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From Environmental Knowledge to Sustainable Behavior: The Mediating Roles of Risk Perception, Environmental Concern, and Behavioral Intention in Saudi Arabia

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Abstract
This study investigates the influence of environmental knowledge, risk perception, environmental concern, and behavioral intention on environmentally sustainable behavior in Saudi Arabia. Data collected from 546 respondents through an Arabic-language online questionnaire were analyzed using partial least squares structural equation modeling (PLS-SEM). The proposed model explains 56.5% of the variance in sustainable behavior, demonstrating substantial explanatory power. Environmental behavioral intention, risk perception, and environmental concern positively influence sustainable behavior, whereas environmental knowledge exhibits a weaker direct effect. However, environmental knowledge and risk perception demonstrate substantial total effects, highlighting their broader influence through indirect pathways. Significant mediating effects of risk perception, environmental concern, and behavioral intention further elucidate the psychological mechanisms underlying sustainable behavior. The study advances environmental sustainability literature and provides actionable insights for policymakers to strengthen environmental education, risk communication, and targeted interventions promoting sustainable practices in Saudi Arabia.
Key Words: Environmental knowledge, environmental risk perception, environmental concern, environmentally sustainable behavioral intention, environmentally sustainable behavior, Saudi Arabia
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Introduction

The ongoing expansion of the economy of developing and emerging global markets is propelled by technological advancements and globalization. Consequently, this has led to an increase in unsustainable consumption patterns and behaviors (Alzubaidi et al. 2021), and depletion of the natural resources in the environment and society (Hüttel et al., 2018). This led to the need to examine human social behavior to comprehend and explore how individuals conform to well-defined and goal-oriented actions. It is also important to understand how individuals plan for these behaviors and anticipate their execution (Ajzen, 1985). This analysis encompasses a cognitive process that can stimulate motivation and intention and, consequently, the formation of repeated behaviors and habits (Abrahamse, 2019; Lanzini et al. 2018).

Environmentally Sustainable Behaviour (hereafter, ESB) gained popularity in recent times, serving as a comprehensive concept and methodology for delineating the myriad actions undertaken by individuals to conserve natural resources, minimize environmental impact, meet the consumption requirements of a green society, and enhance the quality of life without jeopardizing the well-being of future generations (Dong et al. 2020; Han, 2021). At its core, ESB is predicated upon a decision-making approach that strives to strike a harmonious balance between the moral and ethical responsibilities of consumers toward society and the fulfillment of their personal needs and desires (Meulenberg, 2003).

Most studies have focused on specific independent variables, namely personal attitude (Gatersleben et al., 2014; B. Kumar et al., 2017; Wang, 2016), intention (Nguyen et al., 2016; Whitmarsh & O'Neill, 2010), social norms (Hsu et al., 2017; Vermeir & Verbeke, 2006), perceived consumer effectiveness (Gleim et al., 2013; H. Huang, 2016; Kim et al., 2013), and materialism (Dermody et al., 2015; Hurst et al., 2013). These studies have sought to investigate the influence of these variables on ESB. Researchers in this study endeavored to examine ESB from alternative perspectives, including environmental knowledge (hereafter, EK) and environmental risk perception (hereafter, ERP), in addition to environmental concerns (hereafter EC) and environmentally sustainable behavioral intention (hereafter, ESBI). Studies pertaining to this subject predominantly concentrate on Western world, leaving a gap which is underexplored, hence it's appropriate to extend the study in diverse social, financial, and cultural contexts and structures (Elhoushy & Lanzini, 2021) including Saudi Arabia. This

necessitates the application of this scientific inquiry examining the influence of other perceived variables on consumers' intentions and willingness towards ESB in emerging and developing markets (Abdul-Muhmin, 2007; Alzubaidi, 2018; Saari et al. 2021). Saudi Arabia, the largest country in the Middle East, occupies a strategically significant geographic position at the crossroads of Asia, Africa, and Europe. In recent decades, the country has experienced rapid economic growth and substantial population expansion, alongside increasing vulnerability to climate change and related environmental challenges. In response to these socioeconomic and environmental pressures, the Saudi government launched the Vision 2030 initiative in 2016, aiming to diversify the national economy, promote sustainable development, and enhance the country's long-term resilience (Saudi Arabia NTP, 2021-2025). This is achieved by pursuing sustainable economic development, which aims to effectively manage and reconcile the outcomes of economic growth with the emergence of environmental challenges and issues (Al-Tamimi, 2017). This approach primarily concentrates on environmental, social, and economic dimensions (Alshuwaikhat & Mohammed, 2017). Saudi Arabia Vision 2030 also addresses the environment through the enhancement of waste management efficiency, the establishment of comprehensive recycling initiatives, and the reduction of various forms of pollution (Al-Sadoun and Abdel Karim, 2019) to accomplish the principles of the circular economy (Ibrahim & Shirazi, 2021) and the objectives of operational excellence (Saudi Arabia NTP, 2021-2025).

Against the backdrop of Saudi Arabia's growing commitment to sustainability under Vision 2030, this study addresses a critical research priority by examining the determinants of environmentally sustainable behaviour in the country. Specifically, it investigates the relationship between environmental knowledge and environmentally sustainable behaviour, with particular emphasis on the mediating roles of environmental concern, environmental risk perception, and environmentally sustainable behavioural intention. The findings are expected to contribute to a deeper understanding of the psychological and cognitive mechanisms underlying sustainable behavior and provide empirical insights to inform evidence-based policies and strategies. These insights may support government agencies, businesses, and educational institutions in developing targeted interventions to promote environmentally sustainable behaviour and advance Saudi Arabia's sustainability objectives in alignment with Vision 2030.

Review of literature

This study examines the influence of environmental knowledge on environmentally sustainable behaviour, with particular attention to the mediating roles of environmental risk perception, environmental concern, and environmentally sustainable behavioural intention. To establish the theoretical foundation for the proposed relationships, the following literature review critically examines the key constructs, synthesizes relevant empirical findings, and develops the hypotheses underpinning the proposed research framework.

Environmental Knowledge (EK)

Environmental knowledge pertains to individuals' comprehension of environmental issues, their origins, and the requisite measures necessary to resolve these issues (Pagiaslis & Krontalis, 2014). It is an individual's acknowledgment of the societal repercussions of environmental predicaments through diverse sources and implications (Raeisi et al. 2018). As stated by Martinez-Martinez et al. (2019), environmental knowledge comprises a comprehensive understanding of information, principles, and interactions related to the natural environment and its fundamental ecology. According to the information deficit model, consumers' possession of knowledge regarding environmental issues and associated solutions leads to substantial modifications in behavior, driven by a favorable attitude towards scientific principles and a sense of confidence in scientific knowledge (Owens, 2000; Vainio & Paloniemi, 2014). Miller (1983) argued that consumers are unable to make environmentally sustainable purchases and engage in sustainable behavior because of a lack of knowledge and information concerning environmental issues. To address this issue, it is essential to provide consumers with the necessary knowledge and information from a strategic perspective, incorporating the latest and most pertinent available information (Blankenberg & Alhusen, 2019). Environmental awareness had a significant effect on environmental behavior (Arshad et al., 2021). Therefore, sustainable habits can be encouraged by raising awareness of environmental issues and how they affect people's lives, both individually and collectively. Furthermore, the association between environmental concern and environmental conservation behavior was positively moderated by environmental knowledge (Li et al. 2022). The variation in risk perception levels among different regions of the world has been attributed to differences in the level of knowledge about environmental issues (Saari et al., 2021). Conversely, at the individual level, the perception of environmental risks is influenced by cognitive factors related to risk perception and an individual's level of knowledge about the environment (Balžekiene and Telešiene, 2017). Marquart-Pyatt (2018), suggests that enhancing awareness about the factors that drive environmental action towards globally recognized environmental issues and fostering engagement is a matter of global environmental concern, even at the individual level. A study conducted by Zsóka et al., (2013)

found a strong association between environmental knowledge and the formation of attitudes, as well as an increase in intrinsic motivation towards sustainable consumption. This influence is observed indirectly in a sophisticated manner through various combinations of multiple dimensions and perspectives (Su et al. 2021; Bradley et al. 2020; and Truelove & Gillis 2018). Gkargkavouzi et al. (2019) asserted that environmental knowledge enables individuals to become aware of specific behaviors and lifestyle habits that significantly impact climate change. Examples include composting food waste, consuming organic diets, and installing skylights and solar panels (Bradley et al., 2020). It is evident from the literature that knowledge influences an individual's intention and behavior, and previous research on the influence of environmental knowledge supports the idea that knowledge of environmental issues has an impact on environmentally sustainable behavioral intentions and environmentally sustainable behavior. Based on the body of literature, this study postulates that possession of environmental knowledge exerts a notable influence on individuals' discernment of environmental risk perception, degree of environmental concern, and environmentally sustainable behavior, and proposes the following hypotheses.

H1: Environmental knowledge has positive influence on environmental concern.
H2: Environmental knowledge has positive influence on environmental risk perception.
H3: Environmental knowledge has positive influence on environmentally sustainable behavioural intention.
H4: Environmental knowledge has a significant positive influence on environmentally sustainable behavior.

Environmental Concern (EC)

The degree of people's awareness of environmental issues and their ongoing readiness to interact with the environment to find solutions is referred to as environmental concern (Dunlap & Catton, 1979). Concern for the environment encompasses the cognitive understanding of the environment, the willingness to act on environmental issues, and the emotional response to such issues (Franzen & Vogl, 2013). Dunlap and Jones (2002) defined environmental concern as the degree to which individuals are aware of environmental issues and support efforts to address them, as well as their readiness to contribute directly to their resolution. Vainio and Paloniemi (2014), stated that environmental concern is an intrinsic apprehension about the future state of the environment and the detrimental effects of human activities on it. Environmental concerns comprise a wide range of attitudes, beliefs, intentions, and behaviors that encompass various personal, social, economic, and political dimensions and factors (Marquart-Pyatt, 2012; Nawrotzki, 2012; Wang, 2016). Environmental concern can be viewed as a general attitude that includes conative, emotional, and cognitive assessments of environmental conservation (Bamberg & Rees, 2015). Furthermore, concerns about the environment mirrored attitudes toward rising pollution, environmental responsibility, and conservation activities and intentions (Bøhlerengen & Wiium, 2022).

Individuals concerned about sustainability aim to minimize the cognitive dissonance between their beliefs and the rational perception of the environmental consequences of their actions, particularly when the required actions have low costs (Farjam et al. 2019). Previous studies have found that environmental concern indirectly enhances sustainable behavior (Choi & Fielding 2013; Fraj-andrés et al. 2008), as well as behavioral intentions (S. Kumar, 2019; Nordlund, 2002). It can also increase willingness to pay and make sacrifices for the environment (Choi & Fielding 2013; Meyer & Liebe 2010) or promote the consumption of energy resources in a sustainable manner (Sapci & Considine, 2014). Research has indicated that individuals' sense of environmental risk influences how concerned they are about environmental issues, and (Chanin, 2018). The mediating role of environmental concern has been validated in relation to various factors that influence sustainable consumption behavior (Coelho et al. 2017; Huang & Liu, 2017). Some researchers have identified the expression of environmental concern among the public, highlighting that environmental issues are not just an individual concern but also a global public concern (Dunlap & York, 2016; Franzen & Vogl, 2013; Mertig et al. 1997).

Environmental concern is an important phenomenon that can influence environmentally sustainable behavioral intentions and environmentally sustainable behavior. It can also mediate the relationship between environmental knowledge and these two variables; hence, the following hypotheses are proposed:

H5 - Environmental concern positively influences environmentally sustainable behavioral intention.

H6 - Environmental concern positively influences environmentally sustainable behavior.

Environmental risk perception (ERP)

Risk perception pertains to the process of collecting, identifying, and interpreting information about unfamiliar dangers or consequences associated with various events or technologies (Wachinger et al. 2013). Environmental risk perception is correlated with the actual causes of environmental issues and how individuals interpret them (Saari et al. 2021). Predictors of environmental risk perception vary depending on the sample and/or country, and

differences in perceptions of environmental risks can be predicted by considering cognitive, experiential, social, and demographic factors (Bradley et al., 2020; Lee et al. 2015; Van der Linden, 2015). Additionally, it should be noted that the causal direction and association between risk perception, knowledge of the environmental issues, and concern are ambiguous and may exhibit different directions of influence (Zhang, 2010; Balžekiene and Telešiene, 2017; Saari et al., 2021). The recognition of environmental risk perception as a prominent predictor of environmentally sustainable behavior at the individual level arises from its ability to evoke emotional reactions, instill environmental concerns, and foster response efficacy, all of which can be catalyzed by awareness of environmentally sustainable behaviors and strategies for the acquisition, utilization, and recycling of sustainable goods and services. These factors collectively contribute to enhanced personal commitment towards sustainability and corresponding behavioral changes (Bradley et al. 2020; Wang, 2016). Raising an individual's consciousness of environmental risks can aid in the development of pro-environmental behaviors, because environmental risk perception and pro-environmental behavior are strongly correlated (Zeng et al. 2020). Su et al. (2021) affirmed that environmental risk perception is a crucial factor in the link between environmental knowledge and sustainable behavior. This connection is established through an understanding and awareness of environmental hazards and their impacts on human health, economic status, and public society (Kellstedt et al. 2008). The literature explains the role of environmental risk perception in influencing environmentally sustainable behavioural intention and environmentally sustainable behaviour. Literature also explains its role as a mediator. Hence, the following hypothesis is proposed:

H7 – Environmental risk perception positively influences environmentally sustainable behavioral intention.

H8 - Environmental risk perception positively influences environmentally sustainable behavior.

Environmentally Sustainable Behavioural Intention (ESBI)

The concept of "behavioral intention" pertains to an individual's inclination to act in a specific manner and is widely regarded as the immediate precursor to actual behavior; hence, environmentally sustainable behavioral intention can be an indicator of commitment to environmentally sustainable behavior (Saari et al. 2021). Because of the intricate nature of the relationship between environmental concern and environmentally sustainable behavior, numerous scholars have incorporated the mediating role of behavioral intention and cognitive dissonance (Hornsey et al. 2016; Bahl & Kumar, 2019; Nauges & Wheeler, 2017; Saari et al. 2021). The core component of the Theory, conceived by Ajzen, is the notion of behavioral intention, which determines the motivating factors behind individuals' willingness to actively participate in desired behaviors (Ajzen, 1991). The intention to engage in environmentally sustainable behavior involves a readiness to make sacrifices in terms of financial resources, time, or living standards to safeguard the environment from the diverse impacts of human activities (Marquart-Pyatt, 2008). This intention is influenced by psychological, social, institutional, economic, and individual lifestyle characteristics (Blankenberg & Alhusen, 2019). (Sari et al. 2021) found that environmental concerns and environmental risk perception influence environmental behavioral intention. Hence, this study proposes the following hypotheses:

H9 – Environmentally sustainable behavioral intention positively influences environmentally sustainable behavior.

Besides the above direct hypothesis, the following mediating hypothesis are proposed.

Simple Mediation Hypotheses

H10: Environmental concern mediates the relationship between environmental knowledge and environmentally sustainable behavioral intention. [EK → EC → ESBI]
H11: Environmental concern mediates the relationship between environmental knowledge and environmentally sustainable behavior. [EK → EC → ESB]
H12: Environmental risk perception mediates the relationship between environmental knowledge and environmentally sustainable behavioral intention. [EK → ERP → ESBI]
H13: Environmental risk perception mediates the relationship between environmental knowledge and environmentally sustainable behavior. [EK → ERP → ESB]
H14: Environmentally sustainable behavioral intention mediates the relationship between environmental knowledge and environmentally sustainable behavior. [EK → ESBI → ESB]
H15: Environmentally behavioral behavioural intention mediates the relationship between environmental concern and environmentally sustainable behavior. [EC → ESBI → ESB]
H16: Environmentally sustainable behavioral intention mediates the relationship between environmental risk perception and environmentally sustainable behavior. [ERP → ESBI → ESB]

Serial Mediation Hypotheses

H17: Environmental concern and environmentally sustainable behavioral intention sequentially mediate the relationship between environmental knowledge and environmentally sustainable behavior.
[EK → EC → ESBI → ESB]
H18: Environmental risk perception and environmentally sustainable behavioral intention sequentially mediate the relationship between environmental knowledge and environmentally sustainable behavior.
[EK → ERP → ESBI → ESB]

Research Framework

Drawing upon the comprehensive literature review and the formulated hypotheses, the present study proposes a conceptual research framework, illustrated in Figure 1, that aligns with the study's objectives. The framework integrates the key constructs identified in prior empirical research and delineates the hypothesized directional relationships among the independent and dependent variables. These relationships are theoretically grounded in the existing literature and are intended to be empirically examined using data collected from respondents in Saudi Arabia. The proposed framework employs a reflective measurement approach, wherein the observed indicators are conceptualized as manifestations of their respective latent constructs, providing a systematic foundation for evaluating the hypothesized relationships through structural equation modelling.

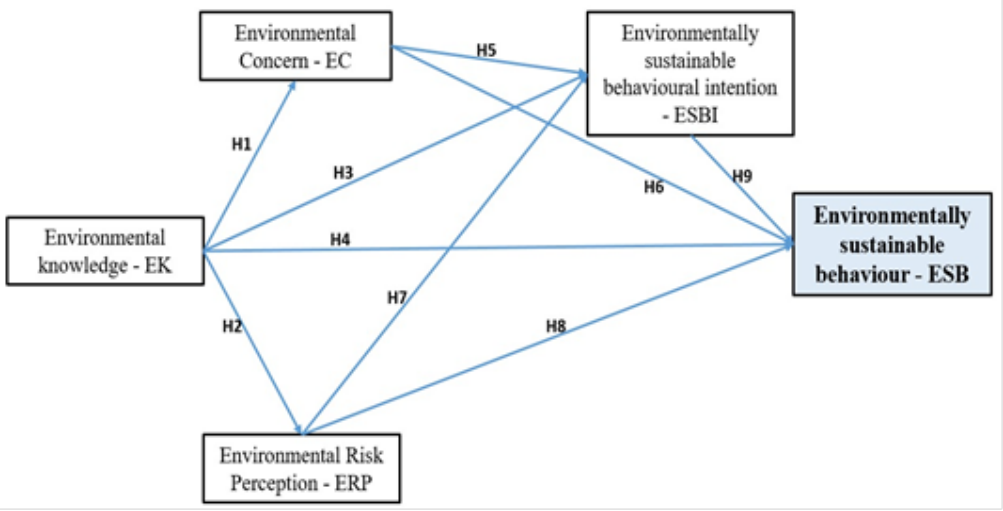


Figure 1: Proposed conceptual framework illustrating the hypothesized relationships among the determinants of environmentally sustainable behavior

Methodology

Questionnaire and measurements

The main objective of this research is to examine how environmental knowledge (EK), environmental risk perception (ERP), environmental concern (EC), and environmentally sustainable behavioral intention (ESBI) influence environmentally sustainable behavior (ESB). The study's questionnaire was thoughtfully developed with useful and reliable items grouped logically to ensure accurate data collection and results calculations. The variables and items in this study were selected based on their suitability and contextual adaptation. Respondents' answers to each item in the survey were analyzed using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

The list below includes the variables, its items, and the sources:

Construct	Measurement Items	Sources
Environmental Knowledge – (EK)	Do you agree that you know about the causes of environmental problems?	Vainio and Paloniemi (2014) Saari, 2021
	Do you agree that you know the solutions to environmental problems?	
	Do you agree that your lifestyle is not harmful to the environment?	
Environmental Risk Perception – (ERP)	Do you agree that Air pollution is caused by cars	Marquart-Pyatt (2015)
	Do you agree Air pollution is caused by industry	
	Do you agree that rise in the world's temperature is caused by climate change	
Environmental Concern – (EC)	Are you concerned about environmental issues?	Vainio and Paloniemi (2014)
	We worry too much about the future of the environment and not enough about prices and jobs	
	People worry too much about human progress harming the environment	
	Many of the claims about environmental threats are real & logical	
Environmentally Sustainable Behavioral Intention – (ESBI)	You are willing to pay higher prices to protect the environment	Lo (2016); Marquart-Pyatt (2008)
	You are willing to pay higher taxes to protect the environment	
	You are willing to accept cuts in your standard of living to protect the environment	
Environmentally Sustainable Behavior – (ESB)	You make special efforts to buy fruit and vegetables grown without pesticides or chemicals (Organic Foods) for environmental reasons	Wang (2017)
	You often reduce the energy or fuel you use at home for environmental reasons	
	You choose to save or re-use water for environmental reasons	
	You avoid buying certain products environmental reasons	

Data collection

The present study was conducted in Saudi Arabia using a structured online questionnaire developed through Google Forms for data collection. Initially, a pilot study was conducted by administering the questionnaire to 50 respondents, and no modifications were deemed necessary. Following the pilot study, the electronic questionnaire link was distributed to individuals residing in Saudi Arabia through various WhatsApp and Telegram groups. A total of 546 valid and usable responses were collected for the final analysis. The sample size of 546 was considered adequate and consistent with the recommended guidelines for conducting structural equation modelling (Hair et al. 2019).

Data Analysis

The collected data were analyzed using the Smart PLS3 program, benefiting from its approaches and features such as the PLS Algorithm, Bootstrapping, blindfolding, PLS prediction analysis, and Importance-Performance Map Analysis (IPMA). PLS-SEM is widely used to analyze measurement and structural models and to evaluate theoretical research (Ringle et al. 2020; Sarstedt et al. 2016), It is highly recommended in behavioral and comparatively complex models and studies (Hair et al. 2020), and is a useful technique to measure the environmental knowledge effect on environmentally sustainable behavior (Antonetti & Maklan, 2014).

PLS-SEM analysis consists of two stages: specification of the measurement model, and evaluation of the structural model. The measurement model specification ensures that the structural model contains only constructs with high indicator loading, convergent validity, composite reliability (CR), and discriminant validity. The purpose of the structural model evaluation is to determine the path coefficients and their significance using the bootstrapping technique (Hair et al. 2020; Sarstedt et al. 2016, 2019). In terms of mediation analysis, Hayes's (2009) procedure was used because it is a more rigorous procedure for determining mediating effects and more

compatible with the PLS-SEM technique.

Results

Demographic Profile

Table 1 presents the demographic characteristics of the respondents, indicating that 48.0% were male and 52.0% were female. The majority of respondents (81.0%) were aged 20–40 years, indicating a substantial representation of young adults in the study sample. This age distribution aligns with Saudi Arabia's relatively youthful demographic profile, characterized by a median age of approximately 29 years (Worldometer, 2026). Consequently, the sample provides valuable insights into the environmental attitudes and sustainable behaviors of young adults, who constitute an important demographic segment of Saudi Arabia's population. Regarding educational attainment, 87.6% of the participants possessed a bachelor's degree or higher academic qualification. These demographic characteristics suggest that the sample predominantly comprised young, educated adults who were likely to possess an adequate understanding of the research topic (Chan, 2001). Furthermore, the findings revealed that 86.0% of respondents reported a personal monthly income below SAR 20,000, whereas the remaining 14.0% earned more than SAR 20,000 per month. Overall, the demographic composition of the sample reflected a predominantly young and well-educated population, providing a suitable respondent base for examining the research constructs.

Table 1: demographic profile of respondents

Variable	Number of respondents		Percent n=546
Gender	Male	262	48.0%
	Female	284	52.0%
Age	< 20 years	34	6.2%
	21 to 30 years	262	48.0%
	31 to 40 years	181	33.2%
	40 to 50 years	49	9.0%
	> 50 years	20	3.7%
Education	High School	43	7.9%
	Diploma	25	4.6%
	Bachelor	338	61.9%
	Master	114	20.9%
	Doctorate	26	4.8%
Income	< 10,000 SAR	345	63.2%
	10,001 to 20,000 SAR	126	23.1%
	20,001 to 30,000 SAR	48	8.8%
	30,001 to 40,000 SAR	11	2.0%
	> 40,000 SAR	16	2.9%

Factor Loading, Reliability, and Validity

The measurement model was evaluated to establish the reliability and validity of the constructs by examining internal consistency reliability, convergent validity, and discriminant validity, following the recommended guidelines for partial least squares structural equation modelling (PLS-SEM) (Hair et al., 2019; Hair et al., 2022). Internal consistency reliability was assessed using Cronbach's alpha and composite reliability (CR). As presented in Table 2, Cronbach's alpha values for all constructs exceeded the recommended threshold of 0.70, confirming satisfactory internal consistency (Nunnally, 1978). Similarly, the CR values surpassed the minimum acceptable criterion of 0.70, providing further evidence of construct reliability (Chin, 1998; Hair et al., 2022). Convergent validity was evaluated using the average variance extracted (AVE), with all constructs exhibiting values above the recommended threshold of 0.50 (Fornell & Larcker, 1981). These findings indicate that the latent constructs explained more than 50% of the variance in their respective indicators, thereby establishing satisfactory convergent validity (Hair et al., 2019). Overall, the results provide evidence of adequate internal consistency reliability and convergent validity of the measurement model, supporting its suitability for subsequent structural model assessment.

Table 2: Factor loadings, Reliability and Convergent validity of the constructs

Constructs	Items	Loadings	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Environmental Knowledge (EK)	EK-1	0.844	0.780	0.788	0.872	0.695
	EK-2	0.875				
	EK-3	0.779				
Environmental Concern (EC)	EC-1	0.815	0.827	0.832	0.886	0.661
	EC-2	0.863				
	EC-3	0.857				
	EC-4	0.709				
Environmental Risk Perception (ERP)	ERP-1	0.892	0.830	0.838	0.897	0.744
	ERP-2	0.845				
	ERP-3	0.851				
Environmentally Sustainable Behavioural Intention (ESBI)	ESBI-1	0.913	0.891	0.897	0.932	0.820
	ESBI-2	0.920				
	ESBI-3	0.884				
Environmentally Sustainable Behaviour (ESB)	ESB-1	0.786	0.845	0.849	0.896	0.684
	ESB-2	0.862				
	ESB-3	0.792				
	ESB-4	0.864				

Discriminant Validity Assessment

Discriminant validity is an essential component of measurement model assessment, reflecting the extent to which a latent construct is empirically distinct from other constructs within the conceptual framework (Bagozzi et al., 1991; Hair et al., 2022). Establishing discriminant validity ensures that each construct captures a unique theoretical dimension and does not exhibit excessive conceptual or empirical overlap with other constructs (Fornell & Larcker, 1981). In the present study, discriminant validity was assessed using the Heterotrait–monotrait ratio of correlations (HTMT), a widely recommended and statistically robust approach for evaluating discriminant validity in partial least squares structural equation modelling (PLS-SEM) (Henseler et al., 2015). The HTMT criterion assesses the relative magnitude of correlations between indicators of different constructs compared with correlations among indicators measuring the same construct. Following the conservative threshold of 0.85 recommended by Henseler et al. (2015), the results presented in Table 3 demonstrate that all HTMT values ranged from 0.321 to 0.750, remaining below the prescribed threshold. The highest HTMT value (0.750) was observed between environmental concern (EC) and environmentally sustainable behavior (ESB), followed by the relationship between environmentally sustainable behavior (ESB) and environmentally sustainable behavioral intention (ESBI) (0.746). These findings provide satisfactory evidence of discriminant validity, confirming that the constructs represent empirically distinguishable dimensions and supporting the adequacy of the measurement model for subsequent structural model analysis (Hair et al., 2019; Hair et al., 2022).

Table 3 : Heterotrait Monotrait ratio (HTMT)

	EC	EK	ERP	ESB	ESBI
EC					
EK	0.524				
ERP	0.503	0.388			
ESB	0.750	0.485	0.507		
ESBI	0.627	0.349	0.321	0.746	

Structural Model

The structural model was evaluated using partial least squares structural equation modeling (PLS-SEM) to examine the relationships among environmental knowledge (EK), environmental concern (EC), environmental risk perception (ERP), environmentally sustainable behavioral intention (ESBI), and environmentally sustainable

behavior (ESB). The proposed framework integrates cognitive, psychological, and behavioral dimensions to explain the mechanisms underlying environmentally sustainable behavior. Following the methodological recommendations of Hair et al. (2019, 2022), the structural model was assessed by examining standardized path coefficients (β) and coefficients of determination (R^2), which provide insights into the direction and magnitude of the hypothesized relationships and the explanatory power of the model.

The results indicate that environmental knowledge positively influences environmental concern (β = 0.423) and environmental risk perception (β = 0.313), suggesting that individuals with greater environmental knowledge tend to demonstrate higher levels of environmental concern and awareness of environmental risks. These findings are consistent with the theoretical argument that environmental knowledge contributes to the development of environmental awareness and facilitates the formation of environmentally responsible attitudes (Kollmuss & Agyeman, 2002; Bamberg & Möser, 2007). However, the direct effects of environmental knowledge on environmentally sustainable behavioral intention (β = 0.068) and environmentally sustainable behavior (β = 0.096) were relatively weak. These findings suggest that environmental knowledge alone may be insufficient to directly translate environmental awareness into sustainable behavioral intentions and actual behavioral practices.

Environmental concern demonstrated positive relationships with environmentally sustainable behavioral intention (β = 0.488) and environmentally sustainable behavior (β = 0.300). These relationships suggest that individuals who express stronger concern about environmental degradation are more inclined to develop intentions to adopt environmentally responsible practices and engage in sustainable behavior. Similarly, environmental risk perception positively influenced environmentally sustainable behavioral intention (β = 0.137) and environmentally sustainable behavior (β = 0.370). The comparatively stronger relationship between environmental risk perception and actual sustainable behavior suggests that individuals' perceptions of environmental threats may be particularly relevant to their engagement in environmentally responsible activities. Furthermore, environmentally sustainable behavioral intention exhibited a positive relationship with environmentally sustainable behavior (β = 0.417), consistent with the Theory of Planned Behavior, which identifies behavioral intention as a central antecedent of actual behavior (Ajzen, 1991).

The explanatory power of the model was assessed through the coefficient of determination (R^2), which represents the proportion of variance in endogenous constructs explained by their predictors. The results revealed that environmental knowledge explained 17.9% of the variance in environmental concern (R^2 = 0.179) and 9.8% of the variance in environmental risk perception (R^2 = 0.098). Furthermore, the combined influence of environmental knowledge, environmental concern, and environmental risk perception explained 29.9% of the variance in environmentally sustainable behavioral intention (R^2 = 0.299). Notably, the model explained 56.5% of the variance in environmentally sustainable behavior (R^2 = 0.565), indicating comparatively substantial explanatory power for the principal outcome variable. Overall, the findings suggest that environmental concern, environmental risk perception, and behavioral intention represent important explanatory factors in environmentally sustainable behavior, while environmental knowledge may contribute to behavioral outcomes through both direct and indirect pathways.

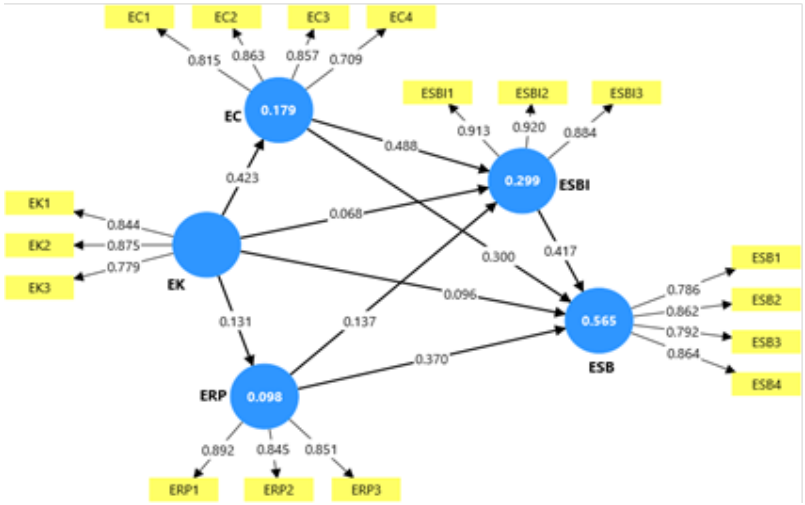


Figure 2: Structural Model Showing the Relationships among EK, EC, ERP, ESBI, and ESB

Hypothesis Testing – direct effects

The structural model was evaluated using the bootstrapping procedure in partial least squares structural equation modelling (PLS-SEM) to examine the significance of the hypothesized direct relationships among environmental knowledge (EK), environmental concern (EC), environmental risk perception (ERP), environmentally sustainable behavioral intention (ESBI), and environmentally sustainable behavior (ESB). The statistical significance of the path coefficients was assessed using t-statistics and p-values, following the methodological recommendations of Hair et al. (2019, 2022). At the 5% significance level, relationships with t-values exceeding 1.96 and p-values below 0.05 were considered statistically significant under a two-tailed test.

As presented in Table 4, Environmental knowledge demonstrated a positive and significant relationship with environmental concern ($\beta = 0.423$, $t = 9.283$, $p < 0.001$) and environmental risk perception ($\beta = 0.131$, $t = 7.131$, $p < 0.001$), providing empirical support for hypotheses H1 and H2. These findings indicate that greater environmental knowledge is associated with increased environmental concern and heightened awareness of environmental risks. Furthermore, environmental knowledge exerted a positive but relatively weak direct influence on environmentally sustainable behavior ($\beta = 0.096$, $t = 2.303$, $p = 0.021$), supporting hypothesis H4. However, its direct relationship with environmentally sustainable behavioral intention was statistically insignificant ($\beta = 0.068$, $t = 1.498$, $p = 0.134$), leading to the rejection of hypothesis H3. These results suggest that environmental knowledge alone may not be sufficient to generate sustainable behavioral intentions, highlighting the potential importance of psychological and motivational factors in translating environmental awareness into behavioral outcomes (Kollmuss & Agyeman, 2002).

Environmental concern exhibited a positive and statistically significant influence on environmentally sustainable behavior ($\beta = 0.300$, $t = 6.880$, $p < 0.001$) and environmentally sustainable behavioral intention ($\beta = 0.488$, $t = 12.180$, $p < 0.001$), supporting hypotheses H5 and H6, respectively. These findings suggest that individuals with greater environmental concern are more likely to develop sustainable behavioral intentions and engage in environmentally responsible practices. The results are consistent with previous research emphasizing the importance of environmental concern in shaping pro-environmental attitudes and behavioral responses (Bamberg & Möser, 2007; Kollmuss & Agyeman, 2002).

Environmental risk perception exhibited a positive and statistically significant influence on environmentally sustainable behavior ($\beta = 0.370$, $t = 4.445$, $p < 0.001$), supporting hypothesis H8. This finding suggests that individuals who perceive greater environmental risks are more likely to engage in environmentally sustainable practices. However, the relationship between environmental risk perception and environmentally sustainable behavioral intention was positive but statistically insignificant at the 5% level ($\beta = 0.137$, $t = 1.651$, $p = 0.099$), indicating that hypothesis H7 was not supported. Finally, environmentally sustainable behavioral intention demonstrated a positive and highly significant influence on environmentally sustainable behavior ($\beta = 0.417$, $t = 11.628$, $p < 0.001$), supporting hypothesis H9. This finding is consistent with the Theory of Planned Behavior, which identifies behavioral intention as a proximal determinant of actual behavior (Ajzen, 1991).

Overall, the structural model results indicate that seven of the nine hypothesized direct relationships were statistically significant, while two relationships (H3 and H7) were not supported at the 5% significance level. Among the direct predictors of environmentally sustainable behavior, behavioral intention exhibited the strongest standardized effect ($\beta = 0.417$), followed by environmental risk perception ($\beta = 0.370$), environmental concern ($\beta = 0.300$), and environmental knowledge ($\beta = 0.096$). The findings highlight the relative importance of psychological and intentional factors in explaining environmentally sustainable behavior. Furthermore, the insignificant direct relationships between environmental knowledge and behavioral intention, and between environmental risk perception and behavioral intention, suggest that the formation of sustainable intentions may involve additional psychological mechanisms. These findings contribute to the understanding of environmentally sustainable behavior by demonstrating that environmental knowledge, concern, risk perception, and behavioral intention exhibit distinct patterns of influence on sustainable behavioral outcomes.

Table 4: Direct effect

H. no.	Direct relation	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Decision
H1	EK -> EC	0.423	0.424	0.046	9.283	0.000	Supported
H2	EK -> ERP	0.131	0.132	0.018	7.131	0.000	Supported
H3	EK -> ESBI	0.068	0.068	0.045	1.498	0.134	Not - supported
H4	EK -> ESB	0.096	0.095	0.042	2.303	0.021	Supported
H5	EC -> ESBI	0.488	0.488	0.040	12.180	0.000	Supported
H6	EC -> ESB	0.300	0.301	0.044	6.880	0.000	Supported
H7	ERP -> ESBI	0.137	0.139	0.083	1.651	0.099	Not- supported
H8	ERP -> ESB	0.370	0.371	0.083	4.445	0.000	Supported
H9	ESBI -> ESB	0.417	0.417	0.036	11.628	0.000	Supported

Indirect effects and mediation hypothesis testing

The mediating effects of environmental concern (EC), environmental risk perception (ERP), and environmentally sustainable behavioral intention (ESBI) on the relationships between environmental knowledge (EK) and environmentally sustainable behavior (ESB) were examined using partial least squares structural equation modeling (PLS-SEM). The significance of the specific indirect effects was assessed through the bootstrapping procedure, following the methodological recommendations of Preacher and Hayes (2008) and Hair et al. (2022). The analysis incorporated both simple and serial mediation pathways to investigate the underlying psychological mechanisms through which environmental knowledge, environmental concern, and risk perception influence sustainable behavioral intentions and actual environmentally responsible behavior. The statistical significance of the indirect effects was evaluated at the 5% significance level, using t-statistics exceeding 1.96 and p-values below 0.05 as the criteria for hypothesis testing.

As presented in Table 5, environmental concern exhibited a positive and statistically significant mediating effect on the relationship between environmental knowledge and environmentally sustainable behavioral intention ($\beta = 0.206$, $t = 7.480$, $p < 0.001$), supporting hypothesis H10. Similarly, environmental concern significantly mediated the relationship between environmental knowledge and environmentally sustainable behavior ($\beta = 0.127$, $t = 5.455$, $p < 0.001$), supporting hypothesis H11. These findings suggest that environmental knowledge contributes to the development of environmental concern, which subsequently influences sustainable behavioral intentions and actual environmentally responsible behavior. The results are consistent with previous research emphasizing that environmental knowledge may influence pro-environmental behavior through psychological and attitudinal mechanisms rather than exclusively through direct relationships (Kollmuss & Agyeman, 2002; Bamberg & Möser, 2007).

The mediating role of environmental risk perception was also examined. The indirect relationship between environmental knowledge and environmentally sustainable behavioral intention through environmental risk perception was positive but statistically insignificant ($\beta = 0.018$, $t = 1.579$, $p = 0.114$), indicating that hypothesis H12 was not supported. Conversely, environmental risk perception significantly mediated the relationship between environmental knowledge and environmentally sustainable behavior ($\beta = 0.049$, $t = 3.800$, $p < 0.001$), supporting hypothesis H13. These findings indicate that environmental risk perception may serve as an important psychological mechanism linking environmental knowledge to actual sustainable behavior, although its mediating influence on behavioral intention was not statistically established. This interpretation is consistent with the broader literature suggesting that perceptions of environmental threats and consequences can influence environmentally responsible behavioral responses (Bamberg & Möser, 2007).

Furthermore, environmentally sustainable behavioral intention did not significantly mediate the relationship between environmental knowledge and environmentally sustainable behavior ($\beta = 0.028$, $t = 1.495$, $p = 0.135$), leading to the rejection of hypothesis H14. However, behavioral intention demonstrated a positive and statistically significant mediating effect on the relationship between environmental concern and environmentally sustainable behavior ($\beta = 0.203$, $t = 8.232$, $p < 0.001$), supporting hypothesis H15. This finding suggests that individuals with greater environmental concern are more likely to develop sustainable behavioral intentions, which subsequently contribute to environmentally responsible behavior. The result is consistent with the Theory of Planned Behavior, which identifies behavioral intention as a central predictor of actual behavior (Ajzen, 1991). In contrast, the mediating effect of behavioral intention on the relationship between environmental risk

perception and environmentally sustainable behavior was statistically insignificant (β = 0.057, t = 1.630, p = 0.103), indicating that hypothesis H16 was not supported.

The serial mediation analysis provided additional insights into the sequential psychological mechanisms underlying environmentally sustainable behavior. The results revealed a positive and statistically significant serial indirect effect of environmental knowledge on environmentally sustainable behavior through environmental concern and behavioral intention (β = 0.086, t = 6.361, p < 0.001), supporting hypothesis H17. This finding suggests that environmental knowledge is associated with greater environmental concern, which subsequently strengthens sustainable behavioral intentions and contributes to environmentally responsible behavior. Such a sequential relationship is consistent with theoretical perspectives emphasizing the interconnected roles of cognitive, affective, and intentional determinants in explaining pro-environmental behavior (Ajzen, 1991; Bamberg & Möser, 2007). However, the serial mediation pathway involving environmental risk perception and behavioral intention was statistically insignificant (β = 0.008, t = 1.563, p = 0.118), indicating that hypothesis H18 was not supported.

Overall, the mediation analysis revealed that five of the nine hypothesized indirect relationships were statistically significant, while four were not supported at the 5% significance level. Environmental concern emerged as a particularly important mediating construct, demonstrating significant indirect effects on both environmentally sustainable behavioral intention and actual sustainable behavior. Furthermore, the significant serial mediation pathway involving environmental concern and behavioral intention highlights the potential sequential mechanisms through which environmental knowledge is associated with environmentally responsible behavior. In contrast, environmental risk perception exhibited a significant indirect effect on sustainable behavior but not on behavioral intention, suggesting that its mediating role differs across behavioral outcomes. Collectively, these findings extend the understanding of environmentally sustainable behavior by highlighting the distinct roles of environmental concern, risk perception, and behavioral intention in explaining the relationships between environmental knowledge and sustainable behavioral outcomes.

Table 5: Specific indirect effect

H. no.	Indirect relations	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Decision
H10	EK -> EC -> ESBI	0.206	0.207	0.028	7.480	0.000	Supported
H11	EK -> EC -> ESB	0.127	0.128	0.023	5.455	0.000	Supported
H12	EK -> ERP -> ESBI	0.018	0.018	0.011	1.579	0.114	Not supported
H13	EK -> ERP -> ESB	0.049	0.049	0.013	3.800	0.000	Supported
H14	EK -> ESBI -> ESB	0.028	0.028	0.019	1.495	0.135	Not supported
H15	EC -> ESBI -> ESB	0.203	0.203	0.025	8.232	0.000	Supported
H16	ERP -> ESBI -> ESB	0.057	0.058	0.035	1.630	0.103	Not supported
H17	EK -> EC -> ESBI -> ESB	0.086	0.086	0.014	6.361	0.000	Supported
H18	EK -> ERP -> ESBI -> ESB	0.008	0.008	0.005	1.563	0.118	Not supported

Discussions

The present study investigated the relationships among environmental knowledge (EK), environmental concern (EC), environmental risk perception (ERP), environmentally sustainable behavioral intention (ESBI), and environmentally sustainable behavior (ESB). The findings provide important empirical insights into the cognitive, affective, and intentional mechanisms underlying environmentally sustainable behavior. By examining both direct and mediating relationships, the study contributes to understanding how environmental knowledge is translated into sustainable behavioral outcomes. The findings reveal that environmental concern, environmental risk perception, and behavioral intention play distinct but interconnected roles in explaining environmentally sustainable behavior.

Environmental Knowledge and Environmentally Sustainable Behavior

The findings demonstrate that environmental knowledge has a positive and statistically significant influence on environmental concern (β = 0.423, p < 0.001) and environmental risk perception (β = 0.131, p < 0.001). These results suggest that individuals possessing greater environmental knowledge are more likely to recognize

environmental challenges, develop concern about ecological deterioration, and perceive the potential risks associated with environmental degradation. The relatively stronger relationship between environmental knowledge and environmental concern indicates that knowledge may be more closely associated with individuals' emotional and evaluative responses to environmental issues than with their perceptions of environmental risks.

These findings are consistent with Kollmuss and Agyeman (2002), who emphasized that environmental knowledge constitutes an important antecedent of environmental awareness but does not necessarily translate directly into environmentally responsible behavior. Similarly, Bamberg and Möser (2007) highlighted the importance of psychological and motivational mechanisms in explaining pro-environmental behavior.

Interestingly, environmental knowledge demonstrated a positive but relatively weak direct influence on environmentally sustainable behavior ($\beta = 0.096$, $p = 0.021$), whereas its relationship with environmentally sustainable behavioral intention was statistically insignificant ($\beta = 0.068$, $p = 0.134$). This finding highlights a potentially important distinction between environmental awareness, behavioral intentions, and actual sustainable practices. Although individuals may possess adequate knowledge about environmental issues, such knowledge does not necessarily motivate them to develop stronger intentions to engage in environmentally sustainable activities. The insignificant relationship between environmental knowledge and behavioral intention is particularly noteworthy because it suggests that environmental awareness alone may be insufficient to stimulate sustainable behavioral intentions. Other factors, including environmental concern, perceived behavioral control, social expectations, and personal values, may influence the translation of environmental knowledge into behavioral intentions. This interpretation is consistent with the knowledge–action gap discussed by Kollmuss and Agyeman (2002).

Environmental Concern as a Determinant of Sustainable Behavioral Intention and Behavior

Environmental concern emerged as an important predictor of both environmentally sustainable behavioral intention ($\beta = 0.488$, $p < 0.001$) and environmentally sustainable behavior ($\beta = 0.300$, $p < 0.001$). The stronger influence on behavioral intention suggests that individuals who are concerned about environmental deterioration are more likely to develop a willingness to engage in sustainable practices. These findings reinforce the argument that environmental concern represents an important psychological mechanism through which environmental awareness is translated into environmentally responsible decisions. Individuals who recognize environmental problems and experience concern about their consequences may be more motivated to adopt practices intended to reduce environmental harm. The results align with Bamberg and Möser (2007), whose meta-analysis demonstrated that pro-environmental behavior is influenced by a combination of psychological determinants, including moral norms, attitudes, and behavioral intentions. The findings also complement the Theory of Planned Behavior (Ajzen, 1991), which emphasizes the role of behavioral intentions in explaining individual behavior. An important implication of this finding is that environmental concern appears to have both direct and intention-mediated associations with sustainable behavior. Consequently, environmental concern should not be viewed merely as an emotional response to environmental problems but also as an important motivational factor associated with environmentally responsible actions.

Environmental Risk Perception and Sustainable Behavior

The findings reveal that environmental risk perception has a positive and statistically significant influence on environmentally sustainable behavior ($\beta = 0.370$, $p < 0.001$). However, its influence on environmentally sustainable behavioral intention was statistically insignificant ($\beta = 0.137$, $p = 0.099$). This distinction provides an important insight into the relationship between perceived environmental threats and sustainable behavioral responses.

The significant relationship between environmental risk perception and sustainable behavior suggests that individuals who perceive environmental degradation as a serious threat may be more likely to engage in environmentally responsible practices. Perceptions of environmental risks may encourage individuals to adopt preventive or protective actions intended to minimize environmental damage. Nevertheless, the insignificant relationship between environmental risk perception and behavioral intention indicates that awareness of environmental threats does not necessarily translate into a stronger intention to undertake sustainable activities. One possible explanation is that risk perception may influence behavioral responses through mechanisms other than explicitly reported intentions. The results extend existing discussions of pro-environmental behavior by demonstrating that environmental risk perception may be more strongly associated with actual sustainable behavior than with behavioral intention in the examined model.

Environmentally Sustainable Behavioral Intention and Actual Behavior

Environmentally sustainable behavioral intention demonstrated a positive and statistically significant relationship with environmentally sustainable behavior ($\beta = 0.417$, $p < 0.001$). Among the direct predictors of

sustainable behavior examined in the study, behavioral intention exhibited the strongest standardized path coefficient. This finding provides empirical support for the central proposition of the Theory of Planned Behavior (Ajzen, 1991), which identifies behavioral intention as a proximal determinant of actual behavior. Individuals who express stronger intentions to engage in environmentally sustainable practices are more likely to report environmentally responsible behaviors. The finding also highlights the importance of examining psychological factors that contribute to the formation of sustainable behavioral intentions. Although environmental knowledge and environmental risk perception did not demonstrate statistically significant direct relationships with behavioral intention, environmental concern emerged as a strong predictor. This suggests that the development of sustainable behavioral intentions may depend more strongly on individuals' concern about environmental problems than on their environmental knowledge or perceived environmental risks alone. Accordingly, interventions intended to encourage environmentally sustainable behavior may benefit from combining environmental education with initiatives that strengthen environmental concern and motivate individuals to adopt sustainable practices.

Mediating Role of Environmental Concern

The mediation analysis provides further evidence of the importance of environmental concern in explaining environmentally sustainable behavior. Environmental concern significantly mediated the relationship between environmental knowledge and environmentally sustainable behavioral intention ($\beta = 0.206$, $p < 0.001$), as well as the relationship between environmental knowledge and environmentally sustainable behavior ($\beta = 0.127$, $p < 0.001$). These findings suggest that environmental knowledge is associated with sustainable behavioral outcomes partly through its relationship with environmental concern. Individuals possessing greater environmental knowledge may develop stronger concern about environmental degradation, which is subsequently associated with more favorable sustainable behavioral intentions and practices. The significant indirect effect of environmental knowledge on behavioral intention through environmental concern is particularly important because the corresponding direct relationship was statistically insignificant. This pattern indicates that environmental concern may represent an important explanatory mechanism linking environmental knowledge with sustainable behavioral intention. Furthermore, the significant direct relationship between environmental knowledge and sustainable behavior, together with its significant indirect relationship through environmental concern, indicates the presence of complementary mediation, whereby both direct and indirect effects operate in the same direction. These findings are consistent with the argument of Kollmuss and Agyeman (2002) that environmental knowledge alone is insufficient to explain environmentally responsible behavior and that psychological factors play an important role in connecting awareness with action.

Mediating Role of Environmental Risk Perception

The mediation results indicate that environmental risk perception significantly mediated the relationship between environmental knowledge and environmentally sustainable behavior ($\beta = 0.049$, $p < 0.001$). However, its mediating effect on the relationship between environmental knowledge and environmentally sustainable behavioral intention was statistically insignificant ($\beta = 0.018$, $p = 0.114$). These findings suggest that environmental risk perception represents a relevant pathway through which environmental knowledge is associated with sustainable behavior. Individuals with greater environmental knowledge may be more aware of environmental threats, and this heightened risk perception may be associated with greater engagement in sustainable practices. Nevertheless, the absence of a statistically significant indirect effect on behavioral intention suggests that risk perception does not necessarily operate through the same psychological mechanisms as environmental concern. The distinction between these mediating relationships is theoretically important. Whereas environmental concern appears to be associated with both the development of sustainable intentions and sustainable behavior, environmental risk perception demonstrates a significant indirect association only with sustainable behavior. This finding suggests that environmental concern and risk perception should be treated as conceptually distinct constructs rather than interchangeable indicators of environmental awareness.

Mediating Role of Environmentally Sustainable Behavioral Intention

The results further demonstrate that environmentally sustainable behavioral intention significantly mediated the relationship between environmental concern and environmentally sustainable behavior ($\beta = 0.203$, $p < 0.001$). This finding reinforces the importance of behavioral intention as a mechanism connecting environmental concern with sustainable practices. The significant direct relationship between environmental concern and sustainable behavior, together with the significant indirect effect through behavioral intention, indicates complementary mediation. Thus, environmental concern is associated with sustainable behavior both directly and indirectly through behavioral intention. Conversely, behavioral intention did not significantly mediate the relationships between environmental knowledge and sustainable behavior ($\beta = 0.028$, $p = 0.135$) or between environmental risk perception and sustainable behavior ($\beta = 0.057$, $p = 0.103$).

These findings indicate that behavioral intention does not function uniformly as a mediator across all environmental determinants. Instead, its mediating role appears to depend on the nature of the antecedent variable. The findings support the broader theoretical argument that sustainable behavior results from multiple psychological processes rather than a single linear relationship between environmental awareness and behavioral action.

Serial Mediation of Environmental Concern and Behavioral Intention

An important contribution of the study is the examination of serial mediation pathways linking environmental knowledge with environmentally sustainable behavior. The results reveal a statistically significant sequential indirect relationship between environmental knowledge and sustainable behavior through environmental concern and behavioral intention ($\beta = 0.086$, $p < 0.001$). This finding suggests that greater environmental knowledge is associated with increased environmental concern, which is subsequently associated with stronger sustainable behavioral intentions and, ultimately, environmentally responsible behavior. This sequential relationship provides empirical support for an integrated cognitive–affective–intentional explanation of environmentally sustainable behavior. Environmental knowledge represents the cognitive dimension, environmental concern reflects an affective and evaluative response, and behavioral intention represents the motivational orientation associated with sustainable behavior. The findings are broadly consistent with the Theory of Planned Behavior (Ajzen, 1991) and the integrated psychological framework of pro-environmental behavior discussed by Bamberg and Möser (2007). In contrast, the serial mediation pathway involving environmental knowledge, environmental risk perception, behavioral intention, and sustainable behavior was statistically insignificant ($\beta = 0.008$, $p = 0.118$). This result further reinforces the distinction between environmental concern and environmental risk perception in the formation of sustainable behavioral intentions. The findings indicate that environmental concern may provide a more effective explanatory pathway for understanding how environmental knowledge is associated with sustainable behavior through behavioral intention.

Theoretical Contributions and Implications

The findings offer several contributions to the literature on environmentally sustainable behavior. First, the study provides empirical evidence that environmental knowledge is associated with sustainable behavior through multiple psychological pathways. The significant indirect effects involving environmental concern and environmental risk perception demonstrate the importance of examining mediating mechanisms rather than relying exclusively on direct relationships. Second, the findings establish the distinctive roles of environmental concern and environmental risk perception. Environmental concern was significantly associated with both behavioral intention and sustainable behavior, whereas environmental risk perception demonstrated a significant direct relationship only with sustainable behavior. This distinction contributes to a more nuanced understanding of the psychological determinants of environmentally responsible practices. Third, the significant mediating effect of behavioral intention between environmental concern and sustainable behavior provides support for the relevance of the Theory of Planned Behavior in explaining sustainable behavioral outcomes. However, the insignificant mediation effects involving environmental knowledge and risk perception indicate that intention-based explanations alone may not fully account for sustainable behavior. Fourth, the significant serial mediation involving environmental knowledge, environmental concern, and behavioral intention contributes to the development of an integrated explanation of environmentally sustainable behavior. The results suggest that the relationship between environmental knowledge and sustainable practices may involve interconnected cognitive, affective, and intentional mechanisms. Finally, the study contributes empirical evidence from Saudi Arabia, providing insights into environmentally sustainable behavior within a national context characterized by growing policy attention to environmental sustainability and responsible resource consumption.

Practical and Policy Implications

The findings have important implications for policymakers, environmental organizations, educational institutions, and sustainability practitioners. The significant influence of environmental knowledge on environmental concern suggests that environmental education and awareness initiatives may contribute to strengthening individuals' concern about ecological challenges. However, because environmental knowledge did not demonstrate a significant direct relationship with sustainable behavioral intention, information-oriented campaigns alone may be insufficient to encourage sustainable practices. Environmental awareness programs should therefore seek not only to disseminate environmental information but also to communicate the consequences of environmental degradation and strengthen individuals' personal concern about environmental protection. Furthermore, the significant relationship between environmental risk perception and sustainable behavior highlights the potential relevance of environmental risk communication. Public awareness initiatives may benefit from providing clear, credible, and accessible information about environmental threats and their implications for individuals and communities. The strong relationship between behavioral intention and

sustainable behavior also suggests the importance of developing initiatives that encourage individuals to translate environmental concern into practical commitments. Such initiatives may include sustainability education, community participation, environmental campaigns, and programs promoting responsible consumption and resource conservation. Within the Saudi Arabian context, these findings may inform environmental awareness and behavioral change initiatives aligned with the sustainability objectives of Saudi Vision 2030 and the Saudi Green Initiative.

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