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Research Article

Analyzing the knowledge and attitudes of architects in Türkiye on circular economy in the built environment

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ABSTRACT

The circular economy (CE) model offers solutions to prevent environmental and ecological degradation, aiming for sustainability. This study aims to analyze CE awareness among architects in Türkiye. A descriptive research approach was conducted using a structured survey to determine architects' awareness of CE principles and strategies in the built environment. Based on the survey data, explanatory research was undertaken to explore the relationships between variables, test the proposed hypotheses, and provide more precise insights. The study found that architects in Türkiye have a low level of knowledge about CE but demonstrate a high level of positive attitude towards CE. The knowledge gap is particularly pronounced among architects with undergraduate education. Furthermore, as architects' knowledge of CE increases, their attitude toward CE becomes more positive. The study also revealed that architects' work experience or their area of practice in architecture significantly influences their CE awareness. These findings suggest that the understanding of CE among architects in Türkiye could be substantially improved, particularly if architects with a bachelor's degree enhance their knowledge of CE. Universities, local authorities, NGOs, and other construction professionals can use this study's results to assess the current state of architects' CE awareness. The study sheds light on an underexplored area in the construction industry in Türkiye. It contributes to the CE literature in Türkiye by providing comprehensive information on architects' awareness of CE in the built environment.

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1. INTRODUCTION

In the construction sector, which accounts for a significant share of material and energy (resource) consumption as well as waste generation (construction, repair, and demolition waste) worldwide [1–4], the commonly used production and consumption approach is described as "take, make, waste" (Linear Economy). This approach, which has negative environmental impacts on the earth and ecosystem and threatens the Sustainability of the built environment, has been challenged by the Circular Economy (CE) model, which is gaining growing attention [5–10].

CE is a restorative and regenerative model designed to maintain products, components, and materials at their highest utility and value by differentiating between technical and biological cycles [11, 12]. The CE model incorporates a regenerative production and consumption process that minimizes raw material inputs, waste generation, car-

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Table 1. R frameworks with specific strategies developed to implement the CE model in different sectors

R Frameworks	Strategies	References
3 R	Reduce, Reuse, and Recycle	Kirchherr et al. [19]; Tserng et al. [74]
4 R	Reduce, Reuse, Remanufacture and Recycle	
5 R	Rethink, Reduce, Reuse, Repair and Recycle	Tserng et al. [72]
6 R	Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture	Wijewansha et al. [14]; Amudjie et al. [55]
9 R	Refuse, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover	
10R	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover	Reike et al. [20]; Vermeulen et al. [21]; Mrad & Ribeiro [24]

CE: Circular Economy.

bon dioxide emissions, and energy losses by slowing, narrowing, and closing material and energy cycles [13, 14]. This model provides innovative solutions to reduce waste and enhance product reuse in the construction sector, supporting sustainable building practices [15–18]. Researchers and practitioners have proposed various strategies for conceptualizing the CE model. These strategies, commonly known as "R Frameworks," provide a "structured and detailed approach to analyzing and implementing the model across various sectors [19–24] (Table 1).

The implementation in the construction sector, which is still in its early stages, has primarily focused on recycling construction and demolition (C&D) waste, with comparatively less emphasis on product reuse [25–28]. However, the construction sector holds significant potential for enabling the selection of environmentally friendly, durable, adaptable, and demountable products [4, 29, 30].

By integrating the CE model into the construction sector, buildings and components with high sustainability potential can be produced. A "Circular Building (CB)" can be defined as a sustainable building type designed and constructed according to Circular Economy (CE) principles and strategies, incorporating both technical and biological cycles to maintain buildings and their components at their highest value and longest lifespan. Circular Bumost Extended utilizes materials, components, and technologies that minimize natural resource and energy consumption while reducing waste generation and environmental impact throughout the entire lifecycle. A CB represents a building system designed to be developed, used, and reused without consuming unnecessary resources, polluting the environment, and degrading ecosystems [3]. Although knowledge and applications of CBs are still in their early stages, they are being researched and implemented in various countries.

Transforming the current linear economy paradigm in the built environment into a Circular Economy (CE) paradigm requires the active involvement of relevant stakeholders [31]. Architects are among the key actors who can significantly contribute to the implementation and advancement of the CE model in the building sector, helping to mitigate the negative impacts of the built environment [32, 33]. A building's capacity to recover products and reuse resources at the end of its lifecycle is strongly influenced by the decisions made by architects [34, 35]. As such, architects play a critical role throughout the building's lifecycle, including the design, construction, occupancy, and end-of-use phases.

A significant barrier to architects implementing Circular Economy (CE) principles in the built environment is their lack of awareness [28, 32, 36]. A sufficient level of CE awareness is essential for architects to effectively apply this new paradigm in the built environment and make informed decisions aligned with CE principles. In other words, for architects to successfully design and construct buildings in accordance not only be aware of CE but also care about and identify the strengths and weaknesses of CE awareness, better understand the challenges and barriers, address deficiencies, and improve current performance, it is crucial to thoroughly investigate and assess architects' knowledge of and attitudes toward CE. A review of the literature addressing the question, "What is the level of CE awareness among architects?" reveals various studies measuring the approaches of stakeholders (e.g., users, owners, architects, producers, etc.) toward CE in the production of the built environment, as well as their awarenesses, perceptions, opinions, and attitudes [10, 28, 37–54]. These studies generally address stakeholders' awareness of specific issues, such as demolition management and recycling, within the CE paradigm rather than comprehensively assessing awareness of CE principles and strategies. Some researchers suggest that awareness of CE among stakeholders in the built environment is moderate [32, 33, 55], and problems, such as limited knowledge about CE in practice, persist [28, 36]. Research also indicates that key barriers to implementing CE principles and strategies include a lack of incentives, insufficient legal regulations, and inadequate knowledge [28, 36].

The literature review found very few studies on CE awareness in the production of the built environment in Türkiye. A survey conducted with architecture students in Tekirdağ revealed that students' CE awareness was insufficient [56]. Another study on CE awareness in the İnegöl furniture sector suggested that the sector's awareness is limited and the full scope of CE is not sufficiently known [57]. However, these studies did not address the awareness of architects. In a survey study conducted to reach a general opinion on the awareness of architects in Istanbul regarding CE and CB, the data collected on the knowledge, attitudes, and behaviors of architects on this issue were reported as rate, percentage, frequency, and average [58]. However, presenting the awareness levels of architects on CE, a new and not very well-known model, using only descriptive statistical values is insufficient to understand the factors and reasons that are effective in the obtained results. Analyses and evaluations based on causal relationships between the relevant variables in determining the CE awareness of architects may help reveal the subject's problematic factors and explain these factors. Therefore, in this study, to measure the awareness levels of architects and identify deficiencies and inadequacies, a path that describes the relationship and interactions of their context with their knowledge and attitude levels was followed. Architects' demographic characteristics, such as age, education level, working time, and working area, maybe the context (variables) that affect and determine their knowledge and attitudes related to CE. Research on the relationship between awareness levels and demographic characteristics in various fields generally shows that demographic characteristics affect awareness [59–66]. These studies provide important insights into how demographic characteristics can affect people's levels of awareness and how the relationships between demographic characteristics and levels of awareness can change. Thus, this study was conducted within the framework of the hypothesis that the differences in the demographic characteristics of architects in Türkiye, such as their age, level of education, length of time working as an architect, and the areas in which they work as architects, may also lead to differences in their awareness of CE.

The main objective of this research is to identify the effects of architects' demographic characteristics on their knowledge and attitudes towards CE. The study analyzes the knowledge and attitudes of architects in Türkiye regarding CE, considering their demographic characteristics (age, education level, working period as an architect, working area as an architect). The study followed a method to measure architects' knowledge and attitude levels toward CE and explain the relationships between these levels and their demographic characteristics.

Within this framework, the study addresses the following questions:

1. Does the increase in the level of architects' knowledge about CE significantly increase the level of attitudes towards CE?
2. Does the age of the architects affect their CE knowledge level and attitude level?
3. Does the education level of architects affect their CE Knowledge level and CE Attitude level?
4. Does the working duration of architects as an architect affect their CE Knowledge level and CE Attitude level?
5. Does the working area of architects as an architect affect the CE Knowledge Level and CE Attitude Level?

The information obtained from the answers will be essential for architects, as decisive actors in the production of the built environment, to explore various aspects of CE and to improve their performance in implementing circular designs.

2. MATERIALS AND METHODS

2.1. Research Approach

A descriptive study assessed architects' knowledge and attitudes toward CE principles and strategies within the built environment. Data were collected through an online survey, employing a convenience sampling method to quickly and efficiently gather responses. Additionally, an explanatory research method was applied to uncover relationships between variables, test the proposed hypotheses, and identify root causes to provide comprehensive and accurate insights [67].

The descriptive research phase included face-to-face interviews with eight experienced architects from diverse professional backgrounds. Semi-structured questions were used to explore their awareness of Sustainability, circular economy (CE), and circular building (CB) concepts. These interviews aimed to identify gaps and refine the survey questions, generate new ideas, and support the development of an effective and well-structured online survey framework. Based on the insights from the interviews, two questionnaire scales were developed to measure architects' knowledge and attitudes toward CE. A comprehensive, structured survey was then conducted using these scales. During the scale development and survey design, a thorough literature review was undertaken to emphasize key CE principles and strategies relevant to the built environment.

The study collected data on architects' Level of Knowledge about CE and Level of Attitude toward CE. Simple Linear Regression analysis was performed to examine whether a significant relationship exists between these two variables. Subsequently, a Multivariate Analysis of Variance (MANOVA) test was conducted to evaluate the influence of demographic characteristics (e.g., age, education level, working period as an architect, and working area as an architect) on the Level of Knowledge and Level of Attitude variables, as well as the strength of these effects. Finally, the findings were analyzed to draw meaningful conclusions and provide actionable insights.

2.2. Research Model

In this study, which investigates the relationship and effect levels between variables, the research variables and hypotheses were formed based on a review of the literature, prevailing assumptions, and the context of the study:

Dependent Variables

- Level of Architects' Knowledge about CE (KLCE),
- Level of Architects' Attitude towards CE (ALCE).

Independent Variables

- Age of Architects,
- Education Levels of Architects,
- Working Period of Architects as Architect,
- Working Areas of Architects as Architect.

Research Hypothesis

H1: Increasing an architect's knowledge level score about CE significantly increases their attitude toward CE.

H2: The age of an architect significantly affects their KLCE and ALCE scores.

H3: The educational level of an architect significantly affects their KLCE and ALCE scores.

H4. The working period of an architect as an architect significantly affects their KLCE and ALCE scores.
H5: The working area of an architect as an architect significantly affects their KLCE and ALCE scores.
The research model is presented in Figure 1.

2.3. Population and Sample

The research population consists of the architects in Türkiye, with the sample comprising 220 architects registered with the TMMOB Chamber of Architects. As of 2023, the total number of architects registered with the TMMOB Chamber of Architects in Türkiye reached 80,789 [68]. Considering the confidence level of 85% and the margin of error of 5%, the sample of 220 registered architects is considered sufficient for the representation of the population of this study.

2.4. Data Collection Instruments

A structured survey was used as this study's primary data collection tool and administered online. The survey link was distributed to members via the TMMOB Istanbul Chamber of Architects website. On 29/08/2023, the survey was sent to 3,399 members, and in 2023, it was sent to add members. The survey was also shared with all faculty members of the Department of Architecture at MSGSU and several social groups comprising architects. Ethical approval for the survey was obtained, and the details are shared in the Acknowledgements section.

The survey is divided into three sections: demographic characteristics of the architects, their level of knowledge about their attitude toward developing the survey data developed using face-to-face interviews with architects, and an extensive literature review. Furthermore, the survey items were developed with input from experts in survey design. While creating the scale items, it was prioritized to measure the awareness of CE principles and concepts during the life cycle of a building. The first step involved analyzing the CE principles and strategies throughout the life cycle of a building (Table 1) [10, 11, 19, 28, 55, 69–76]. The CE principles, strategies, and concepts derived from the literature are summarized in Table 2.

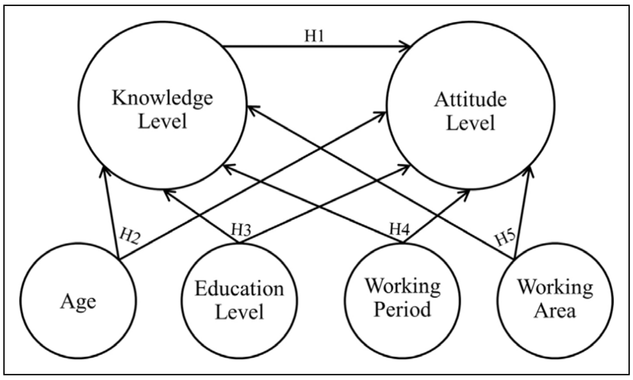

Figure 1. The research model.

In this study, two survey scales were developed to determine the knowledge and attitudes of architects towards CE: Scale for Determining Architects' Level of Knowledge about CE (KLCE Scale) and Scale for Determining Architects' Level of Attitudes Towards CE (ALCE Scale).

2.5. Scale for Determining Architects' Level of Knowledge about CE (KLCE Scale)

The KLCE scale consists of items that determine the architects' knowledge of CE. In developing these items, the basic concepts of the CE model about the built environment were prioritized. First, the CE principles and strategies that can be applied in the life cycle of the building (Table 2) were analyzed, and based on this, basic CE concepts that can explain the subject of CE and are suitable for the research context were identified. Then, based on the face-to-face interviews with the architects, a KLCE scale was developed. The scale consists of 8 items that address CE concepts and measure architects' knowledge of relevant CE principles and strategies. The KLCE scale includes closed-ended items, each offering six response options. Five of these options use a Likert scale, while a "no answer" option was provided for participants who chose not to respond.

A total of 220 architects participated in the survey. Exploratory Factor Analysis (EFA) was conducted to assess the construct validity and factor loadings of the KLCE scale—

Table 2. Key CE principles and strategies that can be considered at different stages of the building life cycle

Life Cycle Stage	Principles And Strategies
Building Design Phase	Design for disassembly; Design for flexibility and adaptability; Waste-free design; Modular design; Use of second-hand (recovered) products in design; Use of recycled materials in design.
Product Design and Production Phase	Minimum (less) use of materials; Optimization of material use; Minimum (less) use of hazardous/toxic materials; Life extension/durability; Design for product disassembly; Product standardization; Reuse of products.
Building Construction/ Assembly Phase	Minimization of construction waste; Procurement of reused (second-hand) products; Procurement of recycled products.
Building/Product Use and Upgrading Phase	Minimization of construction waste; Minimal (less) maintenance of building and building products; Easy repair and improvement of building and building products; Flexibility/adaptability of building and building products.
Building/Product End-of-Use Phase	Minimization of constructional waste; Deconstructability of the building; Dismountability of products; Reuse of products; Recycling of products.

CE: Circular Economy.

Table 3. Results of factor loading analysis of the KLCE scale

	Items	Factor Loadings
K1	My knowledge of the Circular Economy	0.642
K2	My knowledge of flexible/adaptable building	0.732
K3	My knowledge about easy and undamaged dismantling (disassembly) of building	0.769
K4	My knowledge about the reuse of building elements/components	0.825
K5	My knowledge about processing and recycling of building components/materials	0.834
K6	My knowledge about the building is that it requires minimal maintenance and can be easily repaired	0.812
K7	My knowledge about the building that generates mini construction waste	0.809
K8	My knowledge of recovery of construction sites	0.807
	Eigenvalue	**4.879**
	Variance Explained	**60.993**

KLCE: Level of Architects' Knowledge about CE.

the EFA process employed principal components analysis and direct noblemen rotation methods. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated as 0.903. A KMO value exceeding 0.90 is categorized as "excellent" for EFA suitability [77, 78]. Additionally, Bartlett's Test of Sphericity yielded $x^2(28)=1001.372$, $p<0.05$, indicating that the correlations among the items were sufficiently strong to justify conducting EFA.

The EFA results revealed that the KLCE scale, comprising eight items, had a unidimensional structure (single factor). This factor accounted for 60.993% of the total variance. According to the literature, a scale is considered to meet the conditions for EFA validity if the total variance explained exceeds 50% and the factor loadings of the items are more significant than 0.450 [79]. Based on the data obtained during the EFA process, it was concluded that the KLCE scale possesses valid psychometric properties. Table 3 presents the distribution of the KLCE scale items according to their respective factor loadings.

Cronbach's Alpha reliability analysis was performed to assess the reliability of the KLCE scale. The analysis study cited a reliability coefficient of $\alpha=0.906$ for the 8-item scale. According to George and Mallery [80], a Cronbach's Alpha value of $\alpha \geq 0.90$ is categorized as "excellent" reliability. Based on these findings, the KLCE scale is deemed a valid and reliable measurement tool. Table 3 presents the distribution of the KLCE scale items according to their respective factor loadings.

2.6. Scale for Determining Architects' Attitudes Towards CE (ALCE Scale)

The ALCE scale assessed architects' views and opinions on Circular Economy (CE) principles and strategies. The primary aim in developing the items was to capture architects' attitudes regarding the significance and necessity of integrating CE principles and strategies. To achieve this, the CE principles and strategies applicable throughout the entire life cycle of a building were first explored (Table 2). Based on these investigations, the core CE principles and strategies relevant to the research context were identified. Subsequently, through face-to-face interviews with architects and a review of pertinent literature, a 15-item ALCE scale was developed to measure architects' attitudes toward these CE principles and strategies. The ALCE scale consists of closed-ended items, each offering six response options. Five of these options are based on a Likert scale, and an additional 'no answer' option was provided for participants who did not wish to respond to a particular question.

A total of 220 architects participated in the survey, and exploratory factor analysis (EFA) was conducted to assess the ALCE scale's construct validity and factor loadings. The study employed principal components analysis and direct, oblique rotation methods. The results indicated that the scale would meet the validity criteria if four items (T9, T10, T11, and T12) were removed due to their overlap, low factor loadings, and insufficient total variance explained. For the remaining 11 items, the Kaiser-Meyer Olkin (KMO) sampling adequacy value was calculated. According to the literature, a KMO value of at least 0.500 is expected, and Tartlett's should yield a significant result ($p<0.05$) [79]. In this study, the KMO value for the ALCE scale was found to be 0.821, and Bartlett's Test was significant ($\chi^2(55)=697.077$, $p<0.05$). Thus, it was concluded that the scale met the sampling adequacy requirements. A KMO value between 0.800 and 0.900 indicates that the sampling adequacy is categorized as "Very Good" [77, 78].

The analysis revealed that the ALCE scale consisted of two sub-dimensions (factors): 'Caring (Factor 1)' and 'Preferring (Factor 2)' within the context of CE attitudes. The overall validity of the ALCE scale was determined to be 51.041. The sub-dimensional structure of the scale and the EFA results are presented in Table 4. Given that the construct validity exceeded 50% and the factor loadings of the items were more significant, outstanding 0.450, it more significantly concluded that the ALCE scale satisfied the EFA conditions [79].

Cronbach's Alpha reliability analysis was conducted to assess the reliability of the ALCE scale. The analysis revealed that the study coefficient for the 11 items of the scale was $\alpha=0.782$. According to George and Mallery [80], a Cronbach's Alpha value between 0.700 and 0.900 indicates the iteration, suitable means, and its sub-dimension added as a reliable requirement tool.

Table 4. Results of factor analysis of the ALCE scale

	Items	Factor 1	Factor 2
A1	Buildings and building elements/components must be Flexible/Adaptable	0.705	
A2	The buildings and building elements/components must be undamaged and easily dismantled	0.584	
A3	Buildbuilding elements/components must be reusable for the same or different purposes at the end of their service (use) period.	0.726	
A4	It is essential that building components/materials must be processed and recyclable for the same or different purposes at the end of their service life.	0.756	
A5	In selecting building components/materials, it is essential to prefer those that are recyclable (do not contain toxic/harmful substances and can be decomposed).	0.764	
A6	Buildings and elements/components must require minimal maintenance and are easy to repair.	0.677	
A7	Architects must play an active role in the implementation of circular building principles such as "Flexibility/Adaptability," "Easy Dismantling," "Reuse," "Recycling," "Easy Maintenance-Repair," and "Minimum Constructional Waste Generation."	0.705	
A8	It is essential that compulsory courses on circular building principles such as "Flexibility/Adaptability," "Easy Dismountability," "Reuse," "Recycling," "Easy Maintenance-Repair," and "Minimum Structural Waste Generation" must be given in architecture departments in Türkiye.	0.664	
A13	I prefer modular design based on element/component dimensions and standards to prevent crushing and cutting wastes.		0.702
A14	In selecting the elements components, I prefer the longevity (durability) of the elements/components to the aesthetics.		0.735
A15	In selecting components, I prefer the longevity (durability) of the elements/components over their cheapness.		0.788
	Eigenvalue	**4.013**	**1.601**
	Variance Explained	**36.483**	**14.558**
	Total Variance Explained	**51.041**	

ALCE: Level of Architects' Attitude towards CE.

In conclusion, the KLCE and ALCE scales, developed for analyzing the relevant data, are considered valid and reliable instruments for testing the hypotheses and achieving the research objectives.

2.7. Data Analysis

In this study, the data collected using the KLCE and ALCE scales were analyzed independently and about demographic characteristics using IBM SPSS-25 software. After developing the scales, the relationships and effects of the dependent variables—both among themselves and the independent variables—were analyzed to test the research hypotheses.

The survey included a 'No Answer' option for participants who did not wish to respond to specific questions. This option was included in the data analysis to preserve the integrity of the dataset and minimize the impact of extreme values. For items utilizing a 5-point Likert scale, the 'No Answer' response was coded as 3, corresponding to 'Undecided' in the dataset. For the demographic items (independent variables), the 'No Answer' responses were assigned the mean value of the relevant variable in the dataset.

After calculating the mean scores for the items in the KLCE and ALCE scales, the normality of the scale data was assessed. In the survey with 220 participants, the normality test revealed that the ALCE scale values were outside the acceptable range of +1 to -1. Consequently, the 5 participants with extreme values were removed from the dataset, and the normality test was performed on the remaining 215 participants. The skewness value for the KLCE scale was 0.896, and the kurtosis value was 0.698. The skewness value for the ALCE scale was -0.575, and the kurtosis value was -0.341. Based on these results, it was concluded that the data from the 215 participants followed a normal distribution [80]. Given the normal distribution of the data, parametric analyses were chosen to test the study's hypotheses.

3. RESULTS AND DISCUSSION

3.1. The Effect of KLCE on ALCE (H1)

A simple linear regression analysis was conducted to test hypothesis H1 (whether an increase in an architect's knowledge of CE significantly improves their attitude toward it).

This analysis aimed to determine whether the independent variable, KLCE, significantly influences the dependent variable, ALCE, and to assess the strength of this effect. The results of the analysis are presented in Table 5.

As shown in Table 5, the model was found to be significant ($p<0.05$), with the independent variable explaining 5% of the variance in the dependent variable ($R^2=0.050$). Therefore, it was concluded that KLCE had a statistically significant but weak effect on ALCE [79]. The regression

Table 5. Results of regression analysis showing the effect of KLCE on ALCE

Dependent Variable	Independent Variable	Unstandardized Coefficients		Standardize Coefficients			95% Confidence Interval for b	
		b	Std. Error	β	t	p	Lower	Upper
ALCE	(Constant)	47.058	0.903		52.097	0.000	45.278	48.839
	KLCE	0.107	0.032	0.225	3.363	0.001	0.044	0.170

Note(s): n=215; F(1, 213)= 11,307, p=0.001; R^2=0.050; Durbin-Watson= 1.732; Cook's Distance 0.000 to 0,111; Std. Residual -2.642 to 2-202. KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

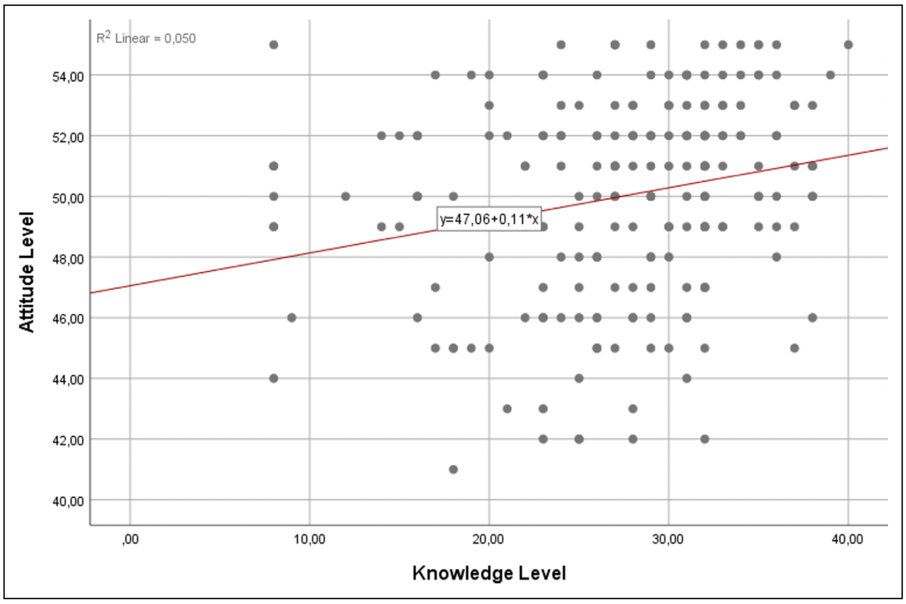

Figure 2. Results of regression analysis showing the effect of KLCE on ALCE.

KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

equation between KLCE and ALCE was determined to be y=47.06 + 0.11 * x. According to this equation, for each 1-unit increase in KLCE, ALCE increases by 0.11 units. Within the 95% confidence interval, a 1-unit increase in KLCE also results in an iLCE ranging from 0.044 to 0.170 units. The relationship between the two variables is also depicted in Figure 2.

Based on the regression analysis findings, the level of architects' knowledge about CE has a statistically significant but weak effect on their attitude towards CE. Consequently, hypothesis H1 was accepted, and it was concluded that only 5% of the architects' attitudes toward CE were attributed to their knowledge of CE. This suggests that architects with higher CE knowledge will exhibit a positive but weak attitude towards CE.

3.2. The Effect of Age on KLCE and ALCE (H2)

To test hypothesis H2 (The age of an architect significantly affects their KLCE and ALCE scores), a MANOVA test was conducted using one independent variable (Age) and two dependent variables (KLCE and ALCE). This analysis aimed to determine whether age significantly affects KLCE and ALCE scores and to assess the strength of any observed effects. The results of the test are presented in Table 6.

Table 6 indicates a significant difference (p=0.038) in the KLCE means based on the age of the architects (independent variable). The Partial Eta-Squared (ηp^2) value, calculated to determine the effect size, was 0.047. According to the literature, $\eta p^2 \approx 0.0099$ is considered a small effect, $\eta p^2 \approx 0.0588$ a moderate effect, and $\eta p^2 > 0.1379$ a significant effect [81, 82]. Based on these benchmarks, the analysis revealed that age has a substantial and moderate effect on their level of knowledge about CE.

However, the Gabriel post-hoc analysis results, conducted to identify specific age group differences in KLCE means, showed that the significant difference was only between architects in the 46–55 age group and those in the 26–35 age group. Specifically, architects in the 46–55 age group had a higher KLCE mean than those in the 26–35 age group (mean difference=4.5578, p=0.036). No significant differences were observed between the KLCE means of other age groups.

Table 6 also shows no significant differences in ALCE means based on the age of the architects (p=0.238). This indicates that architects' attitudes towards CE are not influenced by age, and age does not affect ALCE scores.

The analysis indicates that age partially influences the level of knowledge about CE (KLCE) but does not affect attitudes toward CE (ALCE).

Table 6. MANOVA results showing the effect of Age on KLCE and ALCE scores

Effect	Dependent Variable	Age	n	Mean	sd	df	F	p	Significant Difference	η_p^2
Age	KLCE	20-25 Years	39	26.54	7.33	4	2.588	0.038	–	0.047
		26-35 Years	76	26.36	7.17					
		36-45 Years	31	28.97	5.55					
		46-55 Years	23	30.91	5.50					
		55 Years or Above	46	27.11	6.94					
	ALCE	20-25 Years	39	49.69	3.58	4	1.390	0.238	–	0.026
		26-35 Years	76	49.61	3.58					
		36-45 Years	31	49.90	3.00					
		46-55 Years	23	50.04	3.18					
		55 Years or Above	46	50.98	2.66					

Note(s): KLCE max. Score 40, ALCE max. score 55; Box's test p=0.299; Leven's test p=0.313 for KLCE and p=0.093 for ALCE; Pillai's Trace test p=0.043. MANOVA: Multivariate Analysis of Variance; KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

Table 7. MANOVA results showing the effect of Education Level on KLCE and ALCE scores

Effect	Dependent Variable	Education Level	n	Mean	sd	df	F	p	Significant Difference	η_p^2
Education Level	KLCE	Undergraduate	109	25.98	7.29	3	6.332	0.000	PhD> Undergraduate; Master> Undergraduate	0.083
		Master	61	29.62	6.04					
		PhD	20	30.80	5.51					
		No Answer	25	25.56	5.70					
	ALCE	Undergraduate	109	49.97	3.46	3	0.327	0.806	–	0.005
		Master	61	50.25	2.76					
		PhD	20	50.10	3.31					
		No Answer	25	49.48	3.82					

Note(s): KLCE max. Score 40, ALCE max. score 55; Box's test p=0.222; Leven's test p=0.249 for KLCE and p=0.075 for ALCE; Pillai's Trace test p=0.005. MANOVA: Multivariate Analysis of Variance; KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

3.3. The Effect of Education Level on KLCE and ALCE (H3)

To test hypothesis H3 (The education level of an architect significantly affects their KLCE and ALCE scores), a MANOVA test was conducted using one independent variable (Education Level) and two dependent variables (KLCE and ALCE). This analysis aimed to determine whether education level significantly influences KLCE and ALCE scores and to evaluate the strength of any observed effects. The results of the test are presented in Table 7.

Table 7 indicates significant differences (p=0.000) in the KLCE means based on the education levels of the architects (independent variable). The Partial Eta-Squared (ηp^2) value, which measures the effect size, was calculated to be 0.083. According to established benchmarks, this suggests that the education level of architects has a significant and moderate effect on their knowledge level about CE [81, 82].

However, post-hoc analysis using the Gabriel test, conducted to identify specific differences between education level groups, revealed no significant difference between the mean KLCE scores of the PhD and Master's groups (p=0.979). Significant differences were observed only between the undergraduate PhD and Master's groups. Specifically, the PhD and Master's groups had higher KLCE mean scores than the Undergraduate group (PhD vs. Undergraduate mean difference=4.8183, p=0.009; Master vs. Undergraduate mean difference=3.6413, p=0.004).

Table 7 also shows no significant differences in the ALCE means based on the education levels of the architects (p>0.05). This indicates that architects' attitudes towards CE are not influenced by their education level, and education level does not affect ALCE scores.

As a result, the analysis reveals that the education level of architects significantly impacts their knowledge level about CE (KLCE). Still, it has no significant relationship with attitudes towards CE (ALCE). As such, hypothesis H3 is not accepted.

3.4. The Effect of Working Period on KLCE and ALCE (H4)

To test hypothesis H4 (The working period of an architect as an architect significantly affects the effects their MANOVA test was conducted with one independent vari-

Table 8. MANOVA results showing the effect of the Working Period on KLCE and ALCE scores

Effect	Dependent Variable	Working Period as Architect	n	Mean	sd	df	F	p	Significant Difference	η_p^2
Working Period as Architect	KLCE	1-4 Years	60	26.05	7.48	4	3.771	0.006	(10-20 Years) > (No Answer); (Above 20 Years) > (No Answer)	0.067
		5-9 Years	35	27.37	7.07					
		10-20 Years	32	29.81	5.49					
		Above 20 Years	62	28.84	6.46					
		No Answer	26	24.27	6.23					
	ALCE	1-4 Years	60	49.55	3.19	4	2.224	0.068	–	0.041
		5-9 Years	35	50.23	3.68					
		10-20 Years	32	50.44	3.23					
		Above 20 Years	62	50.66	2.79					
		No Answer	26	48.65	3.84					

Note(s): KLCE max. score 40, ALCE max.s core scorebox's scorebox's5 score ven's test p=0.458 for KLCE and p=0.042 for ALCE; Pillai's Trace test p=0.012. MANOVA: Multivariate Analysis of Variance; KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

Table 9. MANOVA results showing the effect of Working Area on KLCE and ALCE scores

Effect	Dependent Variable	Working Area as Architect	n	Mean	sd	df	F	p	Significant Difference	η_p^2
Working Area as Architect	KLCE	Public Organisation	19	29.68	6.38	5	2.154	0.060	–	0.049
		Private Organisation	72	27.11	6.34					
		Own Company	61	28.49	7.04					
		Mixed/Different	18	28.83	6.71					
		Not Working	28	24.71	7.68					
		No Answer	17	25.24	6.71					
	ALCE	Public Organisation	19	49.32	4.07	5	1.141	0.340	–	0.027
		Private Organisation	72	49.99	3.22					
		Own Company	61	50.74	2.99					
		Mixed/Different	18	49.94	3.28					
		Not Working	28	49.25	3.09					
		No Answer	17	49.53	3.95					

Note(s): KLCE max. score 40, ALCE max .score 55; Box's test p=0.4 40; Leven's test p=0.810 for KLCE and p=0.314 for ALCE; Pillai's Trace test p=0.126. MANOVA: Multivariate Analysis of Variance; KLCE: Level of Architects' Knowledge about CE; ALCE: Level of Architects' Attitude towards CE.

able (Working Period) and two dependent variables (KLCE and ALCE). This analysis aimed to determine whether the working period significantly affects KLCE and ALCE scores and assess the effects of the fed. The results of the test are presented in Table 8.

Table 8 shows significant differences (p=0.006) in the KLCE means based on the working period of the architects (independent variable). The Partial Eta-Squared (ηp^2) value, used to measure the effect size, was calculated to be 0.067. This suggests that the working period of architects has a significant and moderate effect on their Level of Knowledge about CE [81, 82].

However, post-hoc analysis using the Gabriel test, conducted to identify specific differences between working period groups, revealed significant differences only between the "10-20 Years" and "Above 20 Years" groups and the "No Answer" group. Specifically, architects in the "10-20 Years" and "Above 20 Years" groups had higher KLCE mean scores than those who chose the "No Answer" option (mean difference for "10-20 Years" - "No Answer"=5.5433, p=0.019; mean difference for "Above 20 Years" - "No Answer"=4.5695, p=0.032). No significant differences were observed between the KLCE means of other working period groups. Given that there were significant differences only among architects who selected the "No Answer" option, and considering the uncertainty regarding the working period of these architects, this important difference was not accepted in the study.

Table 8 also indicates that significant differences in ALCE means are based on the architects' working years, which is 0.05. This suggests that architects' attitudes towards CE are not influenced by their working experience. The length of the working period does not affect the results.

As a result, the analysis reveals that the working period of the architects significantly affects their Level of Knowledge about CE (KLCE), but it has no. Still, itnship with their L—still Attitude towards CE (ALCE). Therefore, hypothesis H4 is not accepted.

3.5. The Effect of Working Area on KLCE and ALCE (H5)

To test hypothesis H5 (The working area of an architect as an architect significantly affects their KLCE and ALCE scores), a MANOVA test was conducted with one independent variable (Working Area) and two dependent variables (KLCE and ALCE). This analysis aimed to determine whether the working area significantly affects KLCE and ALCE scores and, if so, to assess the strength of any observed effects. The results of the test are presented in Table 9.

Table 9 indicates no significance ($p>0.05$) between the KLCE and ALCE means based on the working area of the architects as an architect. This suggests that architects' knowledge about CE and their attitude towards CE are not influenced by their working area, and the working area does not affect KLCE and ALCE scores.

As a result, the analysis shows that neither the level of knowledge about CE nor the attitude towards CE is related to the working area of architects. Based on these results, hypothesis H5 is not accepted.

4. CONCLUSIONS

The Circular Economy (CE) model aims to promote Sustainability by providing solutions that minimize environmental and ecological degradation. In the built environment, architects can play a crucial role in reducing the ecological damage primarily caused by the construction industry.

However, to effectively perform this role, architects must possess the necessary awareness (both knowledge and attitude) to implement the CE model, a new paradigm within the built environment. A comprehensive understanding of architects' CE awareness is vital to identify their strengths and weaknesses, understand existing challenges and barriers, and improve their performance by addressing the gaps in their knowledge and practices.

This study evaluated CE awareness among architects in Türkiye. There is a gap in the literature regarding comprehensive studies that explore architects' awareness of CE and their demographic characteristics. Therefore, the primary objective of this study was to determine the knowledge and attitudes of architects toward CE principles and strategies in the built environment. The study focused on two awareness variables (knowledge and attitude) and five demographic variables (age, education level, working period, and working area). Based on this framework, five hypotheses were formulated to guide the study.

The first step involved developing a reliable and valid scale to measure architects' knowledge and attitudes regarding CE. Using this scale, a survey was conducted among architects in Türkiye, and the collected data revealed the levels of their knowledge and attitudes toward CE. The findings showed that although most architects acknowledge the importance of CE, their knowledge remains relatively low. This suggests that although architects adopt CE principles, their knowledge is not sufficiently reflected in their preferences and practices. To address this gap, educational institutions and relevant organizations should focus on creating programs that educate architects about CE and equip them to apply this knowledge in their projects effectively.

After determining the knowledge and attitude levels, the study explored the factors and reasons behind these results. It examined the relationships between the two awareness variables and the significant effects of various demographic characteristics on knowledge and attitudes levels.

The findings of this study provide valuable insights into the role of architects in advancing CE within the built environment in Türkiye. The research observed that while architects care about and adopt CE, they lack sufficient knowledge to translate these attitudes into action. Therefore, future research could investigate the barriers preventing architects from translating their strong interest in CE into practice by enhancing their knowledge.

4.1. General Implications

- Correlation between Knowledge and Attitude: Increased knowledge of CE among architects has a slight but significant positive impact on their attitude toward CE, making them more likely to successfully implement it in their professional practice.
- Age and CE Knowledge and Attitude: Architects aged 46-55 had higher CE knowledge than those aged 26-35, with no significant differences in other age groups or attitudes. Age partially affects knowledge but not attitudes. Increasing knowledge, especially for architects under 45, could enhance CE implementation in Türkiye's construction sector.
- Education Level and CE Knowledge and Attitude: Architects with doctoral or master's degrees had higher CE knowledge than those with undergraduate degrees. However, no significant differences were found between doctoral and master's holders or in attitudes based on education. Education level affects knowledge but not attitudes. Raising architects' education levels could help overcome barriers to CE implementation in Türkiye's construction sector.
- Working Period and CE Knowledge and Attitude: Architects with over 10 years of work experience had higher CE knowledge than those who selected "No Answer," but no significant differences were found among the other working period groups. Knowledge and attitudes toward CE were not significantly influenced by professional experience, indicating that CE awareness is independent of tenure in architecture.

- Working Area and CE Knowledge and Attitude: The study revealed that architects' knowledge and attitudes regarding CE are not influenced by their working areas.

4.2. Future Directions

Stakeholder Engagement: The findings of this study can be beneficial for various stakeholders, including governments, universities, local authorities, NGOs, and other building professionals. These groups can use the insights to evaluate the current state of CE awareness among architects and identify areas for improvement. Moreover, the study can serve as a foundation for future research on CE in Türkiye and inform policy decisions to promote Sustainability in the construction industry.

Addressing Knowledge Gaps: Although architects express interest in CE and its importance, they often lack the knowledge necessary to apply it, i.e., This research underscores the need for further investigation into the barriers preventing architects from converting their positive attitudes into actionable knowledge. Identifying these barriers will be critical for creating targeted interventions.

Education and Training: One of the most effective ways to bridge the knowledge gap is through education. The study highlights the importance of integrating CE principles into architectural education, particularly at the undergraduate level. Including CE-related courses in degree programs would provide future architects with the necessary tools to understand and apply these principles. Additionally, architecture students could be encouraged to participate in pro focusing on CE strategies, offering hands-on experience with sustainable design practices.

Professional Development: To further enhance architects' knowledge and attitudes towards CE, organizing interactive learning opportunities such as field studies, seminars, workshops, and collaborative projects is essential. These initiatives would provide architects with practical knowledge and exposure to CE principles, helping to foster a culture of Sustainability within the profession.

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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.

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