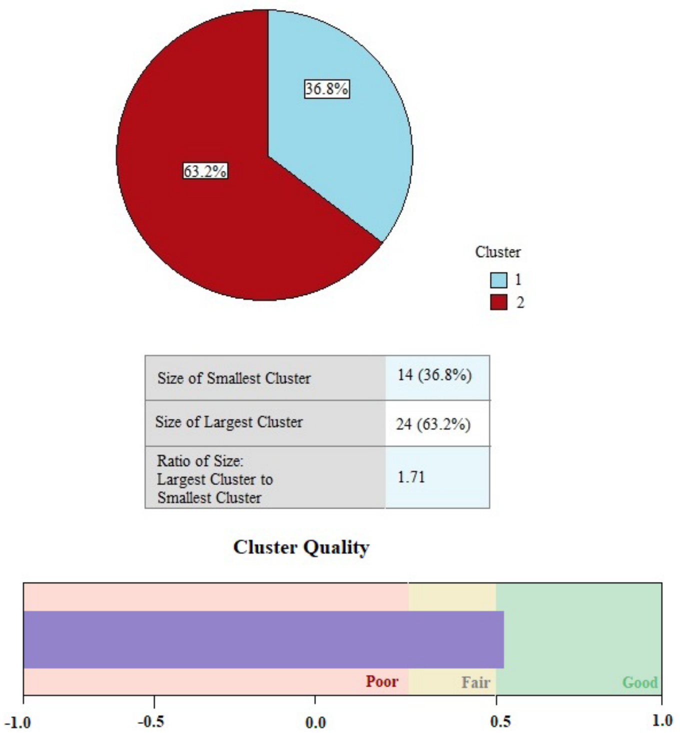


Fig. 2. Cluster sizes and quality

The main variable in the analysis was identified as K3. The importance levels and rankings of other variables are shown in Fig. 3. Fig. 4 illustrates the sizes of the two clusters formed as a result of the analysis and the relative importance of the variables within these clusters. Since variable K3 is the primary variable, the most frequently selected value and its proportion are presented, while the other variables are represented by their average values. Additionally, the frequency distributions of each variable in both clusters are visualized in Table 3.

Overall, upon reviewing the results of the cluster analysis, it can be seen that Cluster 1 represents buildings that are not constructed in accordance with environmental sustainability, while Cluster 2 represents buildings that are constructed in accordance with environmental sustainability. In the upcoming sections, analyses for both managers and companies will be performed, separately evaluating and comparing these two groups.

Figs. 3 and 4 display the sizes of the two clusters and the relative importance of the variables within these clusters. Variable K3 is the most prominent contributor in defining the clusters, with importance values of 4.00 (70.8%) for Cluster 2 and 3.00 (64.3%) for Cluster 1. Additionally, the importance of variables K2, K1, and K4 is higher in Cluster 2, with values of 4.50, 4.54, and 4.25 respectively, compared to lower values of 2.64, 3.00, and 2.93 in Cluster 1. Table 3 illustrates the frequency distribution of the four variables used in the cluster analysis across the two groups. Based on Figs. 3, 4 and Table 3, it has been determined that the differences between the clusters are significant.

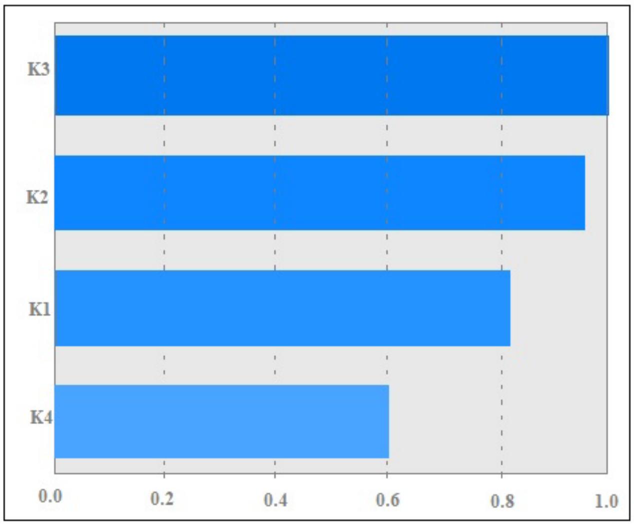


Fig. 3. Predictor importance

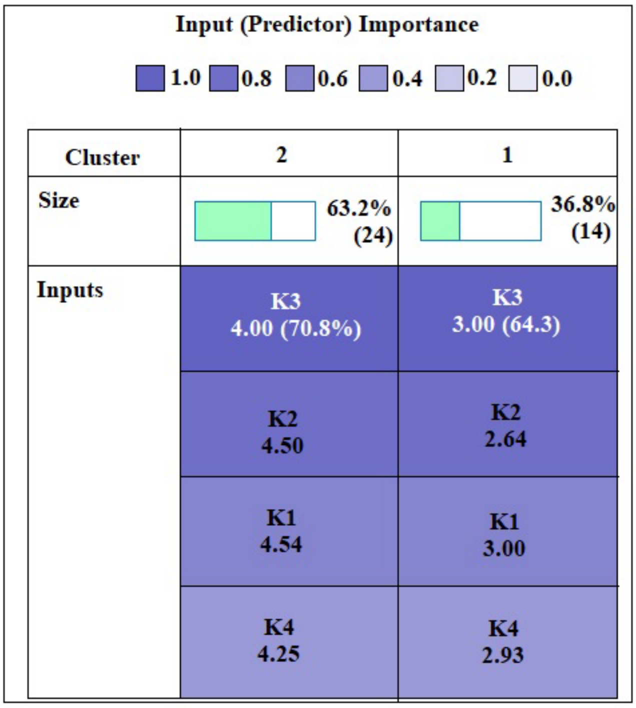


Fig. 4. Cluster predictors

Table 3. Frequency distribution for cluster analysis

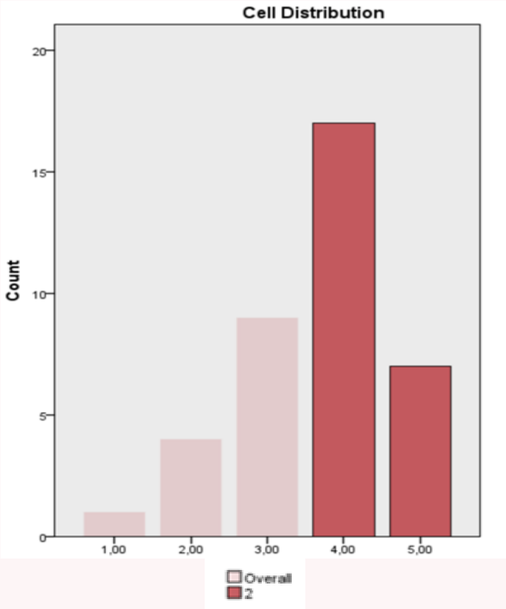
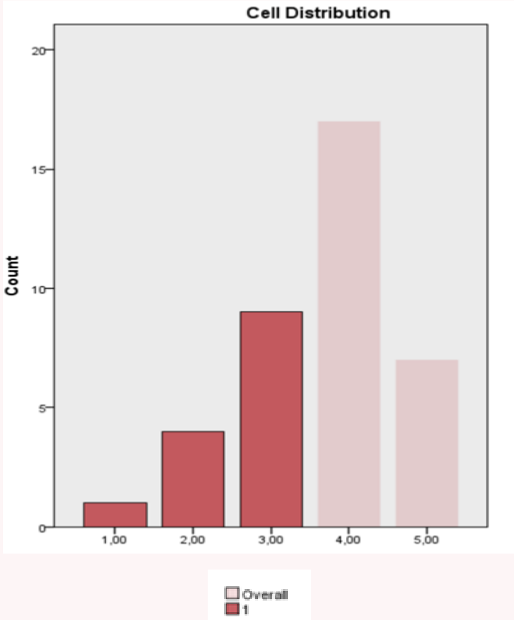
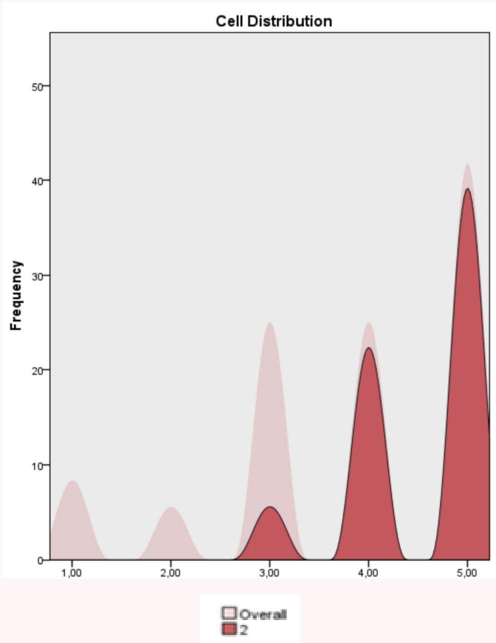
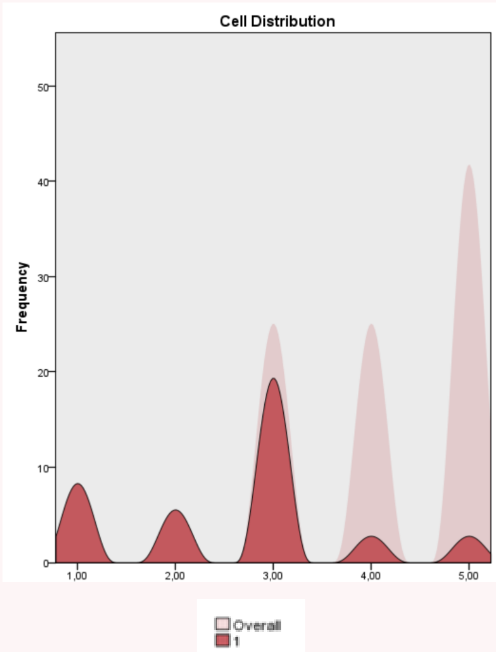
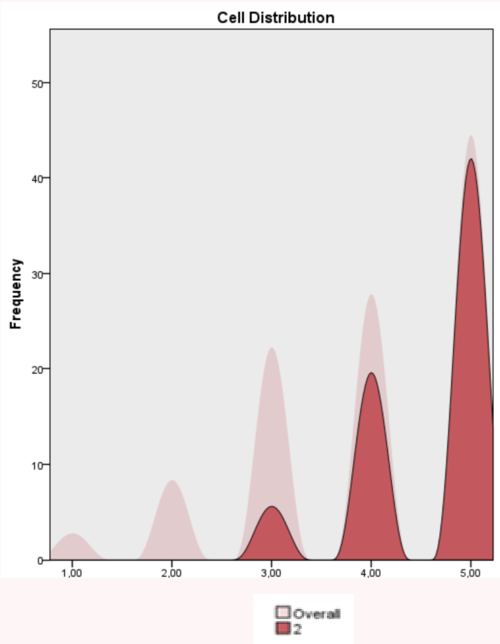
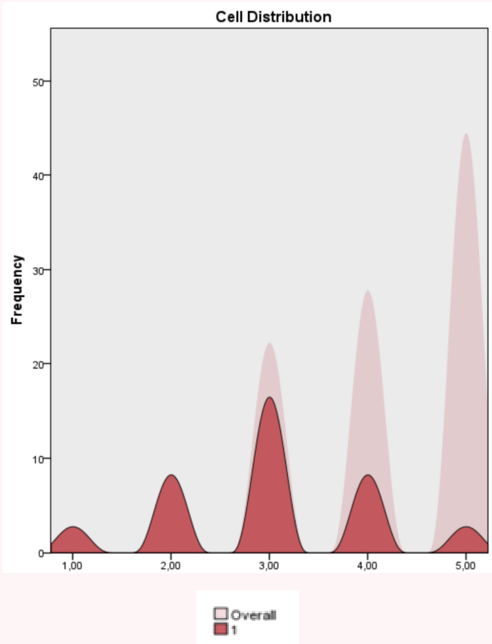
	Buildings constructed in accordance with environmental sustainability (Group2)	Buildings not constructed in accordance with environmental sustainability (Group1)
K3 Sustainability criteria were considered during the construction of the production facility		
K2 The company conducts preliminary research for environmental sustainability		

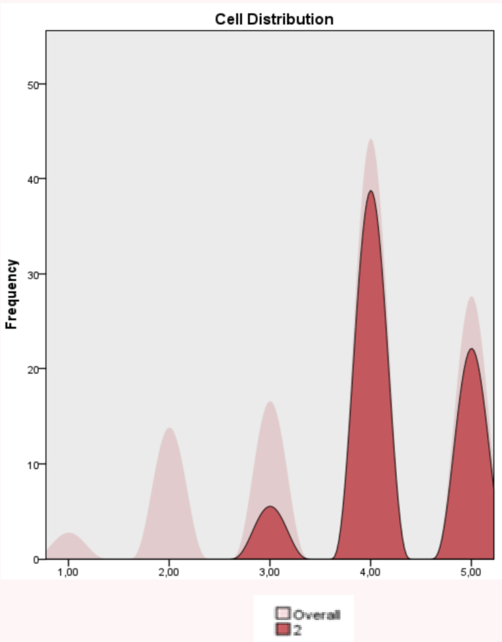
Table 3. Cont'd

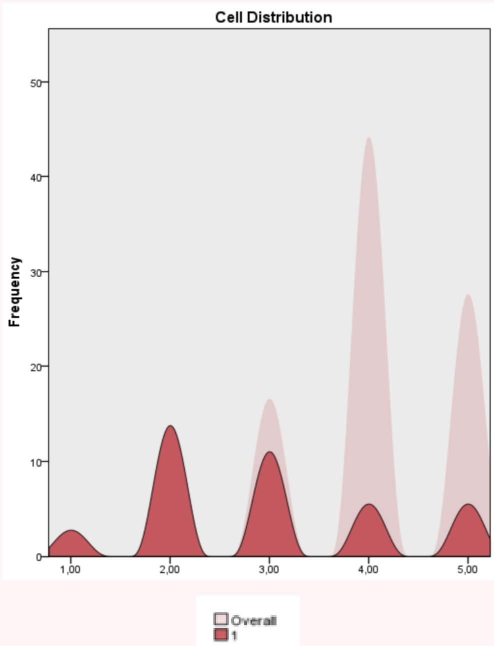
K1 The company has sufficient knowledge about the concept of sustainability





K4 The production facility is structurally suitable for environmental sustainability





4.3. Factor analysis

Factor analysis is a statistical method in which factors are created by combining variables that are related to each other but largely independent of other subsets of variables [45]. In this study, the variables listed in Table 1 were used to assess environmental sustainability in buildings, focusing on the companies and managers. Before performing factor analysis, the suitability of the data for both the company and manager awareness was assessed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. The purpose of the KMO test is to determine how well the other variables can predict a given variable. The sample adequacy (MSA) should fall between 0 and 1, with a value closer to 1 indicating higher reliability of the test. The correlation between the variables is examined using Bartlett's test, which must be statistically significant ($p < 0.05$) for the test to be valid, meaning the value must be less than 0.05 [46].

In this study, factor analysis was performed using SPSS 30.0.0 [44]. The extraction method used was Principal Component Analysis, and the rotation method was Varimax with Kaiser Normalization. Additionally, the alignment of the factors with Group 1 (Buildings not constructed in accordance with environmental sustainability) and Group 2 (Buildings constructed in accordance with environmental sustainability) was determined by the ratio of survey responses with values of 4 and 5 for each variable.

4.3.1. Factor analysis for the company's awareness of environmental sustainability in buildings

In this study, the company's awareness of environmental sustainability in buildings was assessed, and the KMO value was found to be 0.871. The Bartlett test yielded an Approximate Chi-Square value of 447.6, with a significance level of $p < 0.001$.

Table 4 shows the number of factors created for the company's environmental sustainability awareness and the variances of these factors. As shown in this table, two factors were identified for the company's awareness of environmental sustainability in buildings. According to Table 5, six variables are defined for both factors. This table shows the loading of each variable on the respective factor. The first factor (Suitability Potential) accounts for 68.70% of the total variance. The highest portion of the company's environmental sustainability awareness in buildings is associated with this factor. The most important variable in this factor is "Investment in solar energy systems (C3, factor loading: 0.835)." Table 6 shows the compliance rates of each variable and group for the manager's environmental sustainability awareness. The suitability rate for Group 2 is 66.7%, while for Group 1, it is 7.1% (Table 6). Other significant variables in this factor are "Suitability for solar panels (C2, factor loading: 0.826)" and "Activities for clean energy (C4, factor loading: 0.818)." The suitability rates for these variables in Group 2 are 79.2% and 70.8%, respectively, while for Group 1, they are both 21.4%. The average suitability rate for this factor is 81.3% for Group 2 and 22.6% for Group 1 (Table 6).

The second factor (Rainwater Management) accounts for 8.05% of the total variance (Table 4). The most important variable in this factor is "Information on the use of rainwater (C11, factor loading: 0.894)." The suitability rate for Group 2 is 83.3%, while for Group 1, it is 35.7% (Table 6). Another important variable in this factor is "Information on regulations related to rainwater collection, storage, and discharge systems (C12, factor loading: 0.857)." The suitability rate for Group 2 is 70.0%, and for Group 1, it is 28.6%. The average suitability rate for this factor is 77.8% for Group 2 and 26.2% for Group 1. Details for other variables are provided in Tables 5 and 6.

4.3.2. Factor analysis for manager's environmental sustainability awareness in buildings

In this study, the Kaiser-Meyer-Olkin (KMO) value for the manager's environmental sustainability awareness in buildings was found to be 0.853. The Bartlett's Test yielded an Approximate Chi-Square value of 452.3, with a significance of $p < 0.001$.

Table 4. Total variance explained

		Factor	
		1	2
Initial Eigenvalues	Total	8.25	0.97
	% of Variance	68.70	8.05
	Cumulative %	68.70	76.75
Extraction Sums of Squared Loadings	Total	8.25	0.97
	% of Variance	68.70	8.05
	Cumulative %	68.70	76.75
Rotation Sums of Squared Loadings	Total	4.90	4.31
	% of Variance	40.84	35.91
	Cumulative %	40.84	76.75

Table 5. Factor analysis results for the company

	Factor	
	Suitability Potential	Rainwater Management
C3	0.835	
C2	0.826	
C4	0.818	
C10	0.712	
C1	0.698	
C5	0.653	
C11		0.894
C12		0.857
C9		0.783
C6		0.712
C7		0.687
C8		0.637

Table 6. Suitability values of groups according to factors

	Sustainability Awareness of the Company in Buildings	Compliance rate %	
		Group 2	Group 1
Suitability Potential	C3	66.7	7.1
	C2	79.2	21.4
	C4	70.8	21.4
	C10	91.7	35.7
	C1	95.8	28.6
	C5	83.3	21.4
	Mean	81.3	22.6
Rainwater Management	C11	83.3	35.7
	C12	75.0	28.6
	C9	79.2	14.3
	C6	87.5	28.6
	C7	70.8	21.4
	C8	70.8	28.6
	Mean	77.8	26.2

Table 7 shows the number of factors created for the manager's environmental sustainability awareness and the variances of these factors. As seen in this table, two factors were identified for the manager's environmental sustainability awareness in buildings. According to Table 8, the first factor (Knowledge and Awareness) includes 7 variables, while the second factor contains 4 variables. This table shows the loading of each variable on the respective factor. The first factor corresponds to 63.32% of the total variance. The majority of the manager's environmental sustainability awareness in buildings is attributed to this factor. The most significant variable in this factor is "Information on the planning phase and timing of sustainable systems (M10, factor loading: 0.920)" (Table 8). The suitability rate for this variable in Group 2 is 91.7%, while in Group 1, it is 21.4% (Table 9). Other important variables in this factor are, in order, "Information on the depreciation period of sustainable systems (M8, factor loading: 0.860)" and "Information on the processes of installing solar panels (M1, factor loading: 0.837)" (Table 8). The suitability rates for these variables in Group 2 are 83.3% and 83.3%, respectively, while in Group 1, they are 35.7% and 21.4%. The average compatibility rate for this factor is 86.9% for Group 2 and 31.6% for Group 1.

The second factor (Perception of Impact) accounts for 15.44% of the total variance (Table 7). The most significant variable in this factor is "Clean energy has positive contributions to the economy (M6, factor loading: 0.967)." Another important variable in this factor is "Clean energy has positive effects on the environment (M5, factor loading: 0.963)." The suitability rates for these two variables in Group 2 are 95.8%, while in Group 1, they are 57.1% (Table 9). The average compatibility rate for this factor is 94.8% for Group 2 and 55.3% for Group 1. Further details on the variables are presented in Table 8 and Table 9.

4.4. Relative Importance Index (RII)

This method compares the maximum importance reached by each criterion with other variables based on the participants' responses [46]. This method has been used in past studies related to the construction sector and is considered an effective technique [47-52]. In the studies, the importance index has been calculated separately according to Equation (1).

Table 7. Total variance explained

		Factor	
		1	2
Initial Eigenvalues	Total	6.97	1.70
	% of Variance	63.32	15.44
	Cumulative %	63.32	78.75
Extraction Sums of Squared Loadings	Total	6.97	1.70
	% of Variance	63.32	15.44
	Cumulative %	63.32	78.75
Rotation Sums of Squared Loadings	Total	4.56	4.11
	% of Variance	41.41	37.34
	Cumulative %	41.41	78.75

Table 8. Factor analysis results for the manager

	Factor	
	Knowledge and Awareness	Perception of Impact
M10	0.920	
M8	0.860	
M1	0.836	
M9	0.799	
M3	0.768	
M4	0.676	
M11	0.488	
M6		0.967
M5		0.963
M7		0.857
M2		0.792

Table 9. Suitability values of groups according to factors

	Sustainability Awareness of the Manager in Buildings	Compliance rate %	
		Group 2	Group 1
Knowledge and Awareness	M10	91.7	21.4
	M8	83.3	35.7
	M1	83.3	21.4
	M9	95.8	42.8
	M3	87.5	35.7
	M4	79.2	21.4
	M11	87.5	42.9
	Mean	86,9	31,6
Perception of Impact	M6	95.8	57.1
	M5	95.8	57.1
	M7	95.8	50.0
	M2	91.7	57.1
	Mean	94.8	55.3

$$\text{RII} = \frac{\sum W}{A * N} \tag{1}$$

In this context, W denotes the product of the frequencies of the weights assigned by the participants, A represents the highest possible weight on the scale, and N refers to the total number of participants.

Table 10 presents the results of the Relative Importance Index (RII) analysis conducted to evaluate companies' awareness of environmental sustainability in buildings, while Table 11 illustrates the corresponding results for managers.

Table 10. RII for company

		Group 2	Group 1
Suitability Potential	C3	0.77	0.41
	C2	0.83	0.56
	C4	0.79	0.53
	C10	0.92	0.63
	C1	0.89	0.60
	C5	0.83	0.57
	Mean	0.84	0.55
Rainwater Management	C11	0.86	0.67
	C12	0.80	0.63
	C9	0.83	0.61
	C6	0.84	0.63
	C7	0.82	0.61
	C8	0.82	0.60
	Mean	0.83	0.63

Table 11. RII for manager

		Grup 2	Grup 1
Knowledge and Awareness	M10	0.86	0.63
	M8	0.86	0.69
	M1	0.84	0.57
	M9	0.90	0.69
	M3	0.85	0.69
	M4	0.84	0.63
	M11	0.84	0.70
	Mean	0.86	0.66
Perception of Impact	M6	0.95	0.81
	M5	0.94	0.81
	M7	0.94	0.80
	M2	0.93	0.80
	Mean	0.94	0.81

Akadiri [49] classified RII values into five distinct levels: High (0.8 ≤ RII), High-Medium (0.6 ≤ RII < 0.8), Medium (0.4 ≤ RII < 0.6), Medium-Low (0.2 ≤ RII < 0.4), and Low (RII < 0.2).

In the present study, the RII values calculated for both companies and managers are reported in Table 10 and Table 11, respectively. These tables are structured based on the groups and factors identified through cluster and factor analyses. Furthermore, the average RII values were computed for each factor group within each cluster.

An examination of Table 10 reveals that, for Suitability Potential, Group 2 exhibits a high level of relative importance index (RII Mean: 0.84), whereas Group 1 demonstrates a medium level (RII Mean: 0.55). For Rainwater Management, Group 2 again shows a high level of relative importance (RII Mean: 0.83), while Group 1 attains a high-medium level (RII Mean: 0.63). The most significant variable in Group 2 was identified as "The economic contribution of rainwater harvesting" (C10, RII: 0.92), whereas in Group 1, it was "Knowledge about the applications of rainwater use" (C11, RII: 0.67).

According to Table 11, for Knowledge and Awareness, Group 2 was found to have a high level of relative importance index (RII Mean: 0.86), while Group 1 exhibited a high-medium level (RII Mean: 0.66). In Perception of Impact, both Group 2 (RII Mean: 0.94) and Group 1 (RII Mean: 0.81) demonstrated high levels of relative importance. For managers, the most significant variable in Group 2 was identified as “Clean energy has positive economic contributions” (M6, RII: 0.95). In Group 1, the most important variables were “Clean energy has positive economic contributions” (M6, RII: 0.81) and “Clean energy has positive environmental impacts” (M5, RII: 0.81).

5. Conclusions

In this study, the environmental sustainability awareness of companies operating in the construction sector and currently at the facility management stage of the building life cycle, as well as the managers employed by these companies, was evaluated. The main research question of the study is whether designing and constructing production facilities within the framework of environmental sustainability has an impact on the environmental sustainability awareness of companies and managers during the facility management phase.

To this end, a questionnaire was developed based on a literature review and expert opinions. This questionnaire was administered to 38 company managers operating in the construction sector across six different organized industrial zones. A cluster analysis was performed using general information on the environmental sustainability of the facility during the construction phase and the company's environmental sustainability practices. Based on the results, two distinct groups were identified: Group 1, representing structures not constructed in accordance with environmental sustainability principles, and Group 2, representing structures that were built in accordance with such principles.

Subsequently, factor analysis and Relative Importance Index (RII) analysis were conducted using the data set derived from the questionnaire items that assessed companies' and managers’ awareness of environmental sustainability. According to the results of the factor analysis, two factors were identified for both company and manager awareness (Tables 5 and 8). When examining the alignment of these factors with the identified groups, it was found that the explanatory power of the factors for company awareness was 22.6% and 26.2% for Group 1, and 81.3% and 77.8% for Group 2, respectively. For manager awareness, these values were 31.6% and 55.3% for Group 1, and 86.9% and 94.8% for Group 2 (Tables 6 and 9). These results indicate that constructing a building in accordance with environmental sustainability significantly influences the awareness of both companies and managers at the facility management stage in the construction sector.

The final analysis performed in the study was the Relative Importance Index (RII) analysis, which determines the order of importance of the variables. The results revealed that Group 1 had considerably lower RII values and levels compared to Group 2 in terms of environmental sustainability awareness (Table 10). The average RII values for both factors (Suitability Potential and Rainwater Management) also support this finding. In both groups, a variable related to rainwater was identified as the most important factor. The authors believe that this outcome is primarily influenced by recent amendments to the “Regulation on Amendments to the Zoning Regulation for Planned Areas.” This highlights the critical role of governmental regulations and policies in fostering environmental sustainability. Furthermore, while Group 2 prioritized the economic benefits of rainwater harvesting, Group 1 appeared to focus more on the informational aspects.

When this analysis is examined from the managers’ perspective, it was observed that the RII levels of managers in Group 1 and Group 2 were similar for Perception of Impact but differed significantly for Knowledge and Awareness (Table 11). Unlike companies, the managers in both groups identified variables related to clean energy as the most important. In particular, both groups emphasized the economic benefits of clean energy.

In summary, the overall findings of the analyses suggest that whether a building is constructed in accordance with environmental sustainability principles is a fundamental factor influencing the sustainability awareness of both companies and managers in the construction sector, particularly during the facility management phase of the building life cycle. Managers and companies in Group 2, where buildings were constructed sustainably, demonstrated higher awareness and RII values regarding environmental sustainability.

These findings underscore the importance of incorporating environmental sustainability considerations in the early stages of the building life cycle—especially during the design phase—to ensure full adoption of sustainability by companies and managers. In other words, it is evident that buildings designed and constructed within an environmental sustainability framework enhance the environmental sustainability awareness of companies and managers during the facility management phase. This result underscores the necessity of integrating environmental sustainability principles into the building life cycle starting from the design stage.

Moreover, the results indicate that regulations and policy interventions play a significant role in enhancing company-level awareness of environmental sustainability. Making environmental sustainability principles mandatory through legal regulations beginning at the design phase would constitute a critical step in this direction. In particular, incorporating solutions and practices that contribute to the building’s environmental sustainability during the operational phase into architectural design projects would significantly strengthen sectoral awareness. In this context, it is recommended that policymakers further strengthen sustainability-oriented building standards by expanding their scope beyond the enhancements introduced in 2026. Such policy measures would support environmental sustainability in the construction sector and contribute to the wider implementation of sustainability standards.

Moreover, in order to effectively mitigate the adverse impacts of climate change, it is particularly important for managers of facilities that were not originally designed in accordance with principles of environmental sustainability to prioritize training and practices that enhance sustainability awareness, thereby enabling the implementation of the most appropriate sustainability-oriented solutions for their facilities.

Although this study was conducted in a region (38 companies operating in six organized industrial zones within the Marmara Region) characterized by intensive industrial activity, its scope remains limited, which constitutes a primary constraint. Moreover, the absence of an open data inventory necessitated reliance on survey-based data collection, representing an additional limitation. Extending future research to include diverse regions and countries, coupled with the establishment of a comprehensive data inventory to support a robust database, would represent a critical advancement for promoting environmental sustainability.

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Author Contributions

T. Demir: Resources, Data Curation, Writing-Original draft, Writing- Review & Editing. E. Dobrucalı: Conceptualization, Methodology, Resources, Data Curation, Writing-Original draft, Writing- Review & Editing.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

The questionnaire survey procedures were approved by the Sakarya University Ethics Committee on November 20, 2024, number E-61923333-050.99-422136.

Conflict of Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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