Article

Sorting for Sustainability: Harnessing Female Awareness of Zero Waste

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ABSTRACT

Background: Sustainable Development Goal 12 focuses on sustainable consumption and production patterns. Females are more likely to adopt these sustainable consumption practices due to their environmental attitudes. The scope of the present research is to develop a Hungarian model that can provide a theoretical explanation for the formation, viability and empowerment of zero waste awareness among females as they are sensitive to the issue and may have sufficient knowledge about it.

Methods: An online questionnaire was distributed in a university environment in Hungary, resulting in 160 responses after data cleaning. The model was constructed using Partial Least Squares Structural Equation Modelling (PLS-SEM).

Results: The results show that for females, the factors waste sorting and zero waste practicality account for 72.4% of the variance in zero waste awareness. The Beta values indicate that both effects are positive with the effect of the first ($\beta_{ZWS\text{-}ZWA}$ = 0.523) being stronger than the second ($\beta_{ZWP\text{-}ZWA}$ = 0.389). In addition, it can be concluded that women's attitudes toward waste sorting have a strong positive impact (R^2 = 0.542, $\beta_{ZWS\text{-}ZWP}$ = 0.736) on zero waste practicality.

Conclusions: The zero waste attitudes of female university students' behavior are significantly related to the selective collection of waste and the practical use of old products. In addition, waste separation is a practical approach to environmental responsibility, as there is no need to dispose of all end-of-life products if they can be recycled. The model could help the government understand the factors and the mindset from a female perspective in order to partially support the decision-making process related to sustainability.

KEYWORDS: environmental attitude; female; PLS-SEM; recycling waste; sustainable consumption

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ABBREVIATIONS

PLS-SEM, partial least squares-structural equation modeling; SDG, Sustainable Development Goals; ZW, zero waste; B2C, business to customer; C2C, customer to customer; EFA, exploratory factor analysis

INTRODUCTION

Since the 1970s, it can no longer be denied that the current production and consumption methods in the world carry a serious risk to the environmental well-being of future generations. To solve the emerging issues related to this problem, the concept of sustainability and sustainable development gained ground in many areas of human life. The foundation for these concepts was laid down in a report called “Our Common Future” [1] published by the Brundtland Commission, a sub-organization of the UN. In this report, sustainable development is described as “development that meets the need of the present without compromising the ability of future generations to meet their own needs”. For decades, production and consumption habits followed a process referred to in the literature as “cradle-to-grave” or C2G, which covers a linear model in which resources are commonly thrown away after production and use [2]. However, since many of the resources are scarce, this practice threatens the environmental and economic interests of future generations.

The concept circular economy (CE) can be an adequate solution for managing this issue. There have been countless versions of the definition of this term. The most accepted of which is the formulation by Kirchherr et al. [3], who created the following definition by analyzing 114 existing concepts: “A circular economy describes an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at micro level (products, companies, consumers), meso level, (eco-industrial parks) and macro level (city, region, nation and beyond), to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations”. The practices of the CE mean that the resources get used repeatedly (cradle-to-cradle or C2C model), significantly reducing the risk of resource depletion [2,4].

The introduction of the circular economy in all areas of society is not only an advantage in terms of the future. For example, Ferrante and Germani [5] analyzed the relationship between several socio-economic variables (namely the unemployment rate, the Human Development Index, and the percentage of people at risk of poverty or social exclusion) of 23 countries in Europe and found that strengthening the circular economy sector improves conditions in the labor market and helps the catching up process of lower performing countries at EU level. This means

that implementing CE practices may help countries to develop their social, environmental, and economic aspects at present [6].

The United Nation's 2030 Agenda for Sustainable Development is committed to promoting economic, social, and environmental development by including 17 Sustainable Development Goals (SDGs) with associated targets to assess progress [7]. Among those, SDG 12 focuses on sustainable consumption and production patterns, mitigating the impacts of increased resource use [8] by emphasizing the importance of households, especially in urban centers [9], one example of which is the implementation of sustainable urban mobility programs for students who commute to school [10]. Sustainable consumption aims to enhance the quality of life by minimizing the consumption of natural resources and reducing the use of harmful materials and pollution, ensuring that the needs of future generations are not compromised [11]. Sustainable consumption may include sustainable principles as well as sustainable actions [12,13].

Therefore, SDG 12 can be closely linked to the Zero Waste (ZW) initiative which—according to the Zero Waste International Alliance—aims to preserve all resources through responsible production, consumption, reuse, and recovery of products, packaging, and materials. This approach avoids incineration and prevents harmful discharges to land, water, or air, thereby protecting both human health and the environment [14]. The concept of ZW, which targets to minimize waste production and maximize resource efficiency, has garnered significant attention in recent years since it encompasses a wide range of actions, experiences, and interpretations that are emerging in industrial and municipal practice, as well as consumer behavior [15,16]. The ZW trend is not only about using products that create less waste but also about inspiring consumers to make thoughtful choices that positively impact the environment [17]. Therefore, from the perspective of consumption, ZW stands for being a careful consumer [18,19] whose behavior typically includes avoiding the use of disposable products and goods with unnecessary packaging, reusing products as often as possible, and recycling and composting household waste [20], and by doing so lowering their impact on the environment [21]. Reusing and recycling products, packages, as well as waste are important dimensions of consumers' zero waste behavior [22], as they address both the reduction of waste and the sustainable use of resources. These practices are essential for moving towards a zero waste society by e.g., minimizing the amount of waste generated [23], conserving natural resources [24], reducing pollution [25], et cetera. Sang et al. [26] describe the ZW concept as the cross-section of reduce, reuse, and recycle (3R hierarchy); however, this concept may not be the most suitable framework to study the B2C and the C2C approach to ZW behaviors [27].

Research on sustainable consumption observed several moderating factors such as gender [28], income [29], place of residency, and

educational level [30]. The moderating role of gender in ecological contexts is relevant as studies found stronger relationships for women than for men (e.g., [31]). Research suggests that females are more likely to purchase green products as they place a greater concern about environmental attitudes and issues. A study on solar panels revealed that women are more concerned about environmental risks and more willing to support environmental issues than men [18]. Moreover, research on Generation Y green behavior on green products revealed that female consumers are more supportive and accepting of green behavior than male consumers [32]. Regarding green apparel buying behavior, it was also found that gender moderates the association between environmental knowledge and environmental concern. Women are more concerned about the environment at different levels of environmental knowledge [33,34]. Females are also more conscious and cautious when shopping [30] and show higher Zero Waste Behavior (ZWB) intentions than males [35].

From a historical point of view, consumption has always been closely linked to females [36–38]. Women were traditionally responsible for managing the household, which included purchasing goods, preparing meals, and overseeing family needs [39,40]. Nowadays, females also play a pivotal role in making sustainability-related decisions [41] as they are considered to be responsible for 70%–80% of household purchases [42], representing the largest group of consumers shopping for the daily needs of their families [38].

Their decisions directly impact the household's environmental footprint. Literature confirms the assumption that women are more likely to adopt energy-saving behaviors due to their greater environmental awareness [43]. In this regard, Shrestha et al. [44] also pointed out that women demonstrate a higher tendency to conserve energy resources. Females adopt sustainable water conservation practices mainly because of the expected positive results of conservation and social norms [45]. Females also demonstrated a greater willingness to pay for food products labeled as sustainable and showed a higher likelihood of purchasing them [46]. Females are generally more concerned about food waste than males [47]. Moreover, Veselá et al. [48] found that the specifics of the food purchasing process of households (e.g., shopping according to list) have the greatest impact on the amount of food waste for women. Regarding fashion consumption, young female adults can be described with higher levels of sustainable purchasing intentions and socially responsible consumer behavior [49]. Another study on green apparel found females to have a high environmental concern at different intensities of environmental knowledge [34]. The gender-based analysis by Duarte et al. [50] indicated higher interest and positive attitudes among females toward purchasing sustainable packaging. Martinho et al. [51] found that females have greater levels of environmental awareness, which may explain their consumption and recycling patterns regarding sustainable packaging. Research has shown that women tend to exhibit circular behavior more

frequently [52], such as purchasing sustainable clothing [53,54] as well as sorting and properly disposing of textile products [55]. A study of consumer attitudes towards novel circular models in the fashion industry has also demonstrated that the environmental factors that influence the decision to purchase clothing manufactured from waste or recycled materials are slightly more significant for women than for men [56].

Research carried out in Hungary explored behavioral patterns behind household food waste [57], household garden waste, and food waste composting habits [58] as well as the 3R hierarchy principles of the zero waste consumer lifestyle [22]. However, the zero waste awareness of female consumers has not been taken into consideration; therefore, the present study fills the potential gaps and contributes to the literature in different ways. First, this study discusses females' sustainable consumption behavior in the context of a Hungarian campus, which contributes to the existing literature on moderating factors (e.g., educational level, gender) of sustainable consumption [22,59]. Second, the study defines the role of zero waste sorting and zero waste practicality in sustainability-related decisions of females. Present research advances our comprehension of how women engage with environmental practices, particularly in the context of waste management. This focus on zero waste initiatives elucidates the behavioral patterns and environmental attitudes that drive sustainable choices, offering insights into the factors that motivate or hinder such actions. The study not only contributes to the broader literature on environmental awareness but also underscores the importance of practical, everyday actions in shaping sustainable behaviors [32,34,60]. Third, previous studies applied structural equation modeling regarding consumers' food waste behavior [48], generation Y's green behavior on green products [32], zero waste cosmetic products [17]; as a result, the present research can be considered a novel contribution to this type of literature. Finally, the findings of this study also help the government understand the factors and the mindset from the female perspective on ZW to partially support the decision-making process related to sustainability. Thus, the study aims to investigate what factors can influence female awareness of zero waste.

MATERIALS AND METHODS

Hypothesis Development

The hypotheses were developed based on the findings of the literature review and were specifically focused on the female population, aligning with the central objective of the study. The first step in formulating a hypothesis is to acknowledge the confirmation of gender differences in environmental perceptions by several studies (e.g., [61–63]). The findings of the study analyzing university students indicate that female students tend to demonstrate a greater concern for the environment than their male counterparts. This discrepancy is particularly evident in the context

of environmental activism [61]. In synthesizing prior research, it was also determined that gender has an impact on the utilization and stewardship of the environment. However, this phenomenon is not exclusive to one direction. Environmental trends (e.g., ecological degradation) may affect the genders differently [62]. Furthermore, the involvement of females in nature-related work and decision-making processes was identified as a crucial element, as it allows for the extent and manner of use to be evaluated from a unique perspective [63]. Other research (e.g., [64,65]) has yielded comparable results for a more specific aspect of the environment, namely zero waste. This indicates that females exhibit higher levels of knowledge and sensitivity on this topic. However, it is also important to emphasize that females, as important actors in households, may be particularly well placed to adopt and transfer zero waste best practices in the family, thus contributing to achieving zero waste lifestyles [65,66]. Regarding the zero waste paradigm, it is evident that domestic responsibilities are increasingly being ascribed to females. However, the adoption of this lifestyle can engender collective, nature-conscious communities [65]. Nevertheless, the zero waste movement is not the sole source of concern. Indeed, zero waste strategies rely significantly on women, which can result in overburdening and even long-term disability [66].

A particularly promising area of exploration within the field of zero waste theory is the willingness to engage in the sorting of waste materials. Furthermore, the growing presence of foreign nationals (workers, students) in 21st-century societies also underscores the need for a more comprehensive analysis of this zero waste option [67]. Time is a crucial factor in zero waste efforts, particularly for female householders who may lack the opportunity to learn and apply appropriate techniques, such as composting. In addition to composting, waste sorting is a convenient zero waste option for women to adopt, learn, and apply [68]. Promoting waste sorting practices, including education initiatives, can play a pivotal role in fostering awareness and value creation related to zero waste [69]. It is similarly important to consider waste sorting behavior in the context of resource use and waste [70]. To optimize the use of resources and minimize waste, it is essential to integrate reuse and repair options into these efforts [71]. Moreover, it is stated that university students' awareness of waste management is directly linked to their waste reduction, reuse, and recycling behavior [72].

In terms of the application of the zero waste concept, it is widely accepted that this concept encompasses the triad of waste minimization, reuse, and recycling [73]. The appropriate collection, utilization, and reuse of textiles and various types of municipal solid waste are of considerable importance for the protection of the environment [74], and the public can also play a significant role in this effort. Therefore, the practical reuse of certain products can contribute to the perceived importance of zero waste awareness and even have a mediating effect through sorting. This is also

a significant issue in Europe, given the finite nature of the planet's resources. Consequently, reducing waste and eliminating superfluous items has become a crucial concern. In order to gain a deeper understanding of this issue, it is essential to examine the Generation Z customer base, as they represent a significant influence on market trends [75]. The positive impact of zero waste education has also been demonstrated among university students, which may influence their future role in society [69]. These results also confirm the target population of the present study, thereby improving the empirical evidence supporting the hypotheses.

The existing literature on the topic, along with the findings of previous analyses examining the impact of factors associated with the zero waste movement, has led to the formulation of the following hypotheses:

H1: The sorting of waste in the context of the zero waste theory has a significant positive impact on zero waste practicality.

H2: The sorting of waste in the context of the zero waste theory has a significant positive impact on zero waste awareness.

H3: Zero waste practicality has a significant positive impact on zero waste awareness.

The three hypotheses are defined in accordance with the PLS-SEM construction, whereby the level of importance and significance of the pathways within the model are analyzed in order to gain insight into the hypotheses. The results may provide an opportunity to understand the effects on endogenous variables (awareness, practicality). Furthermore, the analysis of the hypotheses provides an opportunity to explore several exciting findings in the context of women's awareness of zero waste. Considering the nature of the hypotheses, it is imperative to prioritize the measurement of public value judgments, which can only be accomplished through the utilization of a subjective measurement method. Consequently, the outcomes are inherently constrained by the limitations of this approach.

Methodology

The collection of data is quantitative in approach, focusing on the measurement of opinions and views held by the target population. Structural equation modeling (SEM) is explicitly recommended for conducting this type of analysis, which is related to both psychology and behavioral science [76,77]. Nevertheless, this methodology represents an excellent alternative for the construction of model versions based on established theories [78]. The SEM variant employed in the present research is partial least squares structural equation modeling (PLS-SEM), as it is the most suitable form for developing and testing theoretical models [79], with an optimal sample size of between 50 and 200 [80]. The objective of the method is to maximize the explained variance of the output variables [81], which represents the explanatory and predictive focus of this study. The term "partial least squares" is derived from the partial

nature of the data analysis, which renders it suitable for smaller sample sizes. It is iterated back and forth several times operationally, with the measurement model optimized first, followed by the structural model. This process is repeated until the forecast becomes optimal [82,83]. The PLS model enables the estimation of path coefficients, which represent the hypothetical links connecting the constructs. The path coefficient values are standardized to a range between −1 and +1, thus allowing the direction and strength of the relationships to be determined. A higher value is typically indicative of statistical significance, however, a bootstrapping method must be employed to determine a standard error for acceptance [84,85]. The following steps constitute the initialization process for PLS-SEM [86,87]:

- determination of internal weights

$$Vji = f(x) = \begin{cases} cov(Y_j; Y_i) \\ 0 \end{cases} \quad (1)$$

$Y_j; Y_i$: adjacent latent variables.

- internal approximation

$$\tilde{Y}_j := \sum_i B_{ji} Y_i \quad (2)$$

b_{ij}: inner weights; Y_i: adjacent latent variables.

- determination of outer weights

$$\tilde{Y}_{jn} = \sum_{k_j} \widetilde{W}_{k_j} X_{k_j n} + D_{jn} \quad Mode\ A\ Block\ for\ reflective\ method \quad (3)$$

$X_{k_j n}$: raw data for indicator; $\widetilde{W}_{k_j}$: outer weights; D_{jn}: error term from a bivariate regression.

- outer approximation

$$Y_{jn} := \sum_{k_j} \widetilde{W}_{k_j} X_{k_j n} \quad (4)$$

$X_{k_j n}$: raw data for indicator; $\widetilde{W}_{k_j}$: outer weights.

The equations are then solved, resulting in the determination of external weights, external loads, and path coefficients, in addition to the estimation of location parameters. This process is repeated until convergence is achieved in the PLS-SEM [87].

In psychological and social science analyses using PLS-SEM, questionnaires are a commonly used method for the collection of data for analysis, which can be done easily and relatively quickly [88]. This finding is consistent with the observation that PLS-SEM has not yet been applied to similar model theories in the field of zero waste. Furthermore, it is a frequently utilized form of SEM for environmental analysis (e.g., [89,90]). In the context of the measurement model of the PLS-SEM, it is possible to distinguish between reflective and formative approaches [91]. The former is more suitable for assessing the ability of a manifest variable to describe a latent variable, while the latter is more suitable for assessing the causal

ability of a latent variable to indicate how much it contributes to its expression [77]. In this study, the reflective measurement model was selected as the focus was on the descriptive ability of the manifest variables that describe the latent variables that form the basis of the zero waste theory under investigation.

It is recommended that exploratory factor analysis (EFA) be conducted to test the novel variable and model structure to be developed using PLS-SEM [92]. Following the recommendations for the collection of data through questionnaires (Likert scales), maximum likelihood estimation and varimax rotation [93] were applied in the implementation of EFA. The criteria and corresponding cut-off values for the EFA-related tests are presented in Table 1. The EFA can be employed to ascertain the validity, reliability, and sufficiency of the construct designed [94].

Table 1. Indicators to be tested in EFA.

Test	Threshold	Source
Correlation	<0.30	[95]
Kurtosis and skewness	between −2 and +2	[96]
Kaiser-Meyer-Olkin (KMO)	>0.60	[97]
Variance inflation factor (VIF)	<5.00	[82,98–100]
Cronbach's alpha	>0.60	
Composite reliability (CR)	>0.60	
Average variance extracted (AVE)	>0.50	

Following the EFA, it should be advisable to conduct further research into the feasibility of PLS-SEM. The initial step is to ascertain the loading/weight values of the items, which should not be below 0.7 [101]. Furthermore, it should include a correlation test using the heterotrait-monotrait ratio (HTMT) and an evaluation of the Fornell-Larcker criterion to ascertain its adequacy. It is advisable to exclude values below 0.9 from the model when undertaking HTMT, given that high values may present some problems in the construct. Concerning the Fornell-Larcker criterion, when utilizing a reflective measurement model, it is important to ensure that the correlations between the latent variables within the construct do not exceed the square root of the AVE values [102,103]. The aforementioned indicators are suitable for the determination of discriminant validity in PLS-SEM [101]. The model fit for PLS-SEM is determined by the values of the normed fit index (NFI) and standardized root mean square residual (SRMR) indicators. The recommended value of NFI is 0.9 for samples larger than 250, but a lower value is acceptable for smaller samples [80]. Based on the recommendation of Lohmöller [86], NFI values higher than 0.5 and as close as possible to 1 are acceptable for model fit. To ascertain the suitability of the model fit, it is necessary to determine that the SRMR value is below the threshold of 0.08 [104]. The final PLS-SEM construct can be analyzed using a process of matching the

aforementioned complex indicator sets. The analyses were conducted using IBM SPSS Statistics 25 and SmartPLS 3.2.9.

Data collection

The methodology described was specifically targeted at female respondents (students, lecturers) in a university environment, as this population may have the broadest knowledge of zero waste and a wider audience in terms of age. The necessity for the use of purposive sampling was thus established, and the most practical method of implementation was found to be online. The main details of the questionnaire survey are presented in Table 2. A preliminary survey of 15 students and lecturers was conducted before the finalization of the questionnaire to ascertain the comprehensibility and understandability of the items. The feedback received was incorporated into the final questionnaire.

Table 2. Details of the sample and data collection.

Property	Value
Sample size	180
Context	Hungary
Valid responses	160
Sampling method	purposive
Confidence level	95%
Validity rate	88.88%
Data collection format	online questionnaire
Data collection implementation	Google Forms
Data collection period	June 2023
Main scale types	nominal, ordinal
Ordinal scale type	5-point Likert scale

A total of 180 responses were received during the survey period (June 2023) from which 160 were identified as valid following data cleaning procedures (main reasons for exclusion: schema answers, male respondent). This resulted in a validity rate of 88.88%. The sample size was consistent with the recommendations set forth by Ringle et al. [79], and thus its use is deemed appropriate. The scale used for the measurement was a 5-point Likert scale (strongly disagree–strongly agree), which was adopted due to its ability to convey information effectively [105].

Table 3 provides a brief overview of the sample, including descriptive statistics on the respondents' demographics and their involvement in zero waste initiatives. The results indicate an age distribution with a clear predominance of the first two groups. This may be attributed to the high proportion of student respondents, although it is also possible that older respondents include both correspondence students and lecturers. The distribution of residences also shows a diverse picture, which can be considered appropriate for the analysis. However, it is notable that the city

group is slightly over-represented. This may be due to the location of the university. The distribution of annual net income is also reflective of the sizeable student contribution, with a high proportion of average income judgments. In terms of knowledge of zero waste, it is fortunate that, as anticipated through the use of purposive sampling, a significant proportion of respondents (90%) are familiar with the concept of zero waste, with more than 60% having already purchased a zero waste product. The lack of knowledge regarding the concept was not considered a valid criterion for exclusion, as it was recognized that the academic community itself might also lack familiarity with the concept. Consequently, it was deemed unnecessary to exclude respondents on the basis of this knowledge gap, as doing so could have potentially distorted the accuracy of the measurement results.

Table 3. Descriptive statistics of the sample.

Variable type	Variable	Category	*N*	%
Demography	Birth interval	1995–2009	44	27.50
		1980–1994	58	36.25
		1965–1979	42	26.25
		1946–1964	16	10.00
	Education level	Secondary	43	26.90
		University	117	73.10
	Type of residence	Capital	19	11.90
		County seat	26	16.30
		City	83	51.90
		Village	32	20.00
	Annual net income	No income	13	8.10
		Below average	17	10.80
		Average	98	61.30
		Above average	32	20.00
Zero waste concept	Zero waste concept knowledge	Yes	144	90.00
		No	16	10.00
	Zero waste product purchase	Yes	105	65.60
		No	55	34.40

The data were collected following the sampling methodology selected and aligned with the research objectives, thus rendering the database suitable for further analysis.

RESULTS

It is crucial to emphasize that only the best-fitting model construction is presented for the results. In particular, it is appropriate to focus on the results of the EFA, as this has demonstrated the robust applicability of the PLS-SEM analysis with the latent and included manifest variables. The

Spearman's rho correlation coefficient was employed for the analysis of ordinal data [106], with values above the prescribed threshold (0.3) observed for a substantial number of correlations [95]. This was met in the analysis, as all but two correlations were above the threshold. The correlation values ranged from 0.257 to 0.677. Concerning multicollinearity, the VIFs did not indicate a problem, with values ranging from 1.459 to 4.324. It is not necessary for a normal distribution to be present for PLS-SEM to be applicable [107]. To address this issue, skewness, and kurtosis values were determined during the exploratory factor analysis (EFA) to assess any deviation from the normal distribution: skewness (−1.988–−0.591), kurtosis (−0.509–2.157). The kurtosis value for one item exceeded the theoretical acceptance criterion of 2 [96], yet this should not be considered a reason for exclusion, given the use of PLS-SEM. The KMO value of 0.924 also provides evidence that the best design developed construction in the EFA is appropriate. It is also important to consider the validity, reliability, and sufficiency of the construct designed (Table 4), particularly given that the items used had not yet been combined to form a similar measurement model [94]. The results indicate that the developed construct, comprising 3 latent variables and their manifest variables, can be applied within the awareness measurement framework of the underlying analytical structure.

Table 4. Summary of EFA validity, reliability, and appropriateness.

Latent variable	Statistical test	Test value
Zero Waste Awareness (ZWA)	Cronbach-alpha	0.911
	Composite reliability (CR)	0.934
	Average Explained Variance (AVE)	0.739
Zero Waste Sorting (ZWS)	Cronbach-alpha	0.889
	Composite reliability (CR)	0.931
	Average Explained Variance (AVE)	0.818
Zero Waste Practicality (ZWP)	Cronbach-alpha	0.814
	Composite reliability (CR)	0.878
	Average Explained Variance (AVE)	0.643

It is appropriate now to consider the manifest variables included and the latent variables constructed using them (Table 5). The 3 latent variables previously constructed by the EFA were thus constructed using a total of 12 manifest variables. The loadings (weights) associated with the manifest variables (Figure 1) are appropriate, with values ranging from 0.746 to 0.930. The lack of model construction resulting from the prior item use in research is bridged by the EFA results, as the indicators of the suitability of the model construction have been adequate.

Table 5. Variables included in PLS-SEM based on EFA.

Latent variable	Manifest variable	Code	Source
ZWS	I collect household waste separately.	ZWS1	[22]
	I dispose of hazardous waste at designated collection points.	ZWS2	
	I take advantage of the opportunities offered by the separate collection islands.	ZWS3	
ZWP	I often use shop packaging containers (e.g., jars, tins) for creative purposes.	ZWP1	[108–111]
	I save the wrapping paper and boxes to reuse them.	ZWP2	
	I buy in bulk to use less packaging material.	ZWP3	
	I add new items to my wardrobe only when needed.	ZWP4	
ZWA	I reduce my energy consumption (e.g., turn off the light).	ZWA1	[112–115]
	I do not use disposable products (e.g., cutlery, plastic bottles).	ZWA2	
	I want to be a consumer who eliminates waste in all areas of my life.	ZWA3	
	I am conscious of the impact my purchases will have on my environment.	ZWA4	
	When I make purchases, I am consciously aware of buying products that are durable.	ZWA5	

To assess discriminant validity, it is necessary to review the Fornell-Larcker criterion and the HTMT values [101]. The values associated with the Fornell-Larcker criterion are presented in Table 6. The results demonstrate that the criterion is met, as the correlations between the latent variables within the construct did not exceed the square root of the AVE values (values in the diagonal) [102,103].

Table 6. Results of the Fornell-Larcker criterion.

Latent Variable Correlations	ZWP	ZWS	ZWA	Acceptance
ZWP	0.802	-	-	Yes
ZWS	0.736	0.904	-	Yes
ZWA	0.774	0.809	0.859	Yes

The results of the HTMT test (Table 7) were within the 0.9 tolerance limit [101], thereby conjointly confirming the discriminant validity of the

construct through the application of this test and the Fornell-Larcker criterion.

Table 7. Results of the HTMT test.

Latent Variables	ZWP	ZWS	ZWA
ZWP	-	-	-
ZWS	0.861	-	-
ZWA	0.892	0.896	-

In addition to meeting the aforementioned tests, model fit metrics are also instrumental in determining the applicability of PLS-SEM. Regarding the developed construct, the NFI value was 0.896 and the SRMR value was 0.057, which aligns with the literature recommendations [86,104]. The developed PLS-SEM construct is therefore considered to be reliable and valid, providing an opportunity to describe the path coefficients and their significance levels based on the bootstrap procedure performed with the 2000 subsample and 95% confidence level (Table 8).

Table 8. Path coefficients determined by the Bootstrap method.

Path	Original Sample	Sample Mean	Standard Deviation	T Statistic	*P* Value
ZWP→ZWA	0.3889	0.3925	0.0695	5.5956	<0.001
ZWS→ZWP	0.7358	0.7309	0.0549	13.4090	<0.001
ZWS→ZWA	0.5229	0.5177	0.0769	6.8019	<0.001

The direct pathways are significant, which provides a good basis for exploring the necessary results in the context of hypothesis testing. Furthermore, the explanatory power of the construct developed is also considered considerable in social science analyses ($R^2 > 0.5$) [116], with 72.4% of the variance in zero waste awareness explained by zero waste sorting and zero waste practicality. The Beta values indicate that both effects are positive and that the effect of the former ($\beta_{WS\text{-}ZWA} = 0.523$) is stronger than the latter one ($\beta_{ZWP\text{-}ZWA} = 0.389$). In addition, it can be concluded that female thinking about waste sorting has a strong positive effect ($R^2 = 0.542$, $\beta_{WS\text{-}ZWP} = 0.736$) on zero waste practicality.

Additionally, 54.2% of the variance in practicality is explained by zero waste sorting. The indirect effect of zero waste awareness through zero waste practicality, which is not part of the hypotheses, was also analyzed. These results indicate that at the 0.05 significance level, the indirect and total effects are significant in addition to the direct effect, which implies an indirect effect of sorting on awareness through practicality. It can therefore be concluded that a partial mediation relationship exists in the construct, where the direct effect ($\beta = 0.523$) is stronger than the indirect effect ($\beta = 0.286$). The positive weights indicate that a higher sorting orientation directly increases zero waste awareness, but also increases practicality, which in turn leads to awareness.

Hypotheses testing

A formal analysis of the hypotheses could be performed (Table 9) based on the results of the EFA and PLS-SEM fit indicators and the path analysis of the construct. The results of the hypothesis testing indicate that all three hypotheses can be accepted and that they can be complemented by the informal mediator effect analysis.

Table 9. Results of hypothesis testing based on PLS-SEM results.

Path	Reason			Result
	Standardized Coefficient Value (SCV)	T statistic	*P*	
H1: ZWS→ZWP	0.7358	13.4090	$P < 0.001$	Supported
H2: ZWS→ZWA	0.5229	6.8019	$P < 0.001$	Supported
H3: ZWP→ZWA	0.3889	5.5956	$P < 0.001$	Supported

In the context of the details of the PLS-SEM construct, the findings have revealed insights that could pave the way for new theoretical and practical research directions.

DISCUSSION

The results of the analysis can be interpreted using the model shown in Figure 1, where the relationship between the 3 latent and the 12 manifest variables are described by the beta values as shown on the arrows. In addition to the relationship between the latent variables examined in the hypotheses, it is also important to closely examine the extent to which each manifest variable influences its corresponding latent variable. In this way, more information can be obtained about what factors influence the appearance of the zero waste concept among women. Therefore, the proposed PLS-SEM can be used to conclude that the Hungarian female consumers' key behavior, which affects ZW awareness, is their selective waste collection characteristics, as well as their practical approach to the ZW lifestyle. Regarding the moderator variables, it should also be noted that these relationships are not significantly affected by age group and settlement type.

For zero waste sorting, the largest effect was made by the third manifest variable ($\beta_{ZWS3} = 0.926$) which is about the use of separate waste collection islands. The two other variables (ZWS1 and ZWS2) also suggest that a key focus of zero waste practices for female university students is the proper classification of various waste types to ensure appropriate treatment. Several studies deal with the expansion of students' knowledge of zero waste sorting within the framework of education. For example, Prodyanatasari et al. [117] attempted to increase the knowledge of elementary school students about waste sorting in the context of school community work (e.g., sorting organic and non-organic waste). The experiment has resulted in a considerable improvement. As a result of the

experiment, the students gained significant knowledge in sorting organic and non-organic waste, which may lead to a cleaner school environment and a healthier lifestyle for students. However, Martin [118] conducted a study among university students to determine whether education related to waste sorting improves waste sorting habits and reduces waste contamination on campus. The findings revealed that the educational campaign did not result in a statistically significant change in students' waste sorting habits.

Learning and applying the correct waste sorting method is one of the first steps toward people achieving a zero waste lifestyle. However, the above studies suggest that providing adequate education on the subject is not enough to achieve visible results. In sustainability research, most empirical studies have shown that green organizational initiatives contribute significantly to improving environmental performance [119]. In the case of the present study, this may mean that although, according to the model, zero waste sorting is important for females, the motivation for this was not necessarily achieved as a result of their education. However, the results of the study also indicate that ZW behaviors comprise a multitude of simple actions (e.g., sorting) [20] that collectively make a significant impact on reducing waste and promoting sustainability.

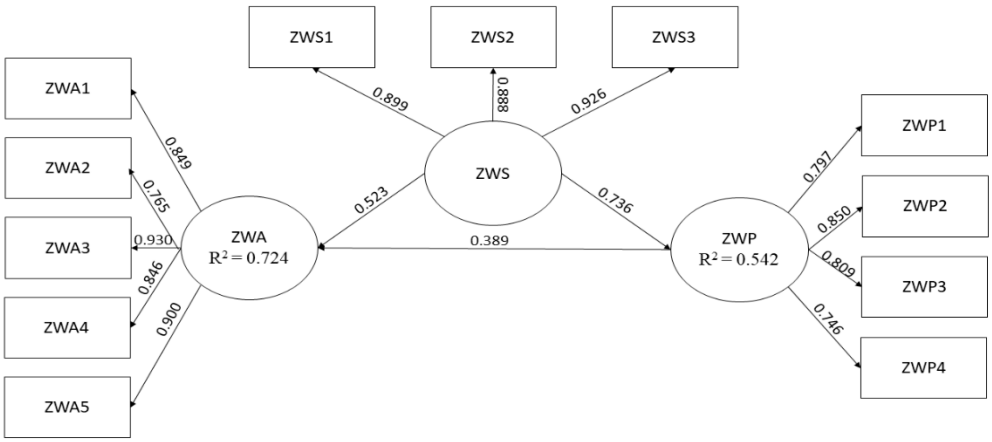

Figure 1. PLS-SEM model with standardized regression weights.

The practical approach to ZW lifestyle (ZWP) is mainly influenced by the handling of packaging (ZWP1, ZWP2, ZWP3) and clothing (ZWP4)—which can significantly contribute to household clutter—with the reuse of packaging waste (β_{ZWP2} = 0.850) as the best describing the factor. The rapid development of e-commerce has led to the widespread use of packaging materials [120], which has increased household waste. Consequently, the growing environmental impact has heightened awareness of sustainable practices (e.g., reuse of packaging containers). The findings of the present research support the reflection that young females acknowledge the necessity for sustainable packaging [121]. Women as highly educated people are more likely to exhibit packaging reusing behaviors [122].

Similarly, clothing also contributes to household waste since the fast fashion industry has led to an increase in clothing purchases. The rapid turnover of clothing items also means that households often accumulate more garments than they need, which causes waste management challenges. Since young females are enthusiastic users of fast fashion [123], it was important to understand their consumer behavior in terms of apparel. The result of our study corresponds with the findings of Mason et al. [49], as young females prioritize practicality and utility over impulsive or trend-driven buying.

Finally, regarding the ZW awareness latent variable, becoming a consumer who minimizes waste in all areas of life demonstrated the strongest effect ($\beta = 0.930$). However, it is important to consider the effects of other manifest variables as well, since by strengthening each other's effect, they exert the greatest influence. This is especially important in the case of ZWA where the explanatory manifest variables cover several areas (energy saving (ZWA1), avoidance of single-use products (ZWA2), adoption of ZW lifestyle (ZWA3), environmental impact of purchase (ZWA4), prioritizing the longevity of products (ZWA5)). Research on pro-environmental choices confirms the connection between awareness and variables such as household energy consumption [124], use of disposable products [60,125], purchase of eco-friendly products [126,127]; however, the present study analyzes these manifest variables collectively, thereby contributing to and expanding the existing literature. As the manifest variables cover not only household waste management activities, it can be concluded that by focusing on sorting (ZWS) and practicality (ZWP), a positive impact on all areas of life—such as conservation of resources (e.g., reducing unnecessary electricity consumption) or changing the consumer mindset (e.g., the desire to eliminate waste in all areas of life)—can be achieved. This suggests that policymakers should enhance zero waste awareness and strengthen regulations in these areas to achieve the best results.

Moreover, it is also possible to consider the zero waste attitudes of female university students in relation to the sustainable development capabilities of universities [128]. Universities that proactively endorse and facilitate sustainable practices, including waste reduction, can empower their students. This fosters a synergistic relationship where student-led initiatives and university policies reinforce each other, creating a mutually beneficial environment.

CONCLUSIONS

The study aims to determine the factors that influence young females' awareness of the zero waste initiative contributing to existing literature in several ways. Hungarian females' sustainable consumption patterns were determined, which are not significantly impacted by age group and residency. Moreover, the proposed PLS-SEM can be used to characterize Hungarian female consumers' pro-environmental behavior. The study

also confirmed the role of ZWS and ZWP on ZWA, by identifying not only the direct impacts of ZWS on ZWA and ZWP on ZWA, but also the indirect impact on ZWS through ZWP on ZWA extending thereby the literature on environmental awareness. Females' behavior is closely linked to selective waste collection and the practical reuse of old products. Moreover, waste separation promotes a practical mindset, highlighting that not all end-of-life products need to be discarded if they can be recycled.

Education on sustainability is important at all educational levels because it equips students with the knowledge and skills necessary to address environmental challenges, promotes responsible stewardship of resources, and fosters innovation in creating sustainable solutions for the future. Incorporating practical projects (project-based learning) where students can work on real-life sustainability and zero waste initiatives, such as campus recycling programs, can provide students with appropriate practices. Universities should encourage and fund research projects that explore innovative solutions for sustainability and zero waste, allowing students to contribute to advancements in these fields.

Despite the limitations of the questionnaire tool, it was considered as an appropriate approach to assessing the factors influencing zero waste awareness of Hungarian females in a campus environment. Moreover, the methodological limitation of using Likert scales is that they rely on self-reported data, which typically results in cross-sectional analyses. The results of the survey, while valuable for decision-makers, should be interpreted with caution as they are not representative. A future objective could be to examine the impact of female contribution to zero waste by analysing panel data on household behaviors. A relevant research direction of moderator variables (age group, comparison of developed and developing countries) could be investigated in the future to provide a more detailed guidance to policy makers.

The model could help the government understand the factors and the mindset from a female perspective in order to partially support the decision-making process related to sustainability from a top-down approach. Decision-makers can support female students' zero waste awareness by implementing educational programs, providing resources, and launching awareness campaigns. They can also offer incentives e.g., scholarships, and research grants, or foster partnerships with organizations to provide mentorship and opportunities. Enacting supportive policies and highlighting female role models in environmental sustainability further empowers and engages female students in zero waste initiatives.

DATA AVAILABILITY

The dataset of the study is available from the authors upon reasonable request.

AUTHOR CONTRIBUTIONS

TV, ÉHR and JPK designed the study. TV validated the concept and methodology. TV, ÉHR and JPK collected the data. TV cleaned and analyzed the data. TV, ÉHR and JPK prepared the original draft. JPK did the supervision and review. TV, ÉHR and JPK worked on the final revision of the manuscript.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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