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Article

Development and Validation of Carbon Footprint Awareness Scale for Boosting Sustainable Circular Economy

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Abstract: This study aims to create and validate the Carbon Footprint Awareness Scale, which is designed to measure individuals' awareness of their environmental impact through greenhouse gas emissions and represented as carbon dioxide equivalents. The scale consists of 19 items on a 5-point Likert scale, which are organized around five key areas: transportation (3 items), fuel consumption (3 items), electricity use (5 items), food consumption (5 items), and waste management (3 items). Expert evaluations and a pilot study confirmed the content validity of the scale. A sample of 553 Gen Z participants was analyzed using reliability testing, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) with AMOS and SPSS to establish the scale's construct validity and reliability. The results show a solid factor structure with good internal consistency (Cronbach's alpha = 0.86) and an explained variance of 56.09%. A second sample (n = 612) was used to confirm the findings, further supporting the scale's psychometric robustness and effectiveness in evaluating carbon footprint awareness in individuals aged 18 and over. This innovative tool not only supports rigorous scientific inquiry into individual carbon footprints but also empowers individuals to play an active role in global efforts to mitigate climate change. By fostering awareness, informing decision making, and promoting sustainable behaviors, the Individual Carbon Footprint Scale contributes to building resilience and sustainability in communities worldwide, ensuring a healthier planet for present and future generations.

Keywords: carbon footprint awareness scale; greenhouse gas emissions; individual carbon footprints; carbon scale development; sustainable circular economy

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1. Introduction

Climate change poses an increasingly urgent threat to global ecosystems, human health, and socio-economic stability [1]. Mitigating this multifaceted challenge necessitates collaborative action across all sectors of society, from individual lifestyle choices to coordinated efforts by communities, businesses, and governments [2]. At the heart of effective climate action lies the need to understand and quantify individual contributions to carbon emissions, which is crucial for designing targeted mitigation strategies and fostering the widespread adoption of sustainable behaviors [3].

The concept of a carbon footprint, measured primarily in units of carbon dioxide equivalents, serves as a crucial indicator of the environmental consequences of human actions [4]. Understanding and mitigating these impacts are critical for achieving sustainable development goals and mitigating climate change effects. Therefore, the development of a reliable and validated scale to assess carbon footprint awareness represents a significant advancement in both research and practical applications. As well, the development and validation of the Individual Carbon Footprint Scale mark a pivotal advancement in environmental psychology and sustainability research. This standardized tool provides researchers with a systematic means to measure and compare individual carbon footprints across diverse demographic and geographic contexts [5]. It is imperative that researchers examining sustainability adopt a holistic approach, considering a range of factors including climate change, energy consumption, user waste production, and the advancement of manufacturing and recycling operations. In order to gain a comprehensive understanding of a given system, researchers should employ a range of sustainability indicators, including those that assess the carbon footprint [6]. By quantifying the environmental impacts of various activities such as transportation, energy consumption, dietary choices, and waste management, the Individual Carbon Footprint Scale enables nuanced investigations into the drivers of carbon emissions and their socioeconomic implications.

Validating the Individual Carbon Footprint Scale is critical to ensuring its reliability and validity as a robust measurement instrument. Rigorous psychometric analyses, including tests for reliability, validity, and factor structure, confirm the questionnaire's accuracy and consistency in assessing individual carbon footprints [7]. These validations enhance the credibility of research findings, supporting evidence-based decision making in policy formulation and practical applications aimed at reducing carbon emissions [8]. Furthermore, conducting cross-cultural validation studies ensures the questionnaire's applicability across different cultural settings, facilitating global comparisons and collaboration in sustainability research [9].

Beyond its utility in research and policy, the Individual Carbon Footprint Scale plays a pivotal role in empowering individuals to take meaningful action towards sustainability.

Developing an Individual Carbon Footprint Scale (ICFS) is important for several reasons [3]. An ICFS helps individuals understand the direct and indirect environmental impact of their lifestyle choices. By quantifying their carbon footprint, people can see how their daily activities, such as energy consumption, transportation, and diet, contribute to climate change [10].

As suggested by past studies, the scale can motivate people to adopt eco-friendlier behaviors by making the impact of their actions more tangible. Small changes, when multiplied across millions of individuals, can lead to significant reductions in overall carbon emissions [9].

Moreover, an ICFS educates people about the various sources of carbon emissions, not just from industrial activities, but also from everyday life. This broader understanding helps build a more climate-conscious society [7]. In fact, the widespread use of an ICFS can increase public discourse around climate change, pushing governments and corporations to take stronger action as individuals to become more vocal about environmental issues.

By providing personalized insights into carbon footprints, the questionnaire enhances awareness about the environmental impacts of everyday choices [10]. Armed with this knowledge, individuals can make informed decisions and adopt behaviors that contribute to reducing their carbon footprint in tangible ways, from energy-efficient practices to sustainable consumption habits [9]. Educational initiatives and behavioral interventions leveraging the ICFQ can further promote environmental literacy and cultivate a sense of personal responsibility towards sustainability [7]. Ultimately, by motivating individuals to take ownership of their environmental footprint, the ICFQ fosters a collective commitment to climate action and the transition towards a more sustainable future [3].

The development and validation of the Individual Carbon Footprint Scale represent a transformative step forward in environmental research and practice [10].

Explaining and validating the Individual Carbon Footprint Scale is crucial for several reasons, as it can help address key environmental, social, and psychological aspects of climate change mitigation. In fact, a validated scale allows individuals to assess their own carbon footprints, leading to better awareness of how personal actions contribute to climate change. In addition, with a validated scale, climate action programs can tailor interventions to specific individuals or groups based on their carbon footprints, making efforts more efficient and effective.

In addition, a validated scale provides a tool for tracking progress in reducing individual carbon emissions over time, both on an individual level and across populations. Furthermore, organizations promoting sustainability can use the scale to assess and report their employees' or customers' carbon footprints, reinforcing accountability.

This innovative tool not only supports rigorous scientific inquiry into individual carbon footprints but also empowers individuals to play an active role in global efforts to mitigate climate change. By fostering awareness, informing decision making, and promoting sustainable behaviors, the Individual Carbon Footprint Scale contributes to building resilience and sustainability in communities worldwide, ensuring a healthier planet for present and future generations.

This article presents the findings and implications of the study, highlighting the scale's development process, validation outcomes, and its potential implications for environmental education, policy formulation, and a sustainable Circular Economy. By elucidating individuals' perceptions and behaviors related to carbon footprint components, the scale offers insights crucial for designing targeted interventions and fostering informed decision making toward achieving global environmental sustainability goals.

2. Materials and Methods

To develop and validate a scale for assessing individuals' awareness of their carbon footprint, the researchers created a self-reporting questionnaire. The researchers used previous research frameworks as a basis for the scale's development. There are many studies in the literature on the measurement of carbon footprint. These studies mostly involve creating a mathematical calculation model or evaluating the carbon footprint in different dimensions. While some studies evaluate fuel consumption, some studies have addressed regional, digital footprint, or ecological footprint evaluations [11–17]. These studies in question were conducted in a variety of countries, each with its own distinct cultural context. However, current study was conducted in Turkey, a country situated between Europe and Asia, and therefore characterized by a cultural synthesis of both continents. The sustainability of life on earth can be ensured by increasing individual awareness of environmental sensitivity. The aim of this scale development study is to examine the behavioral styles of individuals individually and to easily evaluate the carbon footprint on a single scale. A list of 25 items was developed to measure the five dimensions of carbon footprint awareness using a 5-point Likert scale (from 1: strongly disagree to 5: strongly agree).

Sample of the Study

The study sample comprised of Gen Z individuals born after 1997 and over the age of 18. It is known that Gen Z consumers are inclined toward green consumption and especially need to obtain information on the subject [18], that they frequently use artificial intelligence among technological infrastructure possibilities in the process of meeting the relevant need [19], and that they experience satisfaction for the protection of the environment with their experiences [20]. According to Ling et al. (2023), subjective norms, perceived behavioral control, environmental knowledge and social media positively affect the green purchasing behavior of consumers, especially in Gen Z [21]. According to the world population statistics presented by the United Nations, the proportion of individuals in the 11–25 age range in 2021 is 24% [22]. Considering the relevant population statistics, consumption in the coming years will be centered on Gen Z, and therefore, the demographic unit that should be focused on environmental awareness, sustainability, and green consumption issues should be Gen Z individuals. For this reason, this research was conducted among Gen Z.

The participants of the research were recruited by sharing the research link in student groups and sharing it on the social media platforms of the universities. All Generation Z participants who completed the survey completely were included in the sample group. Additionally, it received approval from the Research Ethics Committee of Manisa Celal Bayar University (approval E—050.01.04-674506).

Data collection with three different samples is an effective method to increase validity and reliability in the scale development process. The study followed the guidelines suggested by Bryman and Cramer (2001), which recommend a sample size of at least five times the number of items [23]. In the first stage (n = 125), the design of the scale is tested with small sample groups in pilot studies, and content errors and comprehensibility are evaluated. In the second stage (n = 553), the performance and validity of the scale are tested on a large sample. In the last stage (n = 612), the final version of the scale is validated, and its generalizability is re-confirmed. This approach helps to minimize potential errors and ensure the reliability of the scale across different demographic groups [24].

3. Results

After the conceptual framework was developed in the research, the researchers developed the scale in three stages. These three stages are item generation and validation, reliability and EFA, and CFA for dimensionality and construct validity that provide a comprehensive framework for developing a robust and psychometrically sound scale. Each stage is essential for ensuring the scale's theoretical integrity, reliability, and validity in measuring the intended construct. Following Hinkin's (1998) suggestion, the initial collection and development of items for scale development were based on the theoretical basis or description [25]. The scale was then refined, validated, and confirmed through the following three stages (Figure 1).

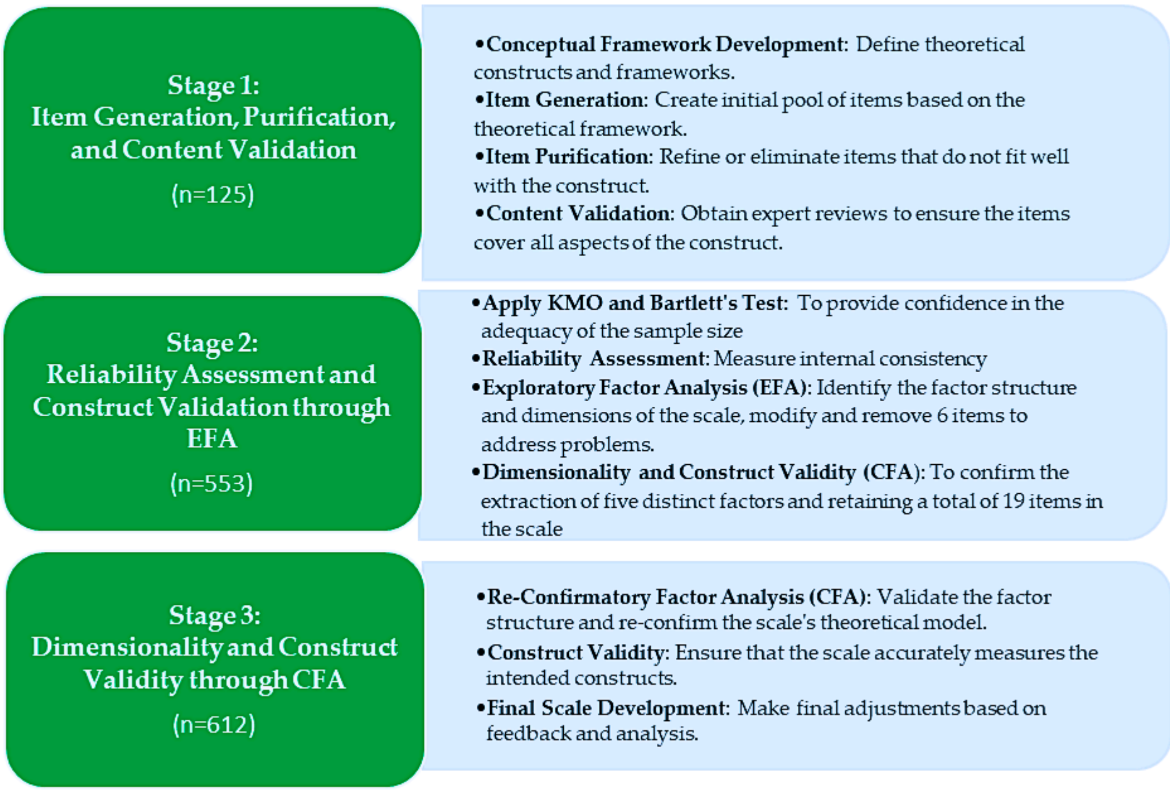

Figure 1. Flowchart for Scale Development Procedure.

3.1. Stage 1: Item Generation, Purification, and Content Validation

In the first stage, items were generated based on the theoretical framework and descriptions relevant to the construct. This stage is crucial for establishing content validity, ensuring that the items adequately cover the construct being measured. Content validity is assessed through expert reviews and revisions, as highlighted by more recent guidelines on scale development [26]. Item purification involves refining or discarding items that do not fit well with the construct, ensuring a focused and coherent measure [24].

The development of the Carbon Footprint Awareness Scale began with the generation of an initial pool of more than 25 items, informed by a comprehensive review of existing literature and preliminary exploratory research [27–30]. The aim was to capture at a single scale diverse dimensions of carbon footprint awareness across various domains such as transportation, energy consumption, dietary habits, and waste management in order to boost the Sustainable Circular Economy.

To ensure the content validity of the scale, a rigorous assessment approach recommended by Hinkin and Tracey (1999) was employed. Four experts, each with extensive academic backgrounds and between 11 to 18 years of experience in environmental psychology and sustainability, were selected for their expertise [31]. These experts were affiliated with different universities spanning across two countries, ensuring a broad perspective and international validation of the scale's content. The experts critically evaluated the initial pool of 25 items based on their relevance, clarity, and comprehensiveness in measuring carbon footprint awareness. Items that received consensus among the experts as clearly representative of the intended construct were retained for further analysis. This iterative process not only validated the content but also refined the language and structure of the scale to enhance its clarity and applicability.

Following expert review and refinement, the scale was consolidated into a comprehensive set of 25 items that effectively captured the multidimensional aspects of carbon footprint awareness. The validated items were organized into distinct factors representing key domains: transportation, fuel consumption, electricity usage, food choices, and waste management.

3.2. Stage 2: Reliability Assessment and Construct Validation through EFA

The second stage focuses on evaluating the reliability of the scale and conducting Exploratory Factor Analysis (EFA). Reliability, typically assessed via internal consistency measures such as Cronbach's alpha, ensures that the items are consistently measuring the same construct [32]. EFA is employed to explore the factor structure of the scale and identify the underlying dimensions of the construct, as it facilitates understanding the grouping of items and the dimensionality of the scale [33,34] and is a crucial statistical technique used to identify underlying factors or dimensions within a set of observed variables (items) [23,35].

EFA is important for several reasons, particularly in the context of social sciences, psychology, education, and other fields where researchers aim to understand underlying relationships between variables [23,35]. In fact, EFA helps researchers identify latent (hidden) variables or factors that explain patterns in the data. For example, in psychological testing, multiple observed behaviors may reflect a single underlying trait like intelligence or anxiety. It simplifies large datasets by reducing the number of observed variables into fewer factors [23,35]. This makes complex datasets more manageable and easier to interpret without a significant loss of information. Furthermore, EFA is often used in the early stages of research to help develop theories or to refine existing theoretical constructs. By identifying the underlying dimensions of a concept, researchers can better define and measure abstract ideas [23,35].

We first checked the sample adequacy for EFA. To ensure robustness in factor analysis, it is recommended that the sample size be at least five times the number of items on the scale [35]. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was also used to assess whether the sample size was sufficient for EFA. A KMO value greater than 0.5 is generally considered acceptable, with higher values indicating better suitability for factor analysis [36]. In this study, the KMO measure yielded a value of 0.898, indicating good sampling adequacy. This suggests that the data provided a suitable basis for factor analysis, with correlations among items being sufficiently strong to proceed with identifying meaningful factors within the Carbon Footprint Awareness Scale. Moreover, the item-to-response ratio exceeded this criterion, indicating that the sample size was adequate for conducting EFA, thereby ensuring reliable factor extraction and interpretation. And for assessment of factorability, Bartlett's test of Sphericity was employed to evaluate whether correlations among items were sufficiently large for EFA [37]. A significant result from

Bartlett's test (Table 1) indicated that the items were adequate for factor analysis, supporting the suitability of the data for further structure detection.

Table 1. Results of KMO.

KMO and Bartlett's Test		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.898
	Approx. Chi-Square	2,792,900
Bartlett's Test of Sphericity	df	171
	Sig.	0.000

df = degrees of freedom; Sig. = significance (p value).

The results from Bartlett's test and the KMO measure underscored the robustness of the dataset for conducting exploratory factor analysis. These statistical tests provided confidence in the adequacy of the sample size and the suitability of the data structure for detecting the underlying dimensions of carbon footprint awareness. The subsequent stages of the study would leverage these findings to extract and interpret factors that contribute to individuals' awareness of their carbon footprint.

According to Kaiser's (1974) recommendation for Exploratory Factor Analysis (EFA), Eigenvalues below 1.0 may suggest unstable factors [36]. Applying this criterion, the study identified and extracted five factors from the Carbon Footprint Awareness Scale, each with Eigenvalues exceeding 1.0. These factors collectively explained 56.09% of the total variance, indicating a substantial contribution to understanding individuals' awareness of their carbon footprint. Table 2 and Figure 2 present comprehensive details on the variance explained by each factor, offering a clear visualization and item-level breakdown for further scrutiny and replication.

Table 2. Total Variance Explained.

Total Variance Explained									
Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	5728	30,147	30,147	5728	30,147	30,147	2798	14,726	14,726
2	1497	7877	38,024	1497	7877	38,024	2248	11,831	26,558
3	1294	6813	44,836	1294	6813	44,836	2015	10,606	37,164
4	1125	5921	50,757	1125	5921	50,757	1809	9519	46,683
5	1014	5336	56,093	1014	5336	56,093	1788	9410	56,093

Extraction Method: Principal Component Analysis.

In conducting the factor analysis of the Carbon Footprint Awareness Scale, the researchers employed Varimax rotation, a type of orthogonal rotation, along with Principal Components Extraction, given the theoretical correlation among the factors. To ensure the accuracy and interpretability of the factors; items with factor loading values below the recommended threshold of 0.30 were systematically removed from the scale. Additionally, items showing cross-loadings across multiple factors were excluded to maintain the scale's integrity, aligning with methodological recommendations [38,39]. A total of six items (items 20th–25th) were removed from the initial pool due to their insufficient factor loading values or tendency to load onto more than one factor. Following this refinement, the factor structure underwent re-analysis, confirming the extraction of five distinct factors and retaining a total of 19 items in the scale. Notably, adjustments were made for items 6 and 13, which were reverse-coded to ensure consistency in the direction of measurement across all items. Table 3 provides a comprehensive overview of the remaining items and their respective factors, all of which demonstrate acceptable factor loading values.

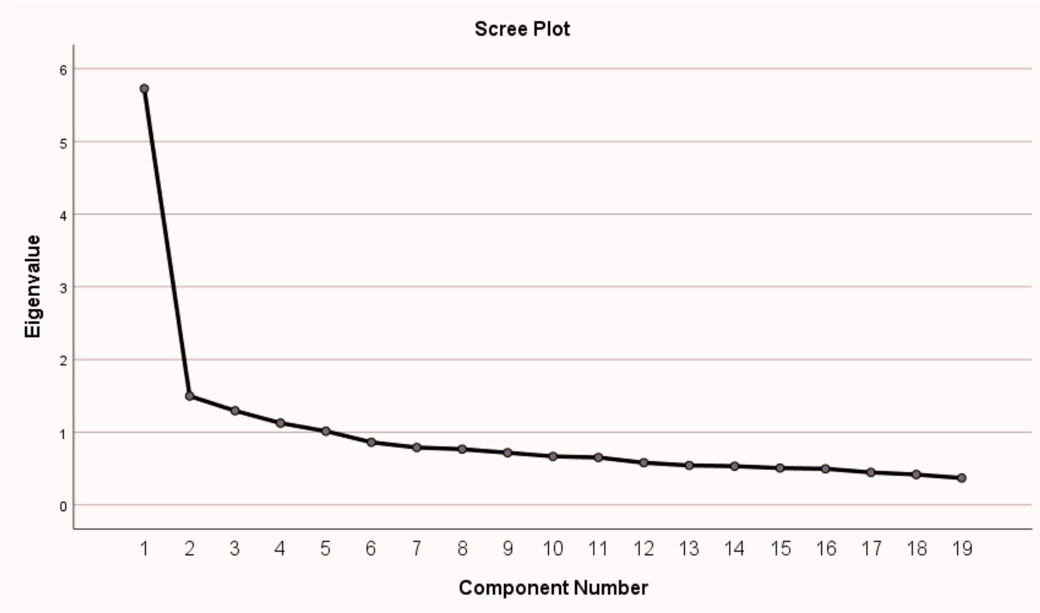

Figure 2. Sree Plot For EFA.

Table 3. Carbon Footprint Awareness Exploratory Factor Analysis.

Rotated Component Matrix [a]						
Scale Items		Components				
		1	2	3	4	5
1.	I prefer public transport for long journeys.	0.736				
2.	I prefer to use my own car for long-distance journeys.	0.655				
3.	I prefer to walk or cycle when traveling short distances.	0.710				
4.	I prefer environmentally friendly energy sources for heating my house.		0.691			
5.	I prefer my house to have heat insulation.		0.699			
6.	I prefer to use air conditioning as a means of heating or cooling.		0.746			
7.	I prefer to use eco-friendly lighting devices (led lamps, etc.) in my home and workplace.			0.780		
8.	I prefer to use eco-friendly (A+, A++, A+++) durable consumer goods (white goods, etc.) in my home.			0.734		
9.	I take care to switch off electrical appliances that are switched on unnecessarily.			0.564		
10.	I do not leave technological devices (telephone, computer, etc.) that are not actively used plugged in.			0.694		
11.	I make sure that the dishwasher or washing machine is full before starting it.			0.570		
12.	I prefer to consume meat dishes for my meals.				0.556	
13.	I throw food waste in the rubbish bin.				0.548	
14.	I try to give food scraps to stray animals.				0.593	
15.	I try to use less water when taking a shower/brushing my teeth.				0.613	
16.	I try to eat organic foods.				0.734	
17.	I prefer environmentally friendly products when buying clothes and shoes.					0.673
18.	I try to separate waste materials for recycling.					0.679
19.	I try to minimize the use of plastic in my daily life.					0.696

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

The theoretical structure of the Carbon Footprint Scale was defined in five factors: Transportation, Fuel consumption, Electricity consumption, Food consumption, and Waste management. Each factor was operationalized using specific items designed to capture different dimensions of carbon footprint awareness.

1. Transportation: This factor encompassed items 1, 2, and 3 of the scale, focusing on assessing individuals' carbon emissions related to their transportation choices and habits.
2. Fuel consumption: Items 4, 5, and 6 were grouped under fuel consumption, examining carbon emissions associated with fuel usage across various activities and contexts.
3. Electricity consumption: Items 7 through 11 were allocated to electricity consumption, measuring individuals' awareness and impact regarding energy use and related carbon emissions in household and commercial settings.
4. Food consumption: Items 12 to 16 were categorized under food consumption, assessing the environmental footprint linked to dietary choices and consumption patterns.
5. Waste management: Finally, items 17, 18, and 19 comprised waste management, focusing on individuals' practices and awareness regarding waste generation, disposal methods, and recycling efforts.

We checked the data reliability by examining Cronbach's alpha value. Reliability, as defined by the degree of internal consistency across multiple measurements of a variable, was assessed using Cronbach's alpha coefficient [40]. This widely accepted measure in psychometric evaluation indicates the extent to which items within each factor correlate with one another [41]. A Cronbach's alpha value above 0.7 is typically considered acceptable for research purposes, indicating strong internal consistency among the items in each factor.

Table 4 presents the factors identified in the Carbon Footprint Scale, the number of items comprising each factor, and their corresponding Cronbach's alpha values. These values provide insights into the reliability and coherence of the scale's factors, demonstrating the robustness of the instrument in measuring different dimensions of carbon footprint awareness effectively.

Table 4. Factor Names, Sample Items, and Reliability.

	Factor Name	Number of Items	Cronbach's Alpha
1	Transportation	3	0.796
2	Fuel consumption	3	0.736
3	Electricity consumption	5	0.823
4	Food consumption	5	0.887
5	Waste management	3	0.729
Total	Carbon Footprint Awareness Scale	19	0.868

3.3. Stage 3: Dimensionality and Construct Validity (CFA)

CFA signifies the subsequent phase where the proposed factor structure undergoes meticulous scrutiny, and structural models are thoroughly evaluated. Within CFA, diverse models are assessed to ascertain the most suitable factor structure for the scale based on achieving acceptable goodness-of-fit indices. In this study, a four-factor model was employed, and the model demonstrating satisfactory goodness-of-fit indices was identified as the second-order factor model [42].

The reliability of the factor structure of Carbon Footprint Awareness was affirmed through the utilization of the Amos software for conducting confirmatory factor analysis on the revised scale. This procedure culminated in the final refinement of the instrument designed to gauge individuals' awareness of their carbon footprint. Figure 3 presents the outcomes of the confirmatory factor analysis (CFA).

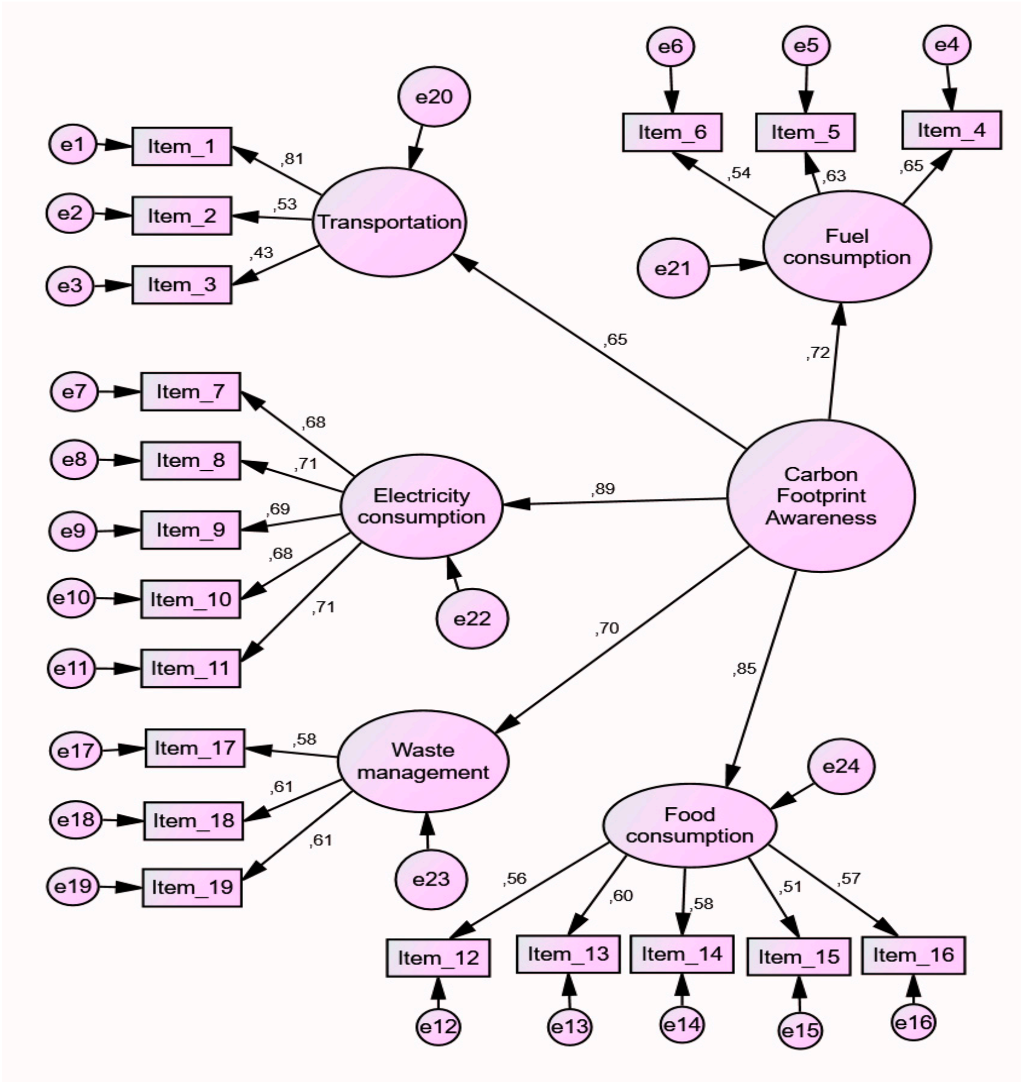

Figure 3. Result of CFA.

The findings from CFA, encompassing goodness-of-fit metrics and standardized coefficients, are detailed in Table 5. These metrics offer crucial insights into the alignment of the proposed model with the observed data, indicating the robustness and validity of the factor structure. Moreover, the standardized coefficients derived from CFA are graphically depicted in Figure 3, providing a visual representation of the relationships between the latent variables and their corresponding observed indicators. The Amos CFA results show standardized estimates. Item1–Item19 are scale questions, and e1–e24 are error terms.

Table 5. Confirmatory Factor Analysis Results of Digital Infidelity Scale (n = 553).

Model	$\Delta\chi^2$	df	$\Delta\chi^2$/df	RMSEA	NFI	IFI	CFI	GFI	p
The second-order CFA model	313,998	147	2.136	0.045	0.889	0.938	0.937	0.940	0.000

df = degrees of freedom; RMSEA = Root Mean Square Error of Approximation; NFI = Normalized Fit Index; IFI = Incremental Fit Index; CFI = Comparative Fit Index; GFI = Goodness of Fit Index.

3.4. Stage 4: Re-Confirmation the Construct the Scale

The final stage involves Re-Confirmatory Factor Analysis to validate the factor structure identified in EFA. CFA tests the fit of the data to a hypothesized measurement model, thereby reconfirming the dimensionality and construct validity of the scale. This stage ensures that the scale adheres to the theoretical model and accurately measures the intended constructs, as articulated by Schumacker and Lomax [43].

Following the initial validation of the scale's structure comprising 19 items, it was administered to a final sample of 612 randomly selected Generation Z participants.

To ascertain the reliability of the Carbon Footprint Awareness scale, Cronbach's alpha coefficients were reassessed, revealing robust internal consistency across its dimensions. As stipulated in academic literature, a Cronbach's alpha threshold of 0.70 or higher signifies satisfactory reliability. Specifically, the dimensions of the scale demonstrated commendable internal consistency: Transportation measured 0.72, Fuel consumption measured 0.77, Electricity consumption measured 0.83, Food consumption measured 0.73, and Waste management yielded 0.74. Moreover, the aggregate Cronbach's alpha for the entire Carbon Footprint Awareness scale was calculated at 0.88, underscoring its strong internal reliability and suggesting that the scale reliably captures and measures respondents' awareness across diverse carbon footprint dimensions. These findings corroborate the scale's suitability for use in research and practical applications concerning environmental consciousness and behavior.

Following the reliability assessment, a measurement model was constructed using IBM SPSS Amos 26 to visually represent the structural model (depicted in Figure 4). This model aimed to validate the revised scale's factor structure through CFA. The analysis conducted on the data from the final sample revealed positive standardized estimates and goodness-of-fit indices that met the criteria for acceptable model fit [44]. Evaluating the fit of structural equation models involved tests of significance and descriptive goodness-of-fit measures [45].

The findings from the standardized estimates of CFA, along with comprehensive statistical details, are presented in Figure 4 and Table 6. Additionally, the examination of regression weights between items indicated consistently high and statistically significant coefficients. These results underscore the robustness of the factor structure of the Carbon Footprint Awareness scale and affirm its construct validity and psychometric properties among Generation Z participants.

Table 6. Re-Confirmatory Factor Analysis Results of Digital Infidelity Scale (n = 612).

Model	$\Delta\chi^2$	df	$\Delta\chi^2$/df	RMSEA	NFI	IFI	CFI	GFI	p
The second-order CFA model	371,486	147	2.527	0.050	0.895	0.934	0.933	0.935	0.000

df = degrees of freedom; RMSEA = Root Mean Square Error of Approximation; NFI = Normalized Fit Index; IFI = Incremental Fit Index; CFI = Comparative Fit Index; GFI = Goodness of Fit Index.

The Confirmatory Factor Analysis (CFA) conducted on the second sample data values yielded favorable results, with positive standardized estimates, and demonstrated good model fit as assessed by various goodness-of-fit indices following the guidelines by Schermelleh-Engel et al. (2003) [46]. Specifically, the CMIN (χ^2) statistic was 2.57, indicating a statistically significant model fit ($p < 0.001$). The Root Mean Square Error of Approximation (RMSEA) was calculated at 0.009, suggesting a close fit of the model to the observed data. The Comparative Fit Index (CFI) registered 0.933, the Normed Fit Index (NFI) was 0.895, the Incremental Fit Index (IFI) was 0.934, and the Goodness-of-Fit Index (GFI) was 0.935, all of which indicated adequate model fit.

The standardized Carbon Footprint Awareness Scale encompasses five dimensions, encompassing a total of 19 items rated on a five-point Likert scale. Detailed descriptions of this structure, along with the final item list, are provided in Annex-3, offering comprehensive insights into the composition and configuration of the scale following its latest refinement phase.

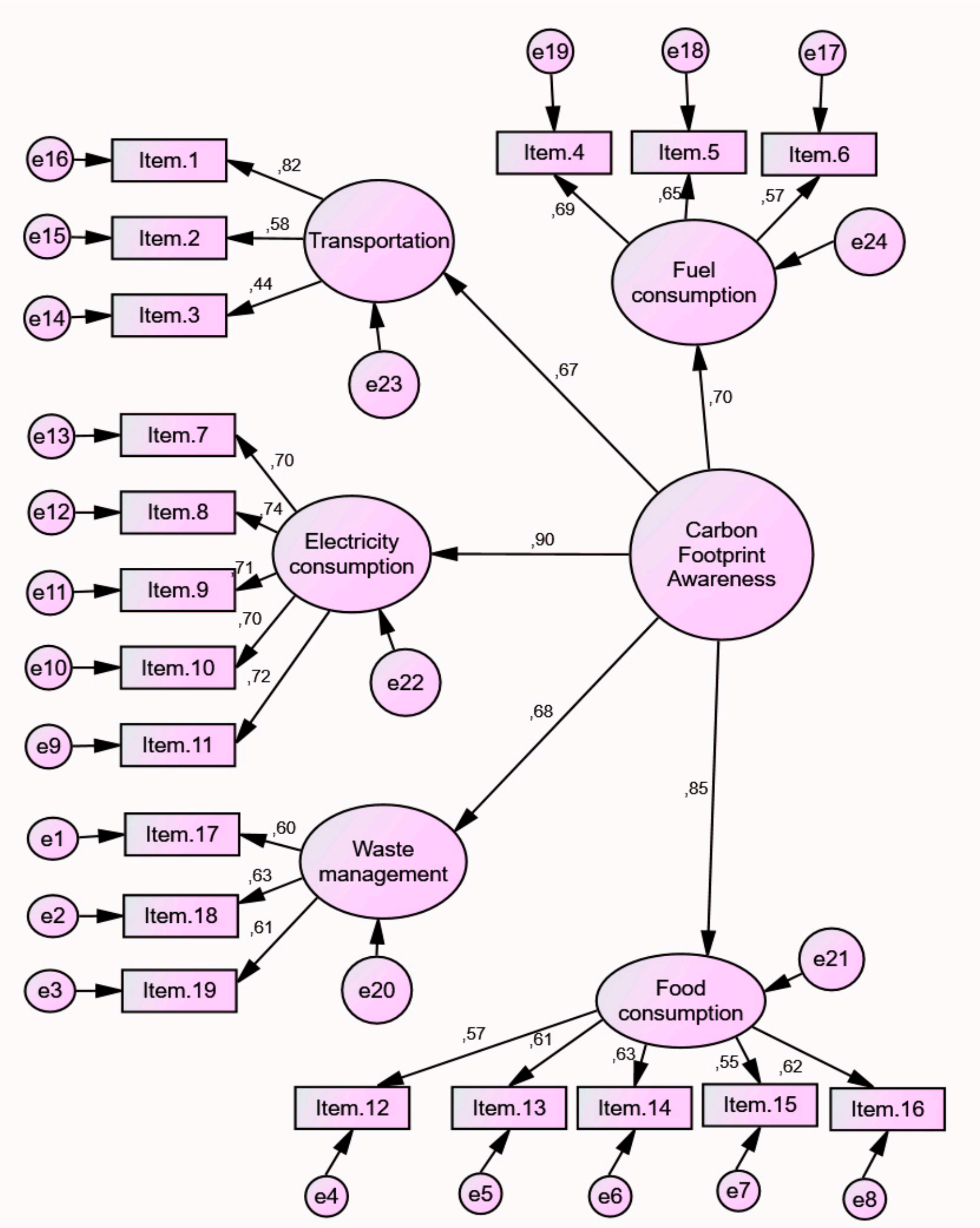

Figure 4. Result of CFA (last sample).

4. Discussion

In the United Nations Framework Convention on Climate Change (UNFCCC, 1992), the human factor affecting climate change is defined as follows: "In addition to the natural climate change observed over comparable time periods, a change in climate as a result of human activities that directly or indirectly disrupt the composition of the global atmosphere" [47]. The is fact that humanity, which has disrupted the natural balance in climate change with industrialization, has continued its activities by institutionalizing them in order to achieve more development and prosperity, has caused global warming at a level that threatens the life on earth. In this context, the 26th Conference of the Parties (COP-26) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Glasgow in November 2021, accelerated the momentum to combat global climate change. And in the Glasgow Climate Pact, the parties agreed to revisit their 2030 climate pledges, or Nationally Determined Contributions (NDC), and communicate Long-term

Low Emissions Development Strategies (LEDSs) towards net zero emissions to align with the Paris Agreement [48].

The carbon footprint is a critical aspect of climate change, as it measures the impact of human activities on the environment and plays a crucial role in sustainable development. The United Nations' Sustainable Development Goals (SDGs) highlight the importance of reducing carbon footprint and promoting sustainable development [49].

Measures should be taken to develop renewable energy technologies such as electric vehicles with minimum carbon emissions, solar energy panels, etc., in order to reduce the undesirable effects of climate change and even to reduce it to 5% below the 1990 values specified in the Kyoto Protocol [50]. The measures to be taken should not only include reducing existing greenhouse gas emissions, but also developing and integrating technologies that minimize carbon emissions into human life. In this context, we need to measure our individual carbon footprint. This research aims to develop and validate a Carbon Footprint Awareness Scale with sound psychometric properties that can be used to measure individuals' awareness of their carbon footprint. The scale can be used in all disciplines and institutions.

More, specifically, the scale can be used in educational settings to teach about sustainability, helping individuals understand the role they play in mitigating climate change. In addition, validating the scale enables researchers to study the psychological and social factors that influence individual carbon footprints, leading to better understanding of how to promote sustainable behavior. In addition, by enabling individuals to quantify and reduce their carbon emissions, the scale can contribute to achieving broader national and global carbon reduction targets, such as those outlined in the Paris Agreement.

Nonetheless, the validated scale can help distribute responsibility for carbon reduction more equitably, recognizing that individual contributions to climate change vary widely based on factors like location, income, and lifestyle.

The study's findings indicate that the proposed Carbon Footprint Awareness Scale, which consists of five factors, is a comprehensive tool for measuring individuals' perceptions of their carbon footprint awareness.

When the rates of carbon footprint formation per capita are examined in the research, it is seen that the highest rate is due to the use of natural gas, oil, and coal with a rate of 15%, and the second place is entertainment and holidays with a rate of 14% [51,52]. These values were not evaluated with a scale and were evaluated with questions prepared by the researchers. In a study conducted in Turkey, the amount of CO_2 emissions of vehicles on the highways in the period 2015–2018 was analyzed. As a result of this study, it was determined that the highest emission was emitted from diesel cars, and the lowest emission was emitted from petrol cars. In this context, it can be considered that the fuel type of the car used by people when calculating their carbon footprint should also be questioned [53]. In another study, the amount of greenhouse gas emissions of a state university was calculated through IPCC calculation methodology (Tier 1 approach). As a result of the research, it was determined that the carbon emission was mostly caused by electricity consumption with 87.85%. In the study, tree planting and the use of a solar power plant, which is a renewable energy source, were suggested to reduce the carbon footprint of the university [51,53]. In a study conducted in the USA, it was found that respondents generally had a low level of knowledge about energy use in the home and how it is reflected in emission factors or daily activities. In addition, about 75 per cent of respondents reported that they knew little or nothing about energy use in their homes. A total of 15.9% of the respondents indicated that a carbon footprint calculator could be effective in changing their daily energy consumption habits [54–57]. Based on this result, the existence of a scale where personal carbon footprint can be measured will increase awareness and make people act more carefully in this regard [58–60]. This study confirms that the awareness of the carbon footprint is a multidimensional construct and requires a comprehensive theoretical background that includes all major elements of carbon footprint that one should be aware of to protect the future world.

Theoretical and Managerial Implications

The scale discussed can play a significant role in mitigating the impact of human activity on the environment and boosting the Sustainable Circular Economy. It can aid in understanding the current situation and developing practical policies and practices to reduce the carbon footprint [61,62].

The Carbon Footprint Awareness Scale holds significant implications for environmental education and policy development. Managers and policymakers can utilize this validated tool to assess and enhance public awareness of carbon footprint impacts across various domains such as transportation, energy consumption, and waste management [63–65]. By understanding individuals' perceptions of their environmental impact, organizations can tailor targeted interventions and educational campaigns to promote sustainable behaviors. Moreover, benchmarking against the scale's dimensions can help businesses and governments track progress towards carbon reduction goals and formulate evidence-based strategies for mitigating environmental harm.

5. Conclusions

This study contributes several insights by introducing and validating the Carbon Footprint Awareness Scale, which is a comprehensive instrument tailored to measure individuals' awareness of their carbon footprint across specific domains. The scale's development involved rigorous validation processes, including expert review, pilot testing, and robust psychometric analyses using large-scale samples from Turkey. By delineating five distinct dimensions—transportation, fuel consumption, electricity consumption, food consumption, and waste management—the scale offers a nuanced understanding of environmental consciousness. This contribution enhances the field by providing a validated tool that bridges research and practice, facilitating informed decision making and fostering sustainable behaviors among individuals and organizations alike [66,67]. Moreover, the scale enriches several past tools and scales validated in different context and geographical areas [68–71]. The concept of the carbon footprint is inherently broad, encompassing studies that are directly related to both climate change and the preservation of the natural environment. Some past studies also focused on these topics [68,71]. It is evident that our study shares common ground with the aforementioned studies in terms of its methodology and findings. The studies in question were conducted in a variety of countries, each with its own distinct cultural context [68–71]. The current study was conducted in Turkey, a country situated between Europe and Asia, and therefore characterized by a cultural synthesis of both continents. Furthermore, our research focused on Generation Z, a demographic that will play a pivotal role in shaping the future of environmental stewardship and societal reconstruction.

Despite the robust validation procedures and encouraging findings, several limitations should be acknowledged. Firstly, the sample was exclusively drawn from Turkey, which may limit the generalizability of the findings to other cultural or geographic contexts. Future studies should consider conducting cross-cultural validations to enhance the scale's applicability across diverse populations. Additionally, while the scale demonstrated strong internal consistency and validity within the Turkish sample, longitudinal studies could provide insights into the stability and responsiveness of individuals' carbon footprint awareness over time. Lastly, the reliance on self-reported data via survey responses may have introduced response biases, necessitating caution in interpreting absolute levels of awareness.

Further validation of the scale can be achieved by using samples from different levels and countries. The literature suggests that such scales should be periodically tested and revised due to the rapidly changing world. A convergent validity can also be established by using similar scales in the carbon footprint domain, which should theoretically correlate and serve the same purpose.

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