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A Multidimensional Model of Household Recycling Behaviour in the Circular Economy: The Role of Attitudes, Convenience and Perceived Disposal Ease Bias

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A Multidimensional Model of Household Recycling Behaviour in the Circular Economy: The Role of Attitudes, Convenience and Perceived Disposal Ease Bias

Abstract: Household packaging waste continues to rise despite increasing investments in selective waste collection systems worldwide. This apparent contradiction suggests that recycling behaviour is shaped not only by attitudes and infrastructure but also by cognitive mechanisms. This study develops an integrated behavioural model incorporating environmental attitudes, perceived convenience and a construct termed perceived disposal ease bias (PDEB), capturing justification-related evaluations in which convenient selective waste collection may be perceived as making additional waste-prevention efforts less necessary. Drawing on a large, post-stratified national dataset (n = 3,950), a stepwise partial least squares structural equation modelling (PLS-SEM) approach was applied to evaluate how motivational, perceived system-usability, and bias-related factors are jointly associated with recycling behaviour in a newly implemented curbside system in Hungary. Convenience shows the strongest association with selective waste collection behaviour, accounting for a substantial share of the association between environmental attitudes and recycling behaviour. Environmental attitudes are also positively associated with recycling participation, although this association weakens when additional factors are considered. PDEB exhibits a small but significant negative association with recycling behaviour and is positively associated with both attitudes and convenience. This pattern suggests that the same factors that encourage recycling are also linked to justification-related evaluations that may reduce the perceived importance of waste prevention. These findings point to a more complex relationship between attitudes and behaviour, in which multiple pathways operate simultaneously. While higher recycling participation may be observed, the results highlight the importance of considering broader perceptions and justification-related evaluations when evaluating environmental outcomes. The findings underscore the need for waste policies that address not only participation but also the perceptions and evaluations associated with how households perceive and engage with circular economy interventions.

Keywords: Selective waste collection, Recycling behaviour, Circular economy, Perceived disposal ease bias, Pro-environmental behaviour, PLS-SEM

1. Introduction

The rapid growth in global packaging waste has placed household recycling systems at the centre of environmental policy debates (Pottinger et al., 2024; Ráti & Maró, 2025; Somlai et al., 2023). Across Europe, selective waste collection schemes, particularly curbside systems and deposit–refund mechanisms, are widely promoted as key instruments for reducing material throughput and achieving circular economy targets (European Environment Agency, 2023). Selective waste collection schemes refer to organised systems through which households are encouraged or required to separate recyclable waste fractions, such as paper, plastic, metal, glass, or organic waste, from mixed municipal waste before disposal. These schemes may take different institutional and infrastructural forms, including curbside collection, drop-off recycling points, bring banks, or deposit–refund systems. Their common objective is to improve the quality and quantity of recyclable materials entering waste management systems by making source separation part of everyday household routines (Martinho et al., 2024; Roca et al., 2022). In this sense, selective waste collection represents not only a technical waste management solution but also a behavioural intervention, as its effectiveness depends on how residents understand, evaluate, and use the available infrastructure. Yet despite substantial increases in recycling participation, total household waste generation has continued to rise in many contexts, suggesting that the behavioural mechanisms underlying selective waste collection are more complex than previously assumed (Maier et al., 2023; Ráti & Maró, 2026a, 2026c). This gap

between system-level expectations and observed environmental outcomes highlights the need for a deeper understanding of how motivational, infrastructural, and cognitive factors jointly shape household recycling behaviour.

From a behavioural economics perspective, recycling behaviour can be understood as a household decision shaped by perceived costs, incentives, social norms, and the choice architecture of waste collection systems. Prior research shows that household recycling is influenced not only by environmental concern, but also by self-interest, moral motives, and social pressure (Czajkowski et al., 2017). Experimental studies further suggest that changes in information, visual cues, social norms, and incentive framing can affect recycling-related decisions by reducing cognitive effort or making desirable behaviours more salient (Lotti et al., 2023; Saulītis et al., 2024). This perspective is particularly relevant for curbside selective waste collection, where convenience and system usability may lower the perceived effort of recycling, while also shaping how households evaluate the sufficiency of their environmental behaviour. Research on pro-environmental behaviour has similarly emphasised that attitudes alone do not fully explain recycling participation. Across several empirical studies, stronger environmental concern has been linked to higher levels of waste sorting and recycling participation (Liu et al., 2021; Mobley et al., 2010; Ráti & Maró, 2025). However, the relationship between attitudes and actual behaviour frequently proves inconsistent when everyday routines, situational constraints, and system usability shape behavioural feasibility. Parallel strands of behavioural research point to an additional layer of complexity. Pro-environmental actions may be associated with compensatory or justification-related processes. Studies on moral licensing, negative spillover, and behavioural rebound show that engaging in one environmentally friendly action may be linked to reduced engagement in other sustainable behaviours in certain contexts (Mazar & Zhong, 2010; Tiefenbeck et al., 2013).

In waste management, this can manifest as reduced guilt associated with producing packaging waste or increased tolerance for single-use items once recycling is perceived as effortless (Castro et al., 2022; Dorner, 2019). Recent studies suggest that the introduction of convenient curbside systems may influence how households evaluate their consumption-related behaviours, as waste is perceived to be effectively managed (Maier et al., 2023). Moreover, convenient recycling systems can create a sense of reduced responsibility, which may be associated with reduced attention to waste avoidance or prevention (Dorner, 2019; Zink & Geyer, 2017). These findings suggest that the behavioural implications of improved recycling infrastructure may be more complex than often assumed. Despite these results, a critical gap persists in the literature. Most studies examine either the determinants of recycling participation or the mechanisms of compensatory behaviour but rarely integrate these perspectives into a single analytical model (see e.g., Hope et al., 2018; Sorkun et al., 2025; Tiefenbeck et al., 2013). As a result, the field lacks empirical work demonstrating how environmental attitudes, convenience perceptions, and bias-driven cognitive mechanisms operate simultaneously in shaping household waste practices. Furthermore, while research on rebound and moral licensing frequently highlights that convenient pro-environmental actions can reduce perceived responsibility for further effort (Maier et al., 2023; Mazar & Zhong, 2010; Truelove et al., 2014), existing research has not yet operationalised a reflective, context-specific construct capturing how perceived disposal convenience is associated with evaluations of the need for waste prevention.

To address these shortcomings and gaps, the present study develops and tests a multidimensional behavioural model incorporating environmental attitudes, understood here as perceived environmental effectiveness of selective waste collection, perceived convenience, and a construct termed perceived disposal ease bias (PDEB). PDEB refers to a specific form of bias-driven rationalisation in which individuals interpret the ease and accessibility of selective

waste collection as justification for reduced attention to the environmental impacts of their consumption. While related to behavioural mechanisms such as moral licensing and rebound effects, PDEB does not refer to changes in actual behaviour per se, but rather to a perception-based cognitive process (Tiefenbeck et al., 2013). In this sense, it is most closely aligned with moral licensing yet differs in that it is not necessarily triggered by prior pro-environmental action, but by the perceived convenience of waste management systems. Thus, PDEB is treated in this study as an operational construct that captures context-specific justification processes rather than as a standalone theoretical framework.

Using a large national sample and a stepwise PLS-SEM modelling strategy, the study examines how these components are interrelated within a newly implemented curbside recycling system. Thus, it enables the observation of both behavioural adaptation and emerging cognitive distortions. Based on the above, this study contributes to the waste behaviour and environmental psychology literature in three key ways. First, by introducing and validating PDEB as a context-specific cognitive construct, this study provides empirical evidence that perceived convenience of waste systems may be associated with justification processes independently of prior pro-environmental action. While previous studies have discussed rebound mechanisms conceptually (Dütschke et al., 2018) and documented moral licensing effects in related behavioural domains (Mazar & Zhong, 2010), these approaches have not explicitly captured bias-driven justification processes linked to the perceived convenience of selective waste collection. In this sense, PDEB provides an empirically tractable way to examine such context-specific cognitive mechanisms. Second, the study demonstrates that environmental attitudes have a dual role. They promote recycling behaviour but also increase susceptibility to bias-based rationalisations. This ambivalence, long theorised but rarely empirically tested (Truelove et al., 2014), adds novelty to the literature on negative behavioural spillovers.

Third, the study advances a comprehensive behavioural modelling approach by integrating motivational, perceived system-usability, and cognitive factors into one explanatory framework. This multidimensional perspective offers a more realistic understanding of household waste practices and highlights the importance of analysing recycling not only as a pro-environmental behaviour but also as a potential source of compensatory mechanisms. Together, these contributions highlight the need to move beyond participation-based assessments of recycling systems and to recognise the coexistence of beneficial and counterproductive behavioural pathways. Understanding these dynamics is essential for designing waste policies that genuinely support environmental sustainability rather than merely increasing recycling rates. To do so, the following section (Section 2) presents the theoretical background and the literature underpinning the model, followed by an overview of the data, the measurement development and methodological approach (Section 3). Section 4 reports the empirical results derived from the modelling and Section 5 discusses their implications for current debates on household recycling. Section 6 concludes by summarising the key contributions and main findings of this paper.

2. Literature review

2.1. Theoretical framework

Understanding household selective waste collection requires a coherent theoretical framework that links motivational, facilitating, and bias-related mechanisms. In this study, the primary theoretical foundation is the Theory of Planned Behaviour (TPB) (Ajzen, 1991, 2020; Ajzen & Fishbein, 2000), complemented by moral licensing and behavioural spillover research as a secondary explanatory lens. The TPB provides the main framework for understanding how environmental attitudes and perceived behavioural control shape household recycling

behaviour. Within this framework, environmental attitudes represent the motivational foundation of selective waste collection (Bamberg & Möser, 2007; Liu et al., 2021; Mobley et al., 2010), while perceived convenience is interpreted as a perceived system-usability component of perceived behavioural control, reflecting the extent to which recycling is perceived as easy, accessible, and feasible in everyday household routines. At the same time, the TPB also emphasises that attitudes do not automatically translate into behaviour, because actual engagement depends on perceived behavioural control and situational feasibility (Kollmuss & Agyeman, 2002; Ráti & Maró, 2025). Individuals evaluate the relative "costs" and "benefits" of participation, often deciding based not on intention alone but on convenience, infrastructure availability, and the clarity of instructions. Studies in waste management show that people are far more likely to participate when systems are simple, accessible, and incorporated seamlessly into household routines (Martinho et al., 2024; Roca et al., 2022). Thus, convenience is not treated in this study as a separate theoretical perspective, but as the infrastructural and practical expression of perceived behavioural control within a TPB-based model of recycling behaviour.

To extend this TPB-based explanation, the study incorporates moral licensing and behavioural spillover research to account for bias-related processes that may accompany convenient recycling systems. Performing a pro-environmental action can sometimes license individuals to behave less sustainably in other domains (Dütschke et al., 2018; Mazar & Zhong, 2010; Tiefenbeck et al., 2013). In waste management, this may take the form of reduced guilt about producing packaging waste, increased tolerance of single-use items, or a stronger belief that greater consumption is acceptable if waste is later recycled. These compensatory mechanisms create a paradox. Recycling rates may increase, yet overall waste generation may also rise (Ráti & Maró, 2025). In this study, this bias-related pathway is operationalised through PDEB, which captures the perception that the availability and convenience of selective waste collection may reduce the perceived need for further waste-prevention efforts. The theoretical framework is therefore built around two core foundations. First, the TPB explains the positive behavioural pathway through which environmental attitudes and perceived convenience support recycling behaviour. Second, moral licensing and behavioural spillover research explain the countervailing cognitive pathway through which convenient recycling systems may also give rise to PDEB. This unified framework allows the study to examine selective waste collection as a behaviour shaped simultaneously by motivation, perceived feasibility, and bias-related justification processes.

2.2. Conceptual background and hypotheses development

2.2.1 Environmental attitudes and selective waste collection

Environmental attitudes are consistently identified as core predictors of pro-environmental behaviour, yet decades of research indicate that their effect is far from deterministic. Meta-analyses show a moderate and highly context-dependent link between attitudes and behaviour (Bamberg & Möser, 2007), suggesting that positive attitudes alone do not guarantee consistent recycling behaviour. Empirical studies nevertheless confirm that individuals with stronger environmental concern tend to engage more frequently in recycling activities (Han, 2020; Tang et al., 2022; Widodo & Wahid, 2018) and a positive attitude contributes to the stabilisation of environmentally friendly habits and the sustainability of participation, as emotional reinforcement and moral satisfaction maintain motivation (Best & Mayerl, 2013; Fraj & Martinez, 2007; Maró et al., 2023; Nieto-Villegas et al., 2026).

H1. A positive attitude towards the environment is positively associated with recycling behaviour in selective waste collection.

2.2.2. Convenience and recycling behaviour

Convenience, defined as the perceived ease, simplicity, and accessibility of selective waste collection, has been identified as one of the most powerful predictors of recycling behaviour. Research shows that reducing the physical and cognitive effort associated with sorting (e.g., through curbside collection, proximity of bins, or simplified rules) leads to higher participation rates (Martinho et al., 2024; Roca et al., 2022; Struk, 2017) and facilitates the acceptance of circular-economy collection systems (Ráti & Maró, 2026b). However, the literature also presents critical debate regarding the magnitude of convenience effects. Some studies suggest that convenience is so dominant that it can overshadow attitudinal variables entirely, meaning that even environmentally indifferent individuals are likely to recycle when systems are extremely easy to use (Thomas & Sharp, 2013). In contrast, other authors argue that convenience acts primarily as a moderator. It enables the enactment of pro-environmental intentions but does not replace motivational foundations (Whitmarsh & O'Neill, 2010). Despite these differences in interpretation, there is broad agreement that convenience plays a central role in shaping recycling behaviour by lowering perceived effort and supporting routine participation (Mbiba, 2014; Roca et al., 2022; Roca et al., 2020).

H2. Convenience is positively associated with recycling behaviour.

2.2.3. Perceived disposal ease bias, convenience and recycling behaviour

While convenience is generally associated with higher recycling participation, behavioural research suggests that pro-environmental actions may also be linked to cognitive processes that influence how individuals evaluate their environmental impact. When individuals perceive that their behaviour contributes positively to environmental protection, they may place less emphasis on other aspects of sustainability, a phenomenon often discussed in relation to moral licensing and behavioural justification (Castro et al., 2022; Dorner, 2019). In waste management, the perceived ease of disposal may contribute to such justification processes. If recycling is experienced as simple and effortless, individuals may interpret their participation as sufficient, potentially reducing attention to other environmentally relevant considerations, such as waste prevention (Castro et al., 2022; Font Vivanco et al., 2016; Maier et al., 2023; Zink & Geyer, 2017). Rather than reflecting changes in actual consumption or waste generation, this mechanism operates at the level of perception and evaluation, influencing how individuals assess the environmental adequacy of their behaviour (Kollmuss & Agyeman, 2002; Steg & Vlek, 2009). Furthermore, prior studies suggest that convenience can shift attention towards waste handling processes rather than broader environmental impacts. When waste management systems are perceived as efficient and accessible, individuals may rely more strongly on these systems in evaluating their environmental behaviour (Maier et al., 2023). In this context, PDEB is not expected to be associated with the amount of recyclable material directly, but rather with how consistently individuals engage in selective waste collection. Because PDEB reflects reduced perceived responsibility within the same household waste-management domain, perceiving recycling as environmentally sufficient may weaken the attention and self-regulatory effort required for repeated and correct waste sorting. This provides a theoretical basis for expecting less consistent recycling participation, although the relationship should not be interpreted as a direct test of waste-prevention behaviour. Based on this reasoning, perceived disposal ease bias is expected to show a negative association with recycling behaviour, while convenience is expected to be positively associated with the emergence of such bias-related evaluations.

H3. Perceived disposal ease bias is negatively associated with the regularity of selective waste collection.

H4. Convenience is positively associated with perceived disposal ease bias.

2.2.4. Environmental attitudes and perceived disposal ease bias

The relationship between environmental attitudes and moral licensing tendencies remains debated in the literature. Some studies suggest that individuals with a strong pro-environmental self-identity are less prone to negative spillover effects, as their behaviour is guided by stable values (Moser & Kleinhückelkotten, 2018). In contrast, other research indicates that a stronger environmental self-concept may be associated with a greater likelihood of justification processes, as individuals who perceive themselves as environmentally responsible may tolerate occasional inconsistencies (Reimers et al., 2022). Empirical findings across domains such as energy conservation, green consumption, and recycling provide mixed evidence, suggesting that pro-environmental attitudes may be linked not only to recycling behaviour but also to context-dependent justification processes (Adıgüzel et al., 2020; Tiefenbeck et al., 2013). In this context, environmental attitudes may be associated with cognitive evaluations that influence how individuals interpret the environmental adequacy of their behaviour, particularly in situations where recycling is highly convenient.

H5. Environmental attitudes are positively associated with perceived disposal ease bias.

3. Materials and methods

3.1. Presentation of the questionnaire and sample

The questionnaire was created using Google Forms, which ensured the anonymity of respondents. Participation was voluntary, and respondents received detailed information about the purpose of the research and the method of data processing before completing the questionnaire. The established methodological recommendations were followed for data collection via social media (Fricker, 2008; Kosinski et al., 2015). Data collection was carried out through specifically selected public social media groups, primarily based on locality and regional relevance, to ensure that the sample provided the broadest possible cross-section of Hungarian society in terms of gender, age group, educational attainment, and region, covering both urban and rural environments. Data collection took place between October 28 and December 5, 2024, when the waste collection system was already fully operational. For this reason, the questionnaire did not allow for a comparison of household responses at the time of the introduction of different systems, but it did make it possible to measure the behaviours and attitudes that had formed under the existing system. The survey was shared in a total of 122 social media groups, each with at least 1,000 members. A total of 4,041 responses were received to the questionnaire. After filtering out incomplete or invalid responses, 3,950 individuals were included in the final analysis. A post-stratification weighting was applied to ensure that the sample was aligned with the national distribution in terms of gender, age, education, and region (see Table 1). Weighting was performed using the anesrake function of the R software package, which implements the raking procedure (DeBell & Krosnick, 2009).

Table 1. Distribution of the post-weighted sample

Variable	Sample distribution	Hungarian distribution
Gender		
Male	33.49%	47.57%
Female	66.51%	52.43%
Age		
18–29	22%	16.04%
30–39	16.35%	15.68%

40–59	42.63%	36.29%
60+	19.01%	31.98%
Region		
Central Hungary	21.39%	31.50%
Central Transdanubia	10.35%	11.03%
Western Transdanubia	9.67%	10.24%
Southern Transdanubia	7.49%	8.89%
Northern Hungary	13.43%	11.30%
Northern Great Plain	21.82%	14.59%
Southern Great Plain	15.8%	12.44%
Highest level of education		
Primary	4.73%	17.07%
Secondary	56%	56.68%
Tertiary	39.27%	26.25%

Note: Own data collection post-weighted using the data published by the Hungarian Central Statistical Office (2025).

3.2. Methods and models used

The analysis employed structural equation modelling (SEM) using the variance-based partial least squares (PLS-SEM) approach. PLS-SEM is particularly suitable for complex attitudinal frameworks in which latent constructs are measured with Likert-type indicators and the assumption of multivariate normality may not hold (Haenlein & Kaplan, 2004; Henseler et al., 2015). In addition, this method is well aligned with predictive objectives and theory-building efforts in emerging research areas, such as consumer participation in selective waste collection (Chin et al., 2020; Pereira et al., 2024). Model building proceeded in three stages, each adding a theoretically motivated layer to the explanatory framework: (1) developing the basic attitude model, (2) integrating the PDEB mechanism, and (3) incorporating perceived convenience and system-usability effects. This stepwise approach allows the incremental contribution of each construct to be assessed while maintaining theoretical coherence across specifications.

3.2.1. Step 1: The basic attitude model

The theoretical framework of the study is grounded in the TPB and research on the attitude–behaviour relationship. Previous literature identifies environmental attitudes as key predictors of pro-environmental behaviour (Ajzen, 1991; Bamberg & Möser, 2007; Langenbach et al., 2020). Empirical studies further show that individuals who hold stronger sustainability-oriented values are more likely to engage in environmentally friendly actions (Cayolla et al., 2023; Essiz et al., 2023; Oreg & Katz-Gerro, 2006). The baseline model is specified using two core constructs: environmental attitudes (EA) and recycling behaviour (RB), measured as the frequency of selective waste collection. In line with the principle of compatibility in the TPB, which holds that attitudes should be assessed at the same level of specificity as the behaviour they are expected to predict, the EA construct in this study is operationalised at the behaviour-specific level. Thus, EA captures domain-specific environmental attitudes, namely respondents' beliefs about the environmental effectiveness of selective waste collection, rather than a general ecological orientation. Furthermore, RB is a self-reported, single-item measure capturing the consistency with which respondents selectively collect the recyclable paper and plastic waste they generate, rather than the absolute frequency of disposal occasions. EA is operationalised as a reflective latent construct with multiple indicators, whereas RB is modelled as a single item. In the structural model, EA is specified as being directly associated with RB, allowing for the examination of the attitude-behaviour relationship. This specification also serves as a

benchmark against which the explanatory contribution of subsequently introduced constructs can be evaluated.

3.2.2. Step 2: A perceived disposal ease bias (PDEB)

In the second stage, the model was extended to incorporate bias-related cognitive processes, drawing on insights from the literature on moral licensing, rebound effects, and behavioural justification (Dütschke et al., 2018; Reimers et al., 2022; Tiefenbeck et al., 2013). Prior research suggests that pro-environmental actions may be associated with subsequent cognitive evaluations that influence how individuals assess the adequacy of their behaviour. The questionnaire included items that capture such evaluative tendencies, particularly those related to reduced perceived responsibility and the justification of behavioural inconsistencies. Within the model, this dimension is represented as PDEB, which reflects a context-dependent cognitive evaluation linked to waste management practices. Although PDEB shares conceptual territory with moral licensing, compensatory beliefs, and rebound effects, it is analytically distinguishable from these concepts. Moral licensing generally refers to a process in which prior moral or pro-environmental behaviour provides individuals with a form of moral credential, thereby weakening motivation to engage in subsequent sustainable behaviour (Mazar & Zhong, 2010; Tiefenbeck et al., 2013). Rebound effects, in contrast, refer to situations in which efficiency gains or easier access to a pro-environmental option are partly offset by behavioural responses that increase overall consumption or reduce net environmental benefits (Zink & Geyer, 2017; Castro et al., 2022).

PDEB differs from both mechanisms in its primary activating condition and empirical focus. It does not require a consciously recalled prior pro-environmental action, nor does it assume measurable cost savings or increased consumption. Instead, it captures a context-specific evaluative tendency whereby the perceived convenience, accessibility, and effectiveness of the waste management system may lead individuals to regard additional waste-prevention efforts as less necessary. In other words, the mechanism is not based primarily on personal moral credit or on realised efficiency gains, but on the subjective perception that the disposal system adequately handles the environmental consequences of household waste. PDEB is therefore treated in this study not as a standalone theory competing with moral licensing or rebound frameworks, but as a context-specific operational construct that captures an infrastructure-induced form of cognitive justification in the domain of selective waste collection. This distinction justifies the development of a context-specific construct rather than the adoption of existing scales. By introducing PDEB at this stage, the model can assess whether bias-related cognitive processes account for additional variance in RB beyond the direct association of EA alone. It should be noted that, while the PDEB items were designed to capture generalised evaluative tendencies, some elements remain contextually linked to recycling practices and system characteristics. Thus, the construct reflects context-specific evaluations rather than a fully abstract cognitive bias, which should be considered when interpreting the structural relationships.

3.2.3. Step 3: The role of convenience

The final model includes EA, RB, PDEB, and Convenience as key constructs. Throughout the analysis, Convenience is used as a concise label for the perceived convenience and usability of the curbside selective waste collection system. This construct should not be interpreted as a purely infrastructural measure. Rather, it captures respondents' overall evaluation of the system's ease of use, efficiency, accessibility, and general usability. Thus, it represents a multidimensional perceived system-usability construct, consistent with the broader

conceptualisation of convenience in recycling behaviour research (Fraj & Martinez, 2007; Martinho et al., 2024; Roca et al., 2022). Its inclusion in the third stage, rather than the baseline model, reflects a deliberate analytical choice. By first establishing the attitude–behaviour and attitude-bias relationships, the model can isolate the incremental and indirect role of convenience without conflating motivational and perceived convenience and system-usability effects. Previous research has shown that positive environmental attitudes are associated with environmentally conscious action (Ajzen, 1991; Cayolla et al., 2023; Langenbach et al., 2020). At the same time, the literature suggests that pro-environmental actions may also be linked to cognitive processes that influence how individuals evaluate their behaviour. In line with this perspective, PDEB is conceptualised as a context-dependent evaluative process, whereby individuals may interpret their behaviour as environmentally sufficient. In the model, PDEB is specified to have a negative association with recycling behaviour. The convenience construct captures the perceived ease of selective waste collection and represents a key component of perceived behavioural control within the TPB framework. Studies show that greater convenience promotes recycling and other sustainable behaviours (Leknoi et al., 2024; Martinho et al., 2024; Roca et al., 2022). Thus, convenience is specified to have a positive association with recycling behaviour. At the same time, prior research suggests that ease of action may also be linked to bias-related evaluations in certain contexts (Truelove et al., 2014), supporting the inclusion of a relationship between convenience and PDEB in the model. The measurement model is reflective for the multi-item constructs (EA, PDEB, and Convenience), each assigned multiple reliable indicators. PLS-SEM is also suitable for handling smaller factors, but special attention should be paid to the AVE, CR, and HTMT indicators during the reliability test (Hair, 2014; Hair Jr et al., 2021). When evaluating the structural model, the focus is on path coefficients, explained variance (R^2), and predictive performance. In addition, bootstrap testing of path coefficients is also performed (Streukens & Leroi-Werelds, 2016).

4. Results

4.1. Measurement model and factor structure

Before estimating the structural model, the measurement structure was assessed through factor-analytic and validity diagnostics. Harman's single-factor test indicated that a single factor accounted for 40.4% of the total variance, below the 50% threshold commonly used to assess common method bias (Podsakoff et al., 2003). The marker-variable approach also did not indicate substantial common method variance, as correlations with theoretically unrelated items ranged from 0.14 to 0.49, with most values below 0.30 (Simmering et al., 2015). The data were suitable for factor analysis (Bartlett, 1954; Field, 2024; Kaiser, 1974): the Kaiser–Meyer–Olkin value was 0.883, Bartlett's test of sphericity was significant ($\chi^2(153) = 25{,}170.165$, $p < 0.001$), communalities ranged from 0.47 to 0.82, and all residual correlations were below 0.20 in absolute value. The principal-component factor analysis supported a three-factor solution. The extracted components had eigenvalues of 5.26, 2.84, and 1.78 and jointly explained 54.9% of the total variance. After retaining only items with loadings of at least 0.60, the final three-factor structure explained 66.3% of the variance before rotation and 27.9%, 20.6%, and 17.7% after varimax rotation. The three factors corresponded to perceived convenience and usability, PDEB, and environmental attitudes. Five items did not reach this 0.60 threshold on any factor and were removed prior to specifying the final structural model (Field, 2024; Hair Jr et al., 2021); they are listed in the Appendix (Table A1).

Table 2. Factor structure of the attitude-related variables

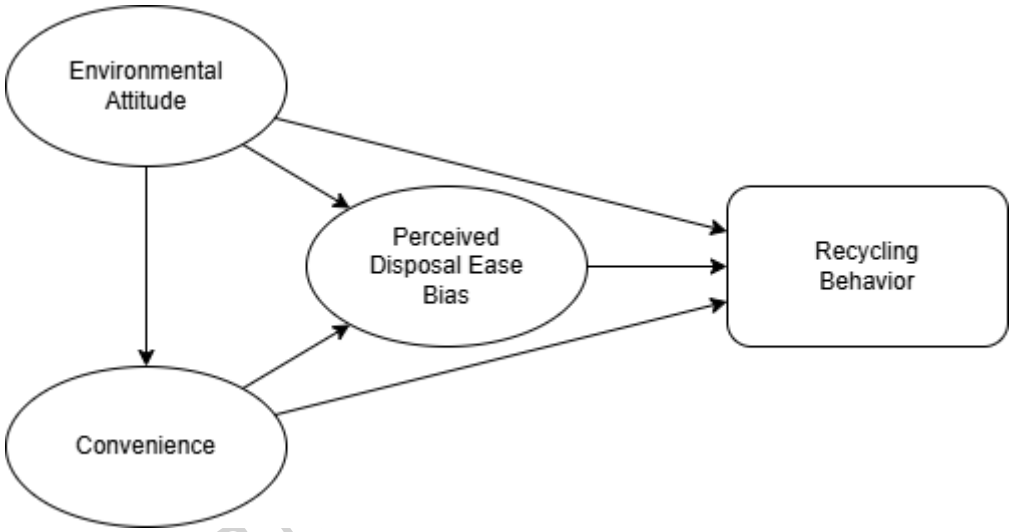
Item	Construct	Supporting lit.	Factor
Selective waste collection contributes to the fight against climate change.	Environmental Attitude (Perceived Environmental Effectiveness of Selective Waste Collection)	(Ajzen, 1991, 2020; Nameghi & Shadi, 2013)	0.8424
Waste management problems can be solved through selective waste collection.		(Ajzen, 1991, 2020; Nameghi & Shadi, 2013)	0.8570
Selective waste collection can solve waste management problems.		(Ajzen, 1991, 2020; Nameghi & Shadi, 2013)	0.7310
The curbside selective waste collection is more convenient than the former recycling drop-off stations.	Convenience	(Ajzen, 2020; Han & Kim, 2010)	0.7708
The availability of selective bins at home makes selective waste collection easier.		(Ajzen, 2020; Han & Kim, 2010)	0.8571
Curbside selective waste collection is simple and convenient.		(Ajzen, 2020; Han & Kim, 2010)	0.8155
Curbside selective waste collection helps me collect waste more efficiently.		(Ajzen, 2020; Han & Kim, 2010)	0.7697
I am glad that the curbside selective waste collection system has been introduced, as it helps me sort my waste better.		(Hansla et al., 2008; Nameghi & Shadi, 2013)	0.6742
I consider curbside selective waste collection to be a good solution.		(Hansla et al., 2008; Nameghi & Shadi, 2013)	0.7089
Since selective waste collection is available, I care less if I forget to bring a bag and must use a single-use plastic bag.	Perceived Disposal Ease Bias*	Own construct based on (Maier et al., 2023; Zink & Geyer, 2017)	0.7163
Because I collect waste selectively, it does not matter how much waste I produce, since it will be recycled anyway.		Own construct based on (Maier et al., 2023; Zink & Geyer, 2017)	0.8571
Thanks to curbside selective waste collection, I do not have to pay as much attention to how much packaged product I buy.		Own construct based on (Maier et al., 2023; Zink & Geyer, 2017)	0.7972
I feel less responsible for the amount of waste I generate because I collect it selectively.		Own construct based on (Maier et al., 2023; Zink & Geyer, 2017)	0.7925

*Note: *Although the wording of the PDEB items does not replicate existing scales verbatim, their formulation is grounded in established literature on environmental attitudes, behavioural spillover, and justification processes. As no validated scale currently exists that captures this specific combination of mechanisms in the context of waste management, the items were conceptually derived and subsequently tested empirically. In this study, PDEB is conceptualised as an operational construct reflecting a context-dependent justification process, whereby individuals evaluate their recycling behaviour as environmentally sufficient due to the*

perceived ease of waste disposal. This perception may reduce the perceived importance of additional pro-environmental considerations, such as waste prevention. Thus, PDEB captures a specific form of subjective environmental self-assessment shaped by the convenience of recycling systems.

RB was measured using a single self-report item: "How regularly do you selectively collect the recyclable paper and plastic waste you generate?" Responses were recorded on a five-point frequency scale: 1 = never, 2 = rarely, 3 = about half of the time, 4 = usually, but not always, and 5 = always. Higher values indicate more regular and consistent selective collection. The distribution of RB was strongly skewed towards consistent selective collection: 44.7% of respondents reported always selectively collecting their recyclable paper and plastic waste, a further 30.2% reported doing so usually, but not always, while only 3.6% reported never doing so (weighted M = 4.02, SD = 1.13 on a 1–5 scale; see Appendix Table A2). Based on the above, the final model structure is presented in Figure 1.

Figure 1. Multidimensional model



In the PLS-SEM modelling process, the following steps were carried out: (1) identification of the main constructs (see Figure 1) based on the theoretical framework; (2) specification of the relationships between latent variables and their measurement indicators (outer model); (3) definition of the regression paths between the latent constructs (inner model). This approach allows a deeper and more complex understanding of the relationships between attitudes, convenience perceptions, PDEB mechanisms, and their influence on reported recycling behaviour. The validity of the outer model was assessed using standard reliability and validity criteria. Internal consistency was confirmed, as Cronbach's alpha, composite reliability (rhoC), and rhoA all exceeded the recommended threshold of 0.70, and convergent validity was established, with the Average Variance Extracted (AVE) above the 0.50 cutoff (Hair Jr et al., 2021). As presented in Table 3, all three constructs demonstrated strong reliability and stable internal consistency.

Table 3. Reliability and convergent validity of constructs

Construct	Cronbach's Alpha	rhoC	AVE	rhoA
EA	0.816	0.822	0.609	0.833
Convenience	0.882	0.882	0.556	0.888

PDEB	0.806	0.769	0.504	0.828

Note: Discriminant validity was assessed applying two approaches: the Heterotrait–Monotrait Ratio of Correlations (HTMT) and the Fornell–Larcker criterion (Fornell & Larcker, 1981; Henseler et al., 2015).

Discriminant validity was assessed using the Heterotrait–Monotrait Ratio of Correlations (HTMT) and the Fornell–Larcker criterion, complemented by 95% bias-corrected and accelerated (BCa) confidence intervals from bootstrapping with 5,000 subsamples (Fornell & Larcker, 1981; Henseler et al., 2015). Both approaches and the additional confidence-interval assessment supported satisfactory discriminant validity (Table 4).

Table 4. Summary of discriminant validity

Construct Pair	**Fornell–Larcker Criterion**	**HTMT Ratio < 0.90**	**HTMT CI Upper Bound < 1.00**
EA → Convenience	0.780 > 0.519	0.582	0.591
EA → PDEB	0.780 > 0.259	0.294	0.305
EA → RB	0.780 > 0.436	0.465	0.477
Convenience → PDEB	0.746 > 0.208	0.224	0.230
Convenience → RB	0.746 > 0.528	0.487	0.496
PDEB → RB	0.710 > 0.071	0.093	0.098

Note: Fornell–Larcker criterion: the square root of each construct's AVE should exceed its correlations with all other constructs. HTMT ratio: acceptable values are below 0.90 (or below 0.85 when applying stricter criteria). HTMT confidence interval: the upper bound of the 95% confidence interval must remain below 1.00.

The structural model was assessed by analysing the path coefficients (β-values) linking the latent constructs and the proportion of explained variance (R^2) for the endogenous variables (Chin, 1998; Hair Jr et al., 2010). The model showed moderate explanatory capacity for Convenience and RB, while PDEB exhibited a lower level of explained variance. All path relationships were statistically significant according to the bootstrapping procedure (5,000 resamples), and the positive Stone–Geisser Q^2 statistics obtained for each endogenous construct confirmed the model's predictive relevance and overall robustness. To further assess the validity of the PDEB construct, three additional validation procedures were conducted. First, a confirmatory factor analysis (CFA) was performed on the PDEB items using the lavaan package in R, with the MLR estimator to account for the ordinal nature of the data. The results indicated excellent model fit (CFI = 0.999, TLI = 0.997, RMSEA = 0.025, SRMR = 0.006), well within conventionally accepted thresholds (Hu & Bentler, 1999), and all standardised loadings were significant and substantial, confirming the unidimensionality of the construct. Second, a split-sample validation assessed the stability of the structural model across independent subsamples: the full weighted sample was randomly divided into two equal halves, and the complete PLS-SEM model was re-estimated for each subsample using 5,000 bootstrap resamples. The path coefficients were highly consistent across both subsamples (ranged only from 0.001 to 0.015), well below the level generally considered indicative of instability (Hair Jr et al., 2021), indicating that the model structure and the role of PDEB within it are robust and not sample specific. Third, nomological validity was assessed by examining whether PDEB relates to the other constructs in theoretically expected directions. As anticipated, PDEB was positively associated with both EA and perceived Convenience, and negatively associated with RB,

consistent with its conceptualisation as a bias-driven justification process that is reinforced by pro-environmental orientations and system convenience while being associated with reduced consistency in recycling engagement.

4.2. Structural model results

The modelling process was carried out in three stages, corresponding to the gradual expansion of the conceptual framework. The estimated path coefficients across the three specifications are summarised in Table 5. The first model focused exclusively on the direct association of environmental attitudes (EA) and recycling behaviour (RB). This baseline specification confirmed the strong and significant role of EA in RB (EA → RB = 0.474), with attitudes alone accounting for 22.5% of the variance (R^2 = 0.225). The second model added the PDEB construct, capturing bias-related evaluative processes. The direct association between EA and RB remained strong (0.503), EA were positively associated with PDEB (EA → PDEB = 0.348), and PDEB showed a small but significant negative association with RB (–0.073). This slight strengthening of the EA → RB path once PDEB is included is consistent with a suppression or complementary mediation effect, suggesting that PDEB captures an additional cognitive dimension associated with RB rather than simply mediating the attitude effect in a conventional sense.

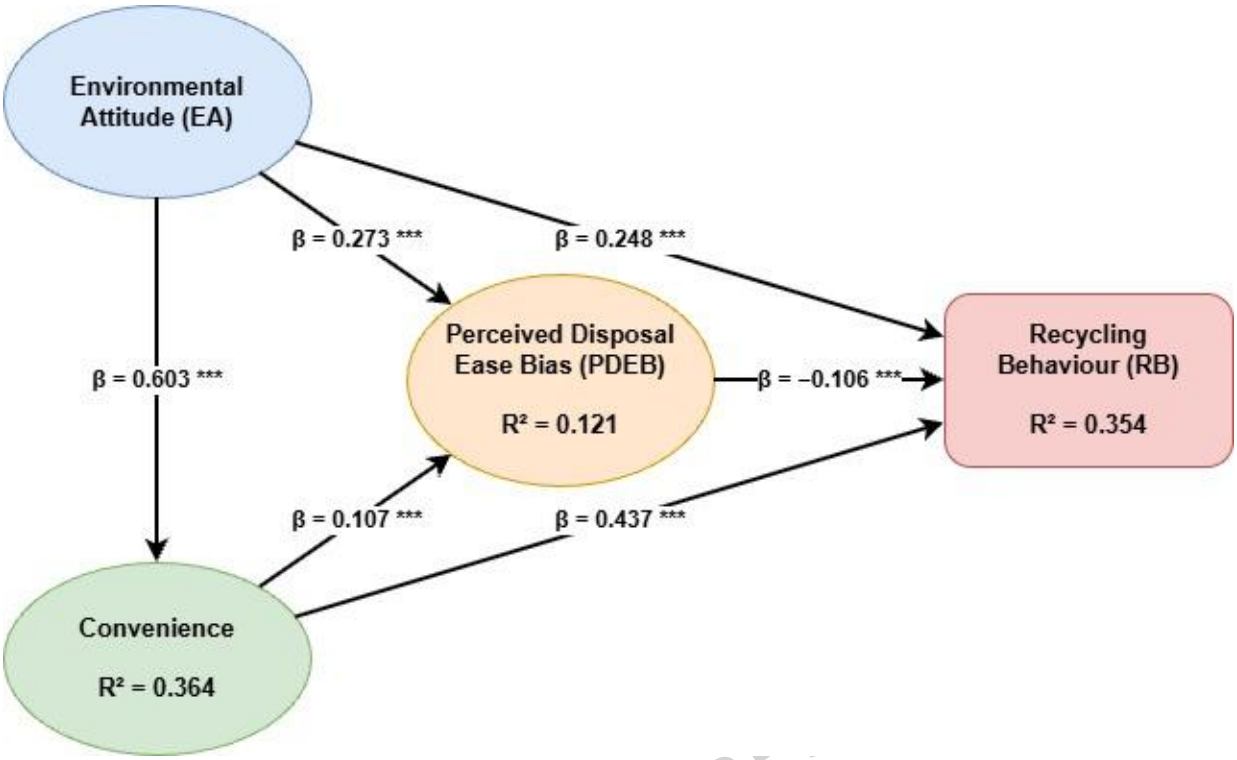
The third model integrated Convenience, completing the conceptual framework and yielding the highest explanatory power (R^2 = 0.364 for Convenience, 0.121 for PDEB, 0.354 for RB). EA were strongly associated with perceived convenience (EA → Convenience = 0.603), which in turn showed a substantial positive association with RB (Convenience → RB = 0.437). The direct association between EA and RB declined to 0.248, indicating that part of this relationship operates through perceived convenience. EA remained positively associated with PDEB, though weaker than in Model 2 (0.273), and convenience also showed a positive association with PDEB (0.107). PDEB retained, and slightly strengthened, its negative association with RB (–0.106). Taken together, these results indicate that EA are linked to RB through multiple pathways: a facilitating route via perceived convenience and a constraining route via PDEB. This highlights the importance of considering both contextual (infrastructural) and cognitive factors when examining pro-environmental behaviour.

Table 5. Comparative path coefficients across models

Path	Model 1	Model 2	Model 3
EA → RB	0.474***	0.503***	0.248***
EA → PDEB	–	0.348***	0.273***
PDEB → RB	–	-0.073***	-0.106***
EA → Convenience	–	–	0.603***
Convenience → RB	–	–	0.437***
Convenience → PDEB	–	–	0.107***

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.*

Figure 2. Final multidimensional model



*Note: *** p < 0.01; ** p < 0.05; * p < 0.10.*

To assess the indirect role of Convenience, the total association between EA and RB was decomposed into direct and indirect components. The total association between EA and RB (0.476) comprised a direct association of 0.248 and a total indirect association of 0.228. The largest specific indirect association operated through perceived convenience (EA → Convenience → RB = 0.264). The PDEB-related indirect associations were small and operated as minor countervailing pathways rather than central mediation mechanisms. The full decomposition is reported in Appendix Table A3.

4.3. Robustness checks

To assess whether the structural relationships are sensitive to the demographic composition of the sample, the final model was re-estimated with demographic controls (gender, age group, education, and region) added as direct predictors of RB. The core relationships remained essentially unchanged: the path coefficients of the main constructs shifted only marginally, and Convenience remained the strongest correlate of RB. The full comparison of the structural paths with and without controls is reported in Table 6, and the coefficients of the individual controls in Table A4. Adding the controls increased the explained variance in RB only slightly (R^2 rising from 0.354 to 0.391), indicating that demographic characteristics account for little variance beyond the attitudinal and cognitive constructs. Educational attainment followed the expected pattern, with tertiary education associated with higher and primary education with lower RB, and younger respondents recycled somewhat less; these demographic effects were nonetheless small relative to the main constructs.

Table 6. Structural path coefficients with and without demographic controls

Structural path	β (without controls)	β (with controls)
EA → Convenience	0.603***	0.603***
EA → PDEB	0.273***	0.260***
EA → RB	0.248***	0.246***
Convenience → PDEB	0.107***	0.085***
Convenience → RB	0.437***	0.397***
PDEB → RB	−0.106***	−0.081***
Explained variance (R^2)		
Convenience	0.364	0.364
PDEB	0.121	0.102
RB	0.354	0.391

*Note: Standardised path coefficients (β) from the final structural model estimated without and with demographic controls (gender, age group, education, region) entered as direct predictors of recycling behaviour (RB). The measurement and structural specification (EA → Convenience → PDEB → RB) is identical across the two models. *** p < 0.01; ** p < 0.05; * p < 0.10.*

As an additional contextual plausibility check, the Hungarian results were situated within comparative European survey evidence on environmental orientation (European Commission, 2024). On general, principle-level environmental attitudes, Hungarian respondents are at or above the EU27 average: 84% agree that environmental issues directly affect their daily life and health (EU27: 78%), 94% consider EU environmental legislation necessary to protect the environment in their country (EU27: 84%), 64% identify promoting the circular economy as one of the most effective ways of tackling environmental problems (EU27: 58%; QB2T), and 59% report a willingness to pay more for products that are easier to repair, recyclable, or sustainably produced (EU27: 47%). When the focus shifts from general orientation to concrete waste-reduction practices, however, the pattern reverses: only 53% of Hungarian respondents report correctly sorting their waste for recycling (EU27: 66%) and 44% report using reusable packaging (EU27: 52%). Hungary thus combines broad, though somewhat less intense, principle-level environmental support with comparatively lower self-reported engagement in specific waste-reduction behaviours.

This pattern provides additional contextual insight for interpreting PDEB. At the population level, Hungary appears to combine relatively strong general environmental endorsement with comparatively lower self-reported engagement in specific waste-reduction practices. This contrast is consistent with the broader attitude–behaviour divergence examined in the present model. Favourable environmental self-perceptions may coexist with justification-related

evaluations and lower engagement in concrete waste-related behaviours. In such a context, the perceived availability and convenience of selective waste collection may contribute to the perception that one's own behaviour is environmentally sufficient. However, this interpretation should be treated with caution. The comparative Eurobarometer items are self-reported and partly intention-based, rather than observed behavioural measures, and they are not identical to the recycling-behaviour item used in the present study. In addition, the data are cross-sectional. Therefore, it should be understood as a contextual plausibility check for the relevance of PDEB in the Hungarian setting, not as direct evidence of the PDEB mechanism itself.

4.4. Interpretation of the hypotheses

The final structural model allowed the simultaneous assessment of all five hypothesised relationships (Figure 2). Each hypothesis was evaluated based on the standardised path coefficients, their significance levels, and the confidence intervals obtained through bootstrapping. The results consistently indicate that EA, Convenience and PDEB show distinct associations with RB. The empirical support for each hypothesis is summarised in Table 7. EA exhibited a positive and statistically significant association with RB (H1). Although the coefficient decreased in magnitude in the full model compared to earlier stages, the association remained robust ($\beta = 0.248$, $p < 0.001$). This suggests that EA continue to function as an important psychological driver of selective waste collection, even when additional factors are considered. Convenience emerged as one of the strongest correlates of RB (H2). The relationship was positive, substantial, and highly significant ($\beta = 0.437$, $p < 0.001$). This indicates that when selective collection is perceived as simple and accessible, participation is more likely to be maintained at higher levels, suggesting a facilitating role of system design.

The analysis also revealed a statistically significant but small negative association between PDEB and RB (H3). Although the magnitude was modest ($\beta = –0.106$, $p < 0.001$), the direction of the relationship is consistent with the proposed model. This suggests that bias-related evaluations may be associated with less consistent engagement in RB. A further statistically significant relationship was observed between Convenience and PDEB (H4). Convenience was positively, although weakly, associated with PDEB ($\beta = 0.107$, $p < 0.001$). Although the effect size is limited, this suggests a potential link between system characteristics and bias-related evaluations. Finally, EA were also positively associated with PDEB (H5). The path coefficient was moderate in size and statistically significant ($\beta = 0.273$, $p < 0.001$). This indicates that pro-environmental attitudes may coexist with bias-related evaluations, suggesting the presence of multiple cognitive processes operating simultaneously. Thus, the results collectively indicate that while attitudes and convenience are positively associated with recycling behaviour, bias-related mechanisms may operate alongside these relationships and be associated with lower consistency in participation.

Table 7. Summary of the hypotheses

Hypothesis	Relationship	Standardised coefficient (β)	Result	Interpretation
H1	Environmental Attitude → Recycling Behaviour	0.248***	Supported	Stronger environmental attitudes are associated with higher recycling behaviour, but their direct association weakens once convenience and bias are included. This suggests that attitudes function primarily as a motivational foundation, rather

				than a standalone driver of behaviour.
H2	Convenience → Recycling Behaviour	0.437***	Supported	Convenience shows the strongest positive association with recycling behaviour. A simple, accessible system substantially strengthens routine participation and appears to account for part of the association between environmental attitudes and recycling behaviour.
H3	PDEB → Recycling Behaviour	–0.106***	Supported	PDEB is slightly but significantly negatively associated with recycling behaviour. This suggests that bias-related evaluative processes may be associated with less consistent engagement in recycling behaviour, even when attitudes and infrastructure are favourable.
H4	Convenience → PDEB	0.107***	Supported	More convenient systems are associated with the bias: greater ease of recycling may be associated with stronger bias-related evaluations, and may be linked to reduced attention to waste prevention.
H5	Environmental Attitude → PDEB	0.273***	Supported	Strong pro-environmental attitudes are positively associated with PDEB. This suggests that pro-environmental attitudes may coexist with justification processes, indicating that multiple cognitive mechanisms may operate simultaneously.

*Note: *** $p < 0.01$*

5. Discussion

5.1. Summary and discussion of the main findings

This study examined the combined associations between environmental attitudes, convenience, PDEB and household selective waste collection in a newly implemented curbside system. The results suggest that recycling behaviour is associated with multiple factors rather than with a single explanatory mechanism. Environmental attitudes showed a positive and significant association with recycling behaviour, which is consistent with prior evidence linking pro-environmental attitudes to waste-related behaviour (Bamberg & Möser, 2007; Mobley et al., 2010). However, the reduction in the environmental attitude–recycling behaviour association

in the full model indicates that the role of attitudes is conditional on other perceived factors, particularly system usability. This finding extends prior research on the attitude–behaviour gap by showing that attitudes do not merely weaken under real-world constraints, but appear to be conditioned by system usability and cognitive evaluations (Blake, 1999; Kollmuss & Agyeman, 2002). Convenience emerged as the strongest correlate of selective waste collection. This is in line with studies showing that simpler, more accessible systems are associated with higher participation (Maró & Ráti, 2026; Martinho et al., 2024; Roca et al., 2022). Convenience appears to be the main perceived system-related factor associated with recycling behaviour. It also accounted for a substantial portion of the association between environmental attitudes and recycling behaviour. This indicates that attitudes are more strongly related to reported recycling behaviour when the system is perceived as easy, accessible, and usable (Whitmarsh & O'Neill, 2010). Thus, the findings support the relevance of perceived system usability in explaining why favourable environmental attitudes may be more closely associated with selective waste collection in everyday household routines.

PDEB showed a small but significant negative association with recycling behaviour. This association may reflect weaker attentional and self-regulatory engagement in repeated waste sorting, although it does not provide evidence of reduced waste-prevention behaviour. This pattern is broadly consistent with behavioural research suggesting that pro-environmental perceptions and actions can sometimes coexist with weaker engagement in related sustainable behaviours (Mazar & Zhong, 2010; Tiefenbeck et al., 2013). However, the present data do not demonstrate moral licensing, rebound effects, or a causal justification mechanism. They show only that PDEB is negatively associated with self-reported recycling behaviour and positively associated with both environmental attitudes and convenience. This suggests a modest but theoretically relevant tension. Favourable attitudes and positive evaluations of system usability may coexist with justification-related perceptions that are associated with lower reported recycling engagement. This interpretation is related to recent work suggesting that convenient recycling systems may be associated with how individuals evaluate consumption-related impacts (Maier et al., 2023). Nevertheless, the findings should be interpreted cautiously because the study did not measure actual waste prevention, packaging consumption, or household waste generation. It shows that recycling participation should not be evaluated only through reported collection behaviour, but also in relation to the perceptions and justification-related evaluations that may accompany the use of convenient recycling systems.

5.2. Theoretical, practical, and policy implications

The findings contribute to several strands of theoretical debate in environmental psychology and circular economy research. First, the results indicate that environmental attitudes are associated with recycling behaviour through potentially ambivalent pathways. They are positively associated with recycling behaviour, while also being positively related to bias-related evaluations. This duality extends prior work showing that pro-environmental self-identity can sometimes increase moral licensing when individuals feel they have already "done enough" (Reimers et al., 2022). Rather than simply confirming the existence of an attitude–behaviour gap, the findings suggest that this gap may partly reflect the coexistence of favourable environmental attitudes and justification-related evaluations. The present study extends this reasoning to household waste management, suggesting that even strongly held attitudes may be linked to context-dependent justification processes when embedded in highly convenient systems. Second, the study contributes to the literature on rebound and behavioural spillover in the context of circular economy systems. The finding that convenience is positively associated with both recycling behaviour and perceived disposal ease bias shows that favourable evaluations of system usability may coexist with justification-related evaluations, a pattern that is consistent with, but does not directly demonstrate, the mechanisms discussed by

Zink and Geyer (2017). This suggests that the perceived convenience of recycling systems may be associated with multiple evaluative processes. While convenience is positively associated with participation, it may also be associated with justification-related evaluations concerning the perceived adequacy of environmental behaviour. The present study provides an empirical model in which perceived system usability, recycling behaviour, and justification-related evaluations are examined jointly. In doing so, it shows that justification-related evaluations are statistically associated not only with environmental attitudes, but also with the perceived effectiveness and ease of the system. However, the cross-sectional design does not establish whether system convenience activates these evaluations or whether they affect actual waste-prevention behaviour.

From a practical perspective, the findings highlight the need for waste management systems to balance convenience with informational and motivational interventions. While convenience is essential for high recycling rates, policymakers should be cautious in assuming that improved infrastructure alone leads to better environmental outcomes. Therefore, communication strategies accompanying curbside or deposit–refund systems may need to place greater emphasis on waste prevention alongside recycling, which may receive less attention in recycling-focused communication. This recommendation should be understood as a precautionary policy consideration rather than as evidence that convenient recycling systems reduce waste-prevention behaviour. Studies on behavioural spillover show that targeted communication can help reduce the risk of justification-related interpretations by reinforcing coherent behavioural narratives (Truelove et al., 2014). Thus, systems that significantly reduce the effort associated with waste sorting could be complemented by communication that maintains the salience of waste prevention and consumption-related impacts. Monitoring frameworks could also incorporate metrics beyond recycling rates, including total household waste generation and consumption patterns. Furthermore, system design can be complemented by feedback mechanisms (e.g., household-level waste weight data) or differentiated incentives that reward waste reduction, not just waste sorting. These approaches are in line with broader circular economy strategies emphasising dematerialisation and consumption reduction as primary goals (Castro et al., 2022). The findings suggest that policies aimed at improving recycling infrastructure should also account for the perceptions and justification-related evaluations associated with how individuals interpret and engage with these systems. Without attention to perceived disposal ease bias and related justification-related evaluations, assessments of such systems may remain incomplete, particularly when relying only on reported recycling participation.

5.3. Limitations and future research

When interpreting the results, the study's limitations should be acknowledged. The convenience construct integrates multiple evaluative dimensions, including perceived ease, efficiency, and general system satisfaction. While the factor analysis confirmed empirical distinctiveness from the other constructs, future research could decompose these components to examine whether physical accessibility and affective system evaluation exert differential effects on recycling behaviour and bias-related processes. The cross-sectional design prevents drawing strong causal inferences. In particular, the direction of the relationship between PDEB and recycling behaviour cannot be definitively established. While the model specifies PDEB as being associated with behaviour, it is also plausible that lower engagement in recycling may lead to post-hoc justification processes. Thus, the PDEB–recycling behaviour relationship should be interpreted as an association rather than as evidence of a directional mechanism. PDEB and RB were measured using the same self-report questionnaire. Their small negative association may

therefore partly reflect shared method variance. Although Harman's single-factor result of 40.4% was below the conventional 50% threshold and the marker-variable analysis did not indicate substantial common-method variance, this proportion is not negligible and these diagnostics cannot rule out method-related bias. The association should therefore be interpreted cautiously.

Moreover, the measurement of PDEB relied on newly developed items, as no prior validated scale exists. While reliability was satisfactory, further refinement and cross-validation, particularly across different cultural and infrastructural contexts, would help to strengthen the robustness and generalisability of the construct. The PDEB items capture justification-related evaluations that are conceptually oriented toward waste prevention and consumption, such as reduced concern about packaging use or waste generation. In the present study, however, the outcome variable is self-reported recycling behaviour in the context of selective waste collection, rather than direct waste-prevention behaviour or packaging consumption. PDEB should therefore be interpreted as a cognitive-evaluative construct associated with reported recycling behaviour, not as a behavioural measure of waste prevention itself. The present survey did not include direct measures of waste prevention, packaging consumption, or household waste generation. Consequently, the relationship between PDEB and prevention-oriented behaviour could not be tested directly. Future research should examine PDEB against prevention- and consumption-related outcomes, which would provide a more direct test of the mechanism that the construct is intended to capture.

In addition, the study did not distinguish between different recyclable waste fractions beyond the self-reported selective collection of recyclable paper and plastic waste. This is important because recycling behaviour may vary substantially across waste types. Some materials, such as paper or certain plastic packaging, may be easier for households to identify, store, and place in selective collection systems, whereas other fractions may involve more complex sorting rules, lower perceived recyclability, or less established collection procedures. Thus, the associations observed in this study should not be generalised to all forms of household recycling. They are most directly applicable to reported selective collection of recyclable paper and plastic waste in the curbside system examined here. Future research should test whether the role of attitudes, perceived system usability, and PDEB differs across specific waste fractions, such as glass, metal, organic waste, electronic waste, or mixed packaging materials.

Finally, although post-stratification weighting was applied to improve the demographic alignment of the sample with the Hungarian population, and demographic controls were included in the model, these procedures cannot fully eliminate self-selection bias. Individuals with stronger environmental interest, higher online engagement, or greater involvement with the curbside selective waste collection system may have been more likely to participate. Therefore, the findings should not be interpreted as deriving from a fully probability-based representative sample. Future research should validate the model using probability sampling, administrative recycling data, or observational measures of household waste sorting behaviour, and should incorporate income and other socio-economic indicators alongside the controls used here. Future longitudinal, experimental, and observational studies could further clarify the temporal dynamics of PDEB and identify interventions that support both selective collection and waste prevention.

6. Conclusion

This study examines how environmental attitudes, convenience, and perceived disposal ease bias are jointly associated with household selective waste collection in the context of a newly implemented curbside recycling system. Drawing on a large, post-stratified sample and a stepwise PLS-SEM modelling strategy, the analysis shows that recycling behaviour reflects the interplay of motivational, infrastructural, and cognitive mechanisms. Environmental attitudes provide an important psychological foundation for selective waste collection, but their direct association is partly accounted for by their association with perceived convenience and they are also positively associated with bias-related evaluative processes. The findings confirm that convenience is strongly associated with recycling behaviour. When selective collection is perceived as simple, accessible, and embedded in everyday routines, higher participation is observed. At the same time, convenience accounts for a substantial share of the relationship between environmental attitudes and behaviour, suggesting that positive attitudes are more likely to translate into action when supported by user-friendly infrastructure. This pattern highlights the importance of system design supporting the association between favourable environmental attitudes and self-reported recycling participation in everyday household practices.

A central contribution of this study is the operationalisation of PDEB as a context-specific justification-related evaluative construct. PDEB shows a negative association with recycling behaviour and is positively related to both environmental attitudes and convenience. These findings suggest that the same factors that encourage recycling may also be associated with justification-related evaluations concerning the perceived importance of other environmentally relevant considerations. Overall, the results indicate that recycling behaviour is shaped by multiple pathways that may operate in different directions. While attitudes and convenience facilitate participation, bias-related mechanisms may be associated with lower consistency in engagement. These findings underline the importance of considering both self-reported behavioural participation and the perceptions and justification-related evaluations associated with it when evaluating the functioning of selective waste collection systems. Furthermore, these findings contribute to circular economy research by highlighting that the assessment of recycling systems should consider not only reported participation rates, but also the perceptions and justification-related evaluations associated with their use.

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding declaration: This research received no external funding.

Ethical statement: All procedures performed in this study were in accordance with the ethical standards of the institutional committee of the corresponding author's university and with the Declaration of Helsinki.

Consent to Participate: Participation in the online questionnaire was voluntary and anonymous, and informed consent was obtained from all participants before completing the survey.

Consent to Publish: Not applicable.

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8. Appendix

Table A1. Excluded items based on factor loadings

Item Code	Questionnaire Statement	Reason for Exclusion
q5	I am not aware of which recyclable waste belongs in which bin.	Factor loading < 0.60
q6	I would appreciate receiving more information about proper selective waste collection.	Factor loading < 0.60
q7	I prefer to buy packaged products if I know the packaging is recyclable.	Factor loading < 0.60
q11	If I moved to a place without selective waste collection, I would try to generate less waste.	Factor loading < 0.60
q13	I did not collect waste selectively when only public recycling islands were available.	Factor loading < 0.60

Table A2. Recycling behaviour (RB) response distribution

Value	Anchor (EN)	% (weighted)
1	Never	3.56
2	Rarely	10.13
3	About half of the time	11.40
4	Usually, but not always	30.21
5	Always	44.69
Total		**100.00**

Note: Single self-report item; ordinal 1–5 scale. "How regularly do you selectively collect the recyclable paper and plastic waste you generate?" Response scale (5-point): 1 = never, 2 = rarely, 3 = about half of the time, 4 = usually, but not always, 5 = always. Higher values indicate more regular and consistent selective collection. Percentages are post-stratification weighted (n = 3,950). Weighted M = 4.02, SD = 1.13. The mean and SD are reported as approximations and the variable is treated as ordinal in interpretation.

Table A3. Decomposition of total, direct, and indirect effects on recycling behaviour (RB)

Effect	Path	β	95% CI
Environmental attitude → Recycling behaviour			
Direct	EA → RB	0.248	[0.232, 0.260]
Indirect	EA → Convenience → RB	0.264	[0.253, 0.273]
Indirect	EA → PDEB → RB	−0.029	[−0.030, −0.025]
Indirect	EA → Convenience → PDEB → RB	−0.007	[−0.008, −0.004]
Total indirect		0.228	—
Total effect	**EA → RB**	**0.476**	**[0.467, 0.490]**
Convenience → Recycling behaviour			
Direct	Convenience → RB	0.437	[0.424, 0.452]
Indirect	Convenience → PDEB → RB	−0.011	[−0.013, −0.007]
Total effect	**Convenience → RB**	**0.426**	**[0.414, 0.444]**

Note: Standardised path coefficients (β) from the final structural model (Model 3). Point estimates of the specific indirect effects were calculated as the products of the corresponding structural path coefficients reported in Table 5. The total indirect effect equals the sum of all specific indirect effects, and the total effect equals the direct effect plus the total indirect effect. The reported 95% confidence intervals are based on bootstrapping with 5,000 resamples. PDEB = perceived disposal ease bias; EA = environmental attitude; RB = recycling behaviour. The EA → Convenience → RB pathway is the only substantively strong indirect association; the PDEB-related indirect associations are small and operate as minor countervailing pathways.

Table A4. Coefficients of the demographic control variables

Control variable	β (→ RB)
Gender (reference: female)	
Male	−0.011**
Age group (reference: 40–59)	
18–29	−0.091***
30–39	−0.026**
60+	0.011*
Educational attainment (reference: secondary/vocational)	
Primary	−0.117***
Tertiary	0.070***
Region (reference: Budapest)	
Northern Great Plain	−0.014**
Northern Hungary	0.000
Pest	0.025**
Southern Great Plain	−0.006
Southern Transdanubia	−0.019**
Central Transdanubia	−0.026**
Western Transdanubia	−0.056***

*Note: Standardised coefficients (β) of the demographic controls on recycling behaviour (RB) in the model reported in the "with controls" column of Table 6. Reference categories are female, age 40–59, secondary/vocational education, and Budapest. Significance levels: *** p < 0.01; ** p < 0.05; * p < 0.10.*