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Mapping Barriers to Sustainable Fashion Consumption: Insights from Neutrosophic-Z Number and Delphi-DEMATEL Integration

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Abstract: This study investigates the barriers to sustainable consumption within the Vietnamese fashion industry, a critical issue given the sector's significant environmental impact and growing consumer awareness. The research employs an innovative combination of Neutrosophic Z-number sets (NZN), Delphi, and Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodologies to systematically identify and analyze 47 barriers across five key dimensions: Social and Cultural Factors, Pricing and Affordability, Policy and Education, Perception and Image, and Supply Chain and Industry Practices. Through expert evaluations and causal analysis, the study reveals that Policy and Education are the most influential factors, highlighting the need for robust policy frameworks and educational initiatives to drive sustainable consumption. The NZN addresses the limitations of traditional decision-making models by capturing the uncertainty and complexity of consumer behaviors. The findings provide valuable insights for both academics and practitioners, offering theoretical contributions to sustainable consumption research and practical recommendations for businesses and policymakers. These include enhancing product variety and affordability, promoting sustainable practices through education, and improving supply chain transparency. Future research should explore longitudinal studies and comparative analyses across different markets to validate these findings and further refine approaches to fostering sustainability within the fashion industry.

Keywords: Sustainable Consumption; Fashion; Delphi; DEMATEL; Neutrosophic; Z-number; NZN

1. Introduction

1.1 Global fashion industry context

The fashion and textile sector, a colossal entity valued at $2.4 trillion, holds a vital position in the global economy, employing nearly 300 million individuals across the globe (*UN Alliance for Sustainable Fashion*, 2018). However, this economic significance is overshadowed by its profound environmental footprint, positioning it as the world's second-largest polluter (Bailey et al., 2022). The industry's carbon emissions are staggering, representing 8-10% of global totals—surpassing the emissions from both maritime shipping and international aviation (*UN Alliance for Sustainable Fashion*, 2018). Water consumption is another critical issue, with the industry's annual water consumption of around 93 billion cubic meters, a volume that could otherwise fulfill the needs of 5 million people (Ellen MacArthur Foundation, 2017). If current trends persist, greenhouse gas emissions are anticipated to rise by 50% by 2030, signaling a troubling environmental trajectory (Bailey et al., 2022). Additionally, the sector is known as a significant contributor to ocean pollution, generating about 35% of the microplastics that contaminate marine environments and threaten aquatic life (Boucher & Friot, 2017). Beyond ecological damage, the industry faces immense material inefficiencies, resulting in annual losses estimated at $100 billion due to poor recycling and resource underuse (Ellen MacArthur Foudation, 2017).

The rise of fast fashion has exacerbated these issues, encouraging the production of low-cost, short-lived garments (Bick et al., 2018). Over the last 15 years, global clothing consumption has surged by 60%, while the lifespan of individual items has halved, leading to 92 million tons of textile waste annually (Amed et at, 2019). This unsustainable model relies heavily on non-renewable resources, intensive energy consumption, and exploitative labor practices, with workers in key garment-producing countries earning less than half the calculated living wage (H&M Group, 2021). To address these challenges, the industry must adopt sustainable practices such as using eco-friendly materials, circular economy models, and ethical labor standards, alongside reducing water and energy consumption (Bailey et al., 2022; Brydges, 2021). Companies like H&M and Patagonia have pioneered initiatives such as garment recycling programs and repair-resale systems, while countries like Sweden have introduced clothing swaps and second-hand libraries to encourage sustainable consumption (Bailey et al., 2022).

1.2 Vietnam's sustainability challenges

Vietnam, a leading fashion manufacturing hub in Southeast Asia, has made strides toward sustainability through policies like Decision 687 and updates to the Law on Environmental Protection (LEP) (Thu Nguyen & Cece Nguyen, 2022). However, the nation faces significant challenges balancing rapid industrial growth with global sustainability standards (Nayak, Panwar, et al., 2019). These issues are mirrored in other developing economies such as Spain, Chile, Bangladesh, and India, which grapple with barriers like economic constraints, low consumer awareness, and limited availability of sustainable products (Adamkiewicz et al., 2022). A critical gap exists between consumers' concerns about unethical practices and purchasing behaviors. Factors such as price sensitivity, skepticism toward sustainability claims, and perceptions of unfashionability exacerbate this disparity (Bianchi & Gonzalez, 2021; Tahniyath Fatima & Saïd Elbanna, 2023). While sustainable fashion research has gained momentum, most studies focus on developed markets such as Europe, Australia, and Sweden (Brydges, 2021; Riemens et al., 2021; Sandvik & Stubbs, 2019). In Vietnam, research often emphasizes supply chain initiatives (Nayak et al., 2022) or luxury brands' perspectives on sustainability (K. T. Nguyen et al., 2023), neglecting the behaviors and perceptions of average consumers. Methodologically, many studies rely on small sample sizes or qualitative methods, limiting their scope and generalizability. This research aims to bridge these gaps by exploring the barriers to sustainable fashion consumption in Vietnam, examining consumer attitudes and behaviors, and proposing tailored strategies that consider local economic and cultural dynamics (Brydges, 2021; Riemens et al., 2021; Sandvik & Stubbs, 2019).

Recognizing the unique challenges and opportunities in Vietnam, where traditional models often fall short in capturing the complexities of innovation, this study adapts and enhances these models to suit the local context. To address the multifaceted barriers to sustainable fashion consumption in Vietnam, the Multi-Criteria Decision-Making (MCDM) approach is applied, integrating Neutrosophic Sets (NS) with Z-Numbers (NZN). NS marks a significant improvement over traditional Fuzzy Sets (FS) by enhancing the ability to model uncertainty. Unlike FS, which uses a single membership grade to represent uncertainty, NS employs three distinct components—truth, indeterminacy, and falsity—offering a more robust and flexible approach (P. H. Nguyen et al., 2024). This structure provides a richer and more nuanced framework to address hesitation, ambiguity, and contradiction inherent in the perception of sustainability among consumers. Compared to fuzzy set extensions such as Triangular Fuzzy Numbers (TFNs) (Zadeh, 1965), Intuitionistic Fuzzy Sets (IFS) (Atanassov, 1986), Pythagorean Fuzzy Sets (PFS) (Yager, 2013), Picture Fuzzy Sets (Bui, 2015), and Spherical Fuzzy Sets (Gündoğdu, 2020), NS offers unparalleled flexibility. TFNs rely on rigid triangular distributions (α with $\alpha \in [0,1]$) that fail to capture non-membership or hesitation, while IFS adds non-membership degrees but does not account for indeterminacy (P. H. Nguyen et al., 2023). In addressing this, Type-2 fuzzy sets (Sepúlveda et al., 2007) tackle uncertainty, and they fail to capture indeterminacy, which is crucial in modeling consumer behaviors influenced by diverse social and environmental factors. PFS and Spherical Fuzzy Sets incorporate degrees of hesitation but impose summation or squared constraints that limit adaptability in real-world scenarios (P. H. Nguyen, 2024). In contrast, NS treats truth, indeterminacy, and falsity as independent variables ranging freely between 0 and 1, allowing for more accurate modeling of consumer behaviors where ambiguity, skepticism, and contradictory perceptions coexist.

Previous NS and MCDM methods applications have primarily focused on domains such as supply chain management, renewable energy, risk assessment, and urban planning. Hosny et al. (2021) employed a Neutrosophic Analytical Hierarchy Process (AHP) with Multiplicative Multi-Objective Optimization based on Ratio Analysis (MULTIMOORA) to optimize sustainable supply chains, while Kalantari et al. (2022) applied a neutrosophical model for closed-loop supply chain networks, addressing inflation and carbon emissions. Yel et al. (2023) utilized Interval-Valued NZN to assess critical success factors in software projects, demonstrating the framework's ability to combine subjective judgments with quantitative evaluations. Additionally, Borah et al. (2023) introduced Quadripartitioned Single-Valued Neutrosophic Z-Numbers (QSVNZN) to model diverse

COVID-19 scenarios, further expanding NZN's applicability in risk management. While these studies demonstrate the versatility of NZN and NS in addressing sustainability challenges, their application in sustainable fashion remains limited. Notably, existing research often neglects the critical role of reliability in modeling consumer perceptions and behaviors, particularly in markets like Vietnam, where cultural, economic, and social factors uniquely influence attitudes toward sustainable fashion. Furthermore, the gap between consumer intent and action, compounded by skepticism toward brand sustainability claims and the high perceived costs of eco-friendly products, highlights the need for a framework that addresses both uncertainty and data reliability.

1.3 Research questions, objectives, and contributions

To achieve this goal, the primary objective is to explore and provide answers to these central research questions:

(i) What factors hinder the successful adoption of sustainable consumption practices in the Vietnamese fashion industry?
(ii) How are these barriers connected within the context of implementing sustainable consumption initiatives?
(iii) How significant are these barriers in affecting the adoption of sustainable consumption practices within the Vietnamese industry?

As a consequence of the previously outlined research questions in the Vietnamese context, this study will strive to achieve the following objectives:

(i) Identify the major barriers hindering sustainable consumption.
(ii) Examine the interconnections among these significant barriers and their cause-effect relationship.
(iii) To provide recommendations for overcoming major barriers and promoting sustainability in the Vietnamese Fashion Industry.

This research offers significant contributions to both theoretical understanding and practical application in sustainable consumption, specifically emphasizing the Vietnamese fashion industry. Theoretically, it introduces a novel approach by integrating NZN with Delphi and DEMATEL methods. This combination offers a robust framework for addressing the complexity and uncertainty of consumer behavior, which traditional models often overlook. Methodologically, the NZN application represents an important advancement, improving the precision of decision-making models by accommodating the inherent uncertainty and vagueness associated with consumer perceptions. Furthermore, integrating expert-driven methods (Delphi) with causal analysis (DEMATEL) provides a systematic approach for prioritizing barriers, offering a replicable framework for future research in other industries or regions. Practically, the findings highlight the critical role of Policy and Education as the most influential drivers of sustainable consumption in the fashion industry. These insights are particularly relevant for designing targeted interventions and developing comprehensive policies that support sustainability. Finally, this study contributes context-specific insights by focusing on the Vietnamese fashion industry, an emerging market with unique sustainability challenges.

The remainder of this study is organized as follows: Section 2 provides an overview of relevant literature on sustainable fashion, highlighting key developments and challenges in the fashion industry. Section 3 introduces the foundational concepts of NZN and their leading operators in decision-making frameworks. Section 4 analyzes the data collected, contextualized within Vietnam’s fashion industry, and discusses the key findings. Finally, Section 5 outlines the study’s implications for theory and practice, addresses its limitations, and proposes potential directions for future research.

2. Literature Review

2.1. Literature Review on Neutrosophic Set, Z-Numbers and NZN applications.

MCDM methods have been widely utilized to analyze the complex interdependencies among factors in uncertain systems. Vishwakarma et al. (2022) emphasize that DEMATEL is particularly effective for distinguishing cause-and-effect relationships, as demonstrated in their identification of critical barriers in sustainable supply chain management. Similarly, Chen et al. (2021) applied DEMATEL to assess key obstacles to implementing the circular economy, showcasing its ability to map relational structures. Riemens et al. (2021) extended these approaches by employing the Delphi-Régnier method to investigate challenges in textile recycling, such as insufficient eco-design practices and policy gaps, thereby offering insights into enhancing circular practices. When combined with expert-driven techniques such as the Delphi method, as shown by Ruano et al. (2023) in their study on sustainability indicators in Belize’s ecotourism sector, MCDM methods enhance decision-making frameworks by incorporating expert consensus and systematic prioritization of factors

(Kilic & Yalcin, 2021). Additionally, these methods have been employed to evaluate sustainable supply chains. Ruano et al. (2023) applied Fuzzy DEMATEL to analyze sustainability indicators, emphasizing their adaptability in varied contexts.

Table 1. *Related works*

Authors	Methods	Domain
Chen et al. (2024)	NZN, Logarithmic Similarity Measure	Evaluates teaching quality.
Diznarda Álvarez Gómez et al. (2022)	Neutrosophic AHP, DEMATEL	Sustainable tourism development.
Hosny et al. (2021)	Neutrosophic AHP, MULTIMOORA	Sustainable suppliers.
Kilic & Yalcin (2021)	Neutrosophic DEMATEL, TOPSIS	Municipalities' environmental sustainability performance
Veeramani et al. (2022)	Neutrosophic DEMATEL	Financial ratios for portfolio optimization in the NASDAQ exchange.
Nguyen et al.(2024)	NZN, DEMATEL, COCOOSO	Cybersecurity risks.
Meza Taipe et al. (2024)	Fuzzy Set Theory, Neutrosophic Sets	Public service quality for native communities in Ucayali.
Ruano et al. (2023)	Fuzzy Delphi, Fuzzy DEMATEL	Sustainable ecotourism.
Vishwakarma et al. (2022)	ISM, Fuzzy MICMAC, DEMATEL	Critical barriers impacting SSCM in the apparel sector.
Riemens et al. (2021)	Delphi-Régnier Method	Challenges in textile recycling to enhance circular practices.
Chen et al. (2021)	DEMATEL, Fuzzy Delphi	Prioritizes barriers to implementing circular economy in the textile industry.

As shown in **Table 1**, the evolution of uncertainty modeling has seen significant advancements with the introduction of NS and Z-numbers; both provide sophisticated frameworks for addressing indeterminacy and imprecision in complex decision-making scenarios. NS, introduced by Smarandache, generalizes classical fuzzy set theory by incorporating three independent membership functions: truth (T), indeterminacy (I), and falsity (F). Unlike traditional fuzzy sets, NS allows these membership functions to operate independently within the interval]−0, 1+[, providing a comprehensive approach to managing vagueness, inconsistency, and contradiction in information. To enhance its practicality, Wang et al. (2010) developed Single-Valued Neutrosophic Sets (SVNS), which constrain the membership values to the interval [0,1], making NST more suitable for real-world applications. NST has been successfully applied across diverse fields, including supply chain management, human resources, medical diagnosis, and project management. For instance, Şahin & Yigider (2014) applied NS to optimize sustainable supply chains, while Comas Rodríguez et al. (2022) utilized it to address uncertainties in project parameters like costs and resource availability, demonstrating the adaptability of NS to intricate decision-making challenges.

Z-numbers, proposed by Zadeh (2011a), offer another significant advancement by explicitly incorporating the reliability of information. A Z-number is an ordered pair (Z = (A, B)), where (A) represents a fuzzy restriction on a variable and (B) denotes the reliability of (A). This dual-layer framework provides a more nuanced representation of uncertainty, addressing both the degree of imprecision and the trustworthiness of the data. Zhang et al. (2023) demonstrated Z-numbers' utility in system reliability assessments, showing their capability to integrate probabilistic and possibilistic uncertainties for more realistic reliability estimates.

The integration of NS and Z-numbers has led to the development of NZN, which combines the multi-dimensional uncertainty modeling of NS with the reliability measures of Z-numbers. NZN frameworks have effectively addressed complex decision-making problems by integrating degrees of truth, falsity, and indeterminacy with reliability scores (Borah & Dutta, 2023). Applications of NZN include cybersecurity risk evaluation (P. H. Nguyen et al., 2024), where a Delphi-DEMATEL-COCOSO approach combined with NZN effectively prioritized strategies in Vietnam's finance sector. Du et al.(2021) introduced NZN-weighted aggregation operators to enhance decision-making precision, while Ye et al.(2021) expressed the inconsistent, incomplete, and indeterminate knowledge and judgments of human cognitions in the real world to refine multi-criteria decision-making methods.

Despite these advancements, the application of NZN in sustainable fashion remains limited. The industry faces unique challenges, including consumer skepticism, greenwashing, and cost barriers, which require nuanced approaches to uncertainty modeling. NZN offers significant advantages in this context by capturing the complexities of consumer attitudes—such as acceptance (truth), doubts about brand authenticity (falsity), and hesitation due to cost or availability (indeterminacy)—and integrating reliability measures to address issues like the credibility of sustainability certifications and brand claims. This dual capability makes NZN particularly suited for analyzing and overcoming barriers to sustainable fashion consumption. By leveraging NZN's robust uncertainty modeling features, this study provides a targeted framework for addressing barriers to sustainable fashion in Vietnam, setting a precedent for advanced decision-making in sustainability efforts across various domains.

The integration of the Delphi (Diznarda Álvarez Gómez et al., 2022), DEMATEL (Torres & Vargas, 2014), and NZN (Du et al., 2021) represents a sophisticated and synergistic approach to addressing complex, uncertain, and interdependent challenges sustainably. The Delphi method, developed in the 1950s, facilitates consensus-building among experts through iterative rounds of questionnaires. While effective for prioritizing issues and identifying critical factors, traditional Delphi methods face limitations in addressing uncertainty and variability in expert judgments. The NZN-enhanced Delphi method overcomes these shortcomings by incorporating the multi-dimensional uncertainty modeling capabilities of NZNs. By integrating truth, indeterminacy, falsity, and reliability measures, NZN Delphi provides a nuanced and robust framework for analyzing ambiguous expert opinions, ensuring a focused and precise identification of the most critical barriers to sustainable fashion adoption. Complementing Delphi, the DEMATEL method maps and analyzes interdependencies among factors within complex systems. By constructing cause-and-effect frameworks, DEMATEL reveals root causes and cascading effects, enabling decision-makers to identify primary drivers and prioritize interventions. Unlike other MCDM methods, such as AHP, which focuses on short-term prioritization, DEMATEL provides long-term insights by clarifying causal relationships among factors. The DEMATEL process—from constructing direct-relation matrices to visualizing results in cause-and-effect diagrams—offers actionable insights highlighting critical elements and root causes. Its application in sustainability-focused research has proven invaluable, particularly in identifying systemic barriers and designing strategies with cascading benefits.

Integrating NZN, Delphi, and DEMATEL creates a comprehensive decision-making framework. NZNs enhance the process by addressing the uncertainty and reliability often inherent in data and expert judgments, ensuring a more accurate representation of barriers and interdependencies. The combined approach is particularly suitable for the sustainable fashion sector, where challenges such as consumer skepticism, greenwashing, and cost barriers require nuanced analysis. For instance, NZN captures consumer skepticism (falsity), hesitation due to availability or cost (indeterminacy), and trust in certifications (reliability), enabling a detailed examination of how these factors interact within the broader system.

This integrated methodology provides several advantages. First, it enhances uncertainty modeling through NZN, enabling a deeper understanding of multi-dimensional challenges. Second, it leverages Delphi's structured consensus-building and DEMATEL's causal analysis to identify root causes and prioritize impactful interventions. Third, it offers actionable insights tailored to Vietnam's sustainable fashion sector's unique cultural, economic, and social context. By combining expert-driven consensus, systemic analysis, and robust uncertainty modeling, this framework bridges gaps in existing research, setting a new standard for addressing sustainability challenges in dynamic environments. Ultimately, this approach facilitates targeted, data-driven strategies to overcome barriers, drive consumer engagement, and promote systemic change in sustainable fashion practices.

2.2 Sustainability in the Fashion Industry

The fashion industry, valued at $2.4 trillion, is recognized as one of the most environmentally unsustainable sectors due to the prevalence of "fast fashion," drastically altering consumer buying and disposal behaviors. Fast fashion prioritizes low-cost, trendy garments, resulting in mass production and consumption that significantly contributes to global textile waste (Vladimirova et al., 2022). This unsustainable business model has led to a surge in material throughput, with brands producing nearly double the clothing output compared to pre-2000 levels. The environmental consequences are extensive, spanning all production phases and including issues such as excessive water use, toxic chemicals, and significant energy consumption (Niinimäki et al., 2020). These practices harm ecosystems and pose health risks to factory workers and consumers.

As sustainability awareness grows, the fashion industry gradually adopts practices emphasizing ethical and eco-friendly standards, reflecting a shift toward responsible consumerism (Amed et at, 2019; Khandual & Pradhan, 2019). This includes a holistic approach to sustainable fashion, focusing on eco-friendly materials, reduced carbon footprints, water conservation, fair labor practices, and extended garment lifecycles (Henninger et al., 2016). Sustainable fashion encompasses diverse approaches, including using organic fabrics, promoting recycling, encouraging clothing swaps, and adopting circular economy principles [38]. For instance, brands like H&M and Patagonia have pioneered initiatives such as garment recycling and resale programs to reduce waste and promote sustainability (Patagonia, 2022).

In Vietnam, companies like An Phuoc are implementing eco-friendly collections using organic and recycled materials, while denim brands are researching water-saving technologies and reducing harmful chemical use in collaboration with the Ministry of Science and Technology (*Sustainable Denim Production Using Lasers and Ozone*, 2024). Furthermore, this study employs the Theory of Planned Behavior (TPB) and the Black Box Model of Consumer Behavior to explore barriers to sustainable fashion consumption in Vietnam. TPB posits that behavior is influenced by attitudes, subjective norms, and perceived behavioral control, providing a robust framework for analyzing consumer intentions (Ajzen, 1991). Saricam et al. (Saricam & Okur, 2019) emphasize the adaptability of TPB across scenarios, including sustainable consumption, by incorporating additional factors like self-identity, ethical values, and past experiences. By integrating TPB with the Black Box Model of Consumer Behavior, this study broadens the analytical lens to include both external and internal factors influencing consumer decision-making. The Black Box Model focuses on the internal cognitive processes that drive consumer behavior, such as perception, motivation, and decision-making, while accounting for external stimuli like marketing messages, product availability, and pricing (Kotler & Keller, 2016). This combined approach allows a nuanced understanding of how external environmental cues interact with internal psychological factors to shape consumer attitudes and behaviors toward sustainable fashion. In the context of Vietnam, where cultural, economic, and social factors uniquely influence consumer decisions, the integration of these models provides a comprehensive framework for identifying and addressing the key barriers to sustainable fashion adoption.

Despite these advancements, significant barriers remain to sustainable fashion adoption. Practical challenges, such as high costs, limited product variety, and the dominance of fast fashion trends, hinder consumers' ability to make sustainable choices (Brandão & Costa, 2021). Although many consumers are willing to purchase from sustainable brands, actual adoption rates remain low due to cost, accessibility, and style preferences (Lambert, 2019). These challenges are particularly evident in Vietnam, where younger consumers show greater interest in sustainability while older generations prioritize cost and convenience (Lambert, 2019). Younger consumers are more receptive to these initiatives, while older generations are less engaged. The effectiveness of these campaigns is influenced by factors such as awareness, accessibility, and budget-friendliness of sustainable clothing options. Local initiatives, such as Green Yarn, are actively fostering sustainable fashion through educational programs via CSR initiatives and workshops such as Fashion Rob My Future (*Fashion Rob My Future – Sustainable Fashion Talkshow*, 2020). These efforts are designed to educate consumers on the environmental implications and offer practical advice for sustainable living, such as using natural materials like Pineapple Leaf Fiber (*Exploring the Applications of Pineapple Yarn in Everyday Life*, 2024).

2.3 Literature Review on Barriers to Sustainable Fashion

The adoption of sustainable practices in fashion remains a significant global challenge, with a pronounced gap between consumer intentions and actual behaviors. Understanding these barriers—categorized into internal and external factors—is essential for promoting sustainable practices, particularly in Vietnam's fashion sector, where cultural, economic, and infrastructural influences shape unique consumption patterns.

2.3.1 Internal Barriers: Social, Cultural, and Perceptual Challenges

Internal barriers to sustainable fashion adoption encompass social and cultural influences, cost concerns, and consumer perceptions of affordability and image. Social and cultural dynamics significantly shape consumer attitudes. While high pricing is often perceived as a primary obstacle, research by Ronda (2024) highlights that consumers are willing to spend more on sustainable products but struggle to find options that align with their tastes and styles. This suggests that availability and design are critical barriers rather than cost alone. Furthermore, a lack of awareness about the environmental harm caused by fast fashion limits consumer action (Becker-Leifhold & Iran, 2018; Lorena Ronda, 2024). Despite growing awareness of sustainability, many consumers remain unaware of the ecological damage their fashion choices cause, further hindering their shift toward sustainable practices.

Perception issues also play a crucial role. Many consumers consider sustainable fashion less stylish or appealing, associating it with subpar design or limited variety (Moon et al., 2014; Sehnem et al., 2024; Vishwakarma et al., 2022). This misconception, compounded by inadequate training in sustainable practices among designers, results in a scarcity of attractive eco-friendly options (Harris et al., 2016; Moon et al., 2014).

Addressing these barriers requires educating consumers and empowering designers to create innovative, stylish, sustainable collections.

2.3.2 External Barriers: Policy, Education, and Industry Practices

External barriers include policy limitations, gaps in education, and unsustainable supply chain practices. The lack of sustainability-focused education in fashion design courses limits professionals' ability to advocate for and implement sustainable practices effectively. For instance, curricula often omitted crucial concepts like upcycling and eco-friendly fashion(Mizrachi & Alon, 2022). Similarly, government policies, such as VAT structures that discourage second-hand clothing purchases or rentals, fail to incentivize circular economy practices.

Additionally, the absence of standardized, transparent certification programs makes it difficult for consumers to identify sustainable products, perpetuating greenwashing (Adamkiewicz et al., 2022; Lorena Ronda, 2024). Studies in markets like the UK have shown that many sustainability claims fail to meet established guidelines, leading to consumer distrust. Establishing clear certification criteria, as proposed by Mizrachi et al. (2022), could address this issue and promote informed consumer choices.

Industry practices, particularly in supply chains, exacerbate barriers to sustainability. Outsourcing production to regions with cheaper labor and lax environmental regulations drives fast fashion's growth, often at significant environmental and social costs (Bick et al., 2018; Nayak, Panwar, et al., 2019). Greenwashing further complicates the landscape, as companies make misleading claims about the sustainability of their products, undermining trust in ethical brands and hindering their success.

2.2.3 A Multidimensional Framework for Understanding Barriers

Effectively addressing barriers to sustainable fashion consumption requires a comprehensive and nuanced approach. This study adopts a multidimensional framework, categorizing these barriers into five key dimensions: Social and Cultural Factors, Pricing and Affordability, Policy and Education, Perception and Image, and Supply Chain and Industry Practices. This structure offers an in-depth analysis of the challenges that hinder the widespread adoption of sustainable fashion practices.

(i) **Social and Cultural Factors:** The pervasive influence of fast fashion culture and societal norms that encourage frequent wardrobe updates and disposable consumption presents a significant barrier to sustainable fashion. Misconceptions that sustainable clothing lacks style or prestige further deter adoption (Bianchi & Gonzalez, 2021). Media portrayals and social influences often reinforce these attitudes, making realigning sustainability with cultural preferences and values imperative.

(ii) **Pricing and Affordability**: Economic barriers, particularly the higher costs of sustainable fashion compared to fast fashion, limit accessibility for many consumers. The fast fashion industry's reliance on low-cost, rapid production exacerbates these affordability challenges (Brandão & Costa, 2021). To address this issue, supply chains must be optimized to reduce costs, and the long-term value of sustainable fashion—such as durability and environmental benefits—must be effectively communicated (Harris et al., 2016).

(iii) **Policy and Education**: Comprehensive policy frameworks and educational initiatives are critical in fostering sustainable practices. Governments can drive change by implementing subsidies, developing transparent certification standards, and enforcing stricter regulations (Mizrachi & Alon, 2022). At the same time, integrating sustainability concepts into educational programs is vital for equipping future professionals and consumers with the knowledge and skills needed to adopt eco-friendly practices (Martín-Sánchez et al., 2022).

(iv) **Perception and Image**: Consumer perceptions significantly influence the adoption of sustainable fashion. Misconceptions about the quality, style, and practicality of sustainable clothing remain widespread, creating resistance to change. Overcoming these barriers requires reshaping public perceptions through positive branding, enhancing product design, and communicating sustainable fashion's environmental and societal benefits(Munir, 2020).

(v) **Supply Chain and Industry Practices**: Systemic issues within supply chains, such as greenwashing, lack of transparency, and high production costs, are substantial barriers to sustainability. Unsustainable practices, often driven by outsourcing to regions with lower labor costs and lax environmental regulations, exacerbate these challenges. Collaboration among stakeholders—including brands, manufacturers, and suppliers—is essential to improve sustainability, enforce accountability, and address financial and technological constraints (W. K. Chen et al., 2021).

2.3.4 Research Contribution and Context in Vietnam

This research identifies 47 key barriers to sustainable fashion consumption through an extensive literature survey validated by expert feedback (as outlined in **Table 2**). These barriers are classified into the five dimensions discussed above, enabling a deeper understanding of their interplay and cumulative impact.

Table 2. Barriers to Sustainable Consumption in the Fashion Industry.

No	Dimensions	Code	Barrier	Definition	References
1	Social and Cultural Factors	SC1	Emergence of Affordable Fashion	Affordable fashion makes it harder for consumers to choose sustainable options.	(Riemens et al., 2021)
2		SC2	Sustainable Fashion Stereotypes	Preconceived notions that sustainable fashion could be less stylish, expensive, or impractical.	(Bianchi & Gonzalez, 2021)
3		SC3	Fashion as a Status Symbol	Consumers prioritize fashion as a status symbol over sustainability.	(Vishwakarma et al., 2022)
4		SC4	Social and Media-Induced Wardrobe Updates	Social media pressure leads consumers to buy more often, reducing sustainable choices.	(Harris et al., 2016)
5	Pricing and Affordability	E01	Economic Growth Impact on Consumption	Increased income drives more spending on fast fashion, which is not a sustainable option.	(Ozdamar Ertekin et al., 2020)
6		E02	High Prices of Sustainable Fashion	Higher costs deter consumers from purchasing sustainable fashion.	(Brandão & Costa, 2021)
7		E03	Consumer Budget Constraints	Limited budgets lead consumers to choose cheaper, less sustainable fashion.	(Harris et al., 2016)
8		E04	Balancing Sustainability and Profitability	Businesses struggle to offer sustainable products that appeal to cost-conscious consumers.	(Monyaki & Cilliers, 2023)
9		E05	Revenue Decline from Long-Lasting Products	Consumers buy less frequently when products last longer, reducing business revenue.	(Harris et al., 2016)
10	Policy and Education	PE1	Social and Cultural Norms Against Sustainability	Cultural norms discourage sustainable consumption habits among consumers.	(Harris et al., 2016) ; (Mizrachi & Alon, 2022)

11		PE2	Changing Definitions of Waste Laws in Fashion	Evolving laws on waste affect consumer access to sustainable fashion.	(Mizrachi & Alon, 2022)
12		PE3	Legal Accountability for Corporations	Corporate responsibility impacts consumer trust sustainably.	(Mizrachi & Alon, 2022)
13		PE4	Advertising Regulations in Fashion	Regulations on advertising affect consumer awareness of sustainable options.	(Mizrachi & Alon, 2022)
14		PE5	Educational Campaigns on Sustainable Consumption	Lack of effective education reduces consumer motivation to choose sustainable fashion.	(Mizrachi & Alon, 2022)
15		PE6	Low Consumer Awareness and Education About Green Consumption	Consumers are less likely to buy sustainably due to a lack of knowledge.	(Harris et al., 2016)
16		PE7	Carbon Taxation on Apparel	Carbon taxes could increase prices, making sustainable fashion less affordable for consumers.	(Mizrachi & Alon, 2022)
17		PE8	Subsidies for Unsustainable Products	Subsidies lower the cost of unsustainable fashion, discouraging sustainable choices.	(Lueg et al., 2015)
18		PE9	Lack of Standards for Sustainable Fashion	Inconsistent standards confuse consumers and hinder sustainable purchasing decisions.	(Bly et al., 2015)
19		PE10	Limited Education Level of a Consumer Segment	Low education levels prevent some consumers from understanding the benefits of sustainable fashion.	(Monyaki & Cilliers, 2023)
20	Perception and Image	PI1	Price Sensitivity Among Consumers	Price-sensitive consumers often choose cheaper, less sustainable options.	(Harris et al., 2016)
21		PI2	Brand-Conscious Consumer Behavior	Consumers prefer well-known brands, even if they are not sustainable.	(Harris et al., 2016)

22	PI3	Focus on Bargain Shopping	The focus on finding bargains leads consumers away from sustainable options.	(Bly et al., 2015); (Medalla et al., 2021)
23	PI4	Shopping as a Leisure Activity	Viewing shopping as entertainment increases the consumption of unsustainable fashion.	(Bly et al., 2015); (Medalla et al., 2021)
24	PI5	Influence of Fashion Trends	Fast-changing trends push consumers to buy frequently, making sustainable choices less appealing.	(Legere & Kang, 2020)
25	PI6	Degree of Consumer Involvement in Fashion	Consumers highly involved in fashion may prioritize trends over sustainability.	(Bly et al., 2015)
26	PI7	Perceived Unattractiveness and Quality of Sustainable Fashion	Negative perceptions about style and quality reduce consumer interest in sustainability.	(Harris et al., 2016)
27	PI8	Misunderstanding of Sustainable Fashion	Misconceptions about sustainability discourage consumers from buying sustainable fashion.	(Harris et al., 2016)
28	PI9	Lack of Focus on Durability	Consumers often overlook durability, preferring cheaper, short-lived fashion.	(Bly et al., 2015)
29	PI10	Aspirational Luxury Fashion	A desire for luxury brands drives consumers towards non-sustainable options.	(Bly et al., 2015)
30	PI11	Impact of Income Levels on Fashion Choices	Lower income limits consumer access to sustainable fashion.	(Harris et al., 2016)
31	PI12	Perception of Sustainable Fashion as Inconvenient	The perceived inconvenience of sustainable fashion reduces consumer interest.	(Harris et al., 2016)
32	PI13	Perceived Lack of Variety and Styles in Sustainable Fashion	Limited style options in sustainable fashion deter consumers.	(Harris et al., 2016)

33		PI14	Complexity and Confusion Around Sustainability	Confusion about sustainability concepts makes consumers hesitant to choose sustainable fashion.	(Bly et al., 2015)
34		PI15	Materialistic Consumer Behavior	Materialism drives consumers to buy more, often choosing unsustainable options.	(Medalla et al., 2021)
35		PI16	Consumer Overconsumption	Excessive buying habits prevent consumers from embracing sustainability.	(Harris et al., 2016)
36		PI17	Disposable Attitude Toward Clothing	Viewing clothes as disposable leads to frequent purchases of unsustainable fashion.	(Harris et al., 2016)
37		PI18	Skepticism Towards the Authenticity of Producers' Sustainability Claims	Doubts about the authenticity of sustainability claims reduce consumer trust.	(Adamkiewicz et al., 2022)
38	Supply Chain and Industry Practices	SI1	Limited Product Variety	The lack of options makes it difficult for consumers to find sustainable fashion that suits their needs.	(Monyaki & Cilliers, 2023)
39		SI2	Supply Chain Transparency Issues	Lack of transparency makes it hard for consumers to verify sustainability claims.	(Bick et al., 2018)
40		SI3	Fair Wages and Working Conditions Challenges	Ethical concerns about production conditions affect consumer choices.	(Nayak et al., 2022)
41		SI4	Greenwashing Practices in the Industry	Misleading claims about sustainability confuse consumers and erode trust.	(Adamkiewicz et al., 2022)
42		SI5	Limited Promotion of Sustainable Brands	Insufficient marketing makes consumers less aware of sustainable options.	(Monyaki & Cilliers, 2023)
43		SI6	Financial Constraints and Scalability Concerns Due to Insufficient Investment in Sustainable Infrastructure	Lack of investment hinders the availability and accessibility of sustainable fashion.	(Monyaki & Cilliers, 2023)
44		SI7	Technological Challenges in Production	Technology limitations restrict the production and variety of sustainable fashion.	(W. K. Chen et al., 2021)

45	SI8	Difficulty in Scaling Local Production	Challenges in expanding sustainable fashion from local to larger markets affect availability.	(Sandvik & Stubbs, 2019);
46	SI9	High Production Costs	High costs of sustainable production limit consumer options and affordability.	(W. K. Chen et al., 2021)
47	SI10	Shift in the Fashion Industry Toward the Circular Economy Trend	The transition to circular economy practices is slow, limiting sustainable fashion choices for consumers.	(W. K. Chen et al., 2021); (Sehnem et al., 2024)

Vietnam's unique cultural and economic context underscores the importance of targeted solutions. For instance, younger Vietnamese consumers exhibit greater openness to sustainable practices, motivated by heightened awareness of environmental issues and a desire for value-driven purchases. In contrast, older generations often prioritize affordability and convenience, presenting a distinct set of challenges for sustainable fashion adoption. Moving beyond a simplistic internal-external categorization, this study's multidimensional framework captures the complexity of these barriers and their interconnections. This approach enhances the ability to design and implement targeted interventions that address the root causes of resistance to sustainable practices. It provides actionable insights for businesses, policymakers, and educators to align their strategies with consumer needs and industry demands. Ultimately, this study contributes to developing a more sustainable fashion industry in Vietnam by bridging the gap between consumer intentions and actual practices. By addressing barriers across social, economic, educational, perceptual, and systemic dimensions, this framework equips stakeholders with the tools to promote sustainable consumption effectively and foster long-term change.

3. Proposed Methods

3.1 Research process

Building on current research in sustainable consumption, this study presents an all-encompassing model to investigate the barriers to sustainable fashion within the Vietnamese context.
It employs an MCDM approach, integrating the DELPHI and DEMATEL methods along with NZN, as shown in **Figure 1**.

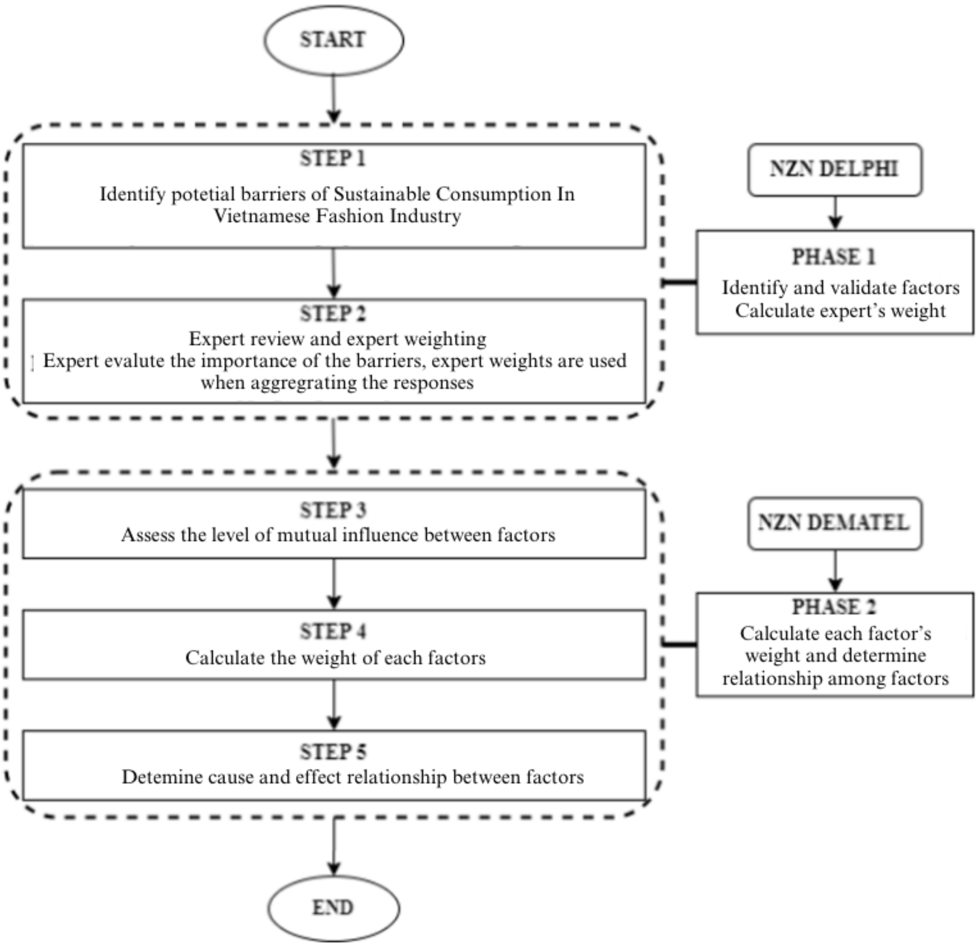

Figure 1. Research Framework

The first phase focuses on identifying key barriers to sustainable practices within the fashion industry in Vietnam. This is achieved through a comprehensive literature review, categorizing the barriers into five main groups: Social and Cultural Factors, Affordability and Pricing, Policy and Education, Image and Perception, and Supply Chain and Industry Practices. The relevance and appropriateness of these barriers are assessed using the NZN DELPHI method. In this phase, structured questionnaires are distributed to experts who evaluate the significance and impact of each barrier. Expert evaluations are weighted based on their expertise and credentials, with these weights converted into NZN values. The data is then aggregated and defuzzified to yield precise and consistent results, ensuring reliable expert input throughout the research. Barriers that do not meet the established criteria are excluded from further analysis.

The second phase investigates the relationships among the validated barriers using the DEMATEL method in combination with the NZN framework. This phase addresses the complex interdependencies between factors, mapping out cause-and-effect relationships. The DEMATEL analysis creates an influence matrix that quantifies the impact of each barrier. The influence matrix undergoes defuzzification to maintain accuracy, ensuring all calculations align with the NZN format.

Data analysis was carried out using Microsoft Excel 2016 and SPSS version 26. Each evaluation, which involved processing input from 30 experts, examining 47 barriers, and ranking various strategies, required approximately 180 minutes. The findings from this study provide valuable guidance for researchers and industry professionals alike, delivering a systematic, evidence-based approach to overcoming obstacles to sustainable fashion consumption in Vietnam.

3.2 Preliminaries

Zadeh (2011b) is defined as a structured pair of fuzzy numbers (A, C), where A conveys the fuzzy value linked to an uncertain variable X, and C reflects the reliability of that value. However, this model does not capture the inherent aspects of indeterminacy and falsity in Z-numbers. To overcome this shortcoming and to provide a more comprehensive framework that includes elements of truth, indeterminacy, and falsity, the NZN has been proposed as an advanced extension of the original framework (Du et al., 2021b).

Definition 1 (Du et al., 2021) : Consider X represents a universe set. An NZN set within X is described by Equation (1):

$$N_z = \{[x, \alpha(A,C)(x), \beta(A,C)(x), \gamma(A,C)(x) | x \epsilon X\} \quad (1)$$

In this context, we define $\alpha(A,C)(x) = (\alpha_A(x), \alpha_C(x))$; $\beta(A,C)(x) = (\beta_A(x), \beta_C(x))$; $\gamma(A,C)(x) = (\gamma_A(x), \gamma_C(x))$ where each component maps X to the interval $X \to [0,1]^2$. These components represent fuzzy values corresponding to truth, indeterminacy, and falsity. Here, A stands for the neutrosophic values associated with elements of the set X, and C is the measure of reliability for those values within the neutrosophic. Each component satisfies a set of predefined conditions, as specified below: $0 \le \alpha_A(x) + \beta_A(x) + \gamma_A(x) \le 3$ and $0 \le \alpha_C(x) + \beta_C(x) + \gamma_C(x) \le 3$

For simplicity and ease of understanding, the element $[x, \alpha(A,C)(x), \beta(A,C)(x), \gamma(A,C)(x)$ in N_Z can be rewritten in a more compact notation as $N_Z = [\alpha(A,C), \beta(A,C), \gamma(A,C)] = [(\alpha_A, \alpha_C), (\beta_A, \beta_C), (\gamma_A, \gamma_C)$, and is referred to as NZN.

Definition 2 (Du et al., 2021; Yazdani et al., 2021): Let $N_{Z1} = [\alpha_1(A,C), \beta_1(A,C), \gamma_1(A,C)] = [(\alpha_{A1}, \alpha_{C1}), (\beta_{A1}, \beta_{C1}), (\gamma_{A1}, \gamma_{C1})$ and $N_{Z2} = [\alpha_2(A,C), \beta_2(A,C), \gamma_2(A,C)] = [(\alpha_{A2}, \alpha_{C2}), (\beta_{A2}, \beta_{C2}), (\gamma_{A2}, \gamma_{C2})$ considers two NZNs, with ϵ>0. The following correspondences are established through Equations (2)-(10):

1. $N_{Z1} \supseteq N_{Z2} \Leftrightarrow \alpha_{A1} \ge \alpha_{A2}, \alpha_{C1} \ge \alpha_{C2}, \beta_{A1} \le \beta_{A2}, \beta_{C1} \le \beta_{C2}, \gamma_{A1} \le \gamma_{A2}$ $and\ \gamma_{C1} \le \gamma_{C2}$ (2)
2. $N_{Z1} = N_{Z2} \Leftrightarrow N_{Z1} \supseteq N_{Z2}\ and\ N_{Z2} \supseteq N_{Z1}$ (3)
3. $N_{Z1} \cup N_{Z2} \Leftrightarrow [(\alpha_{A1} \vee \alpha_{A2},\ \alpha_{C1} \vee \alpha_{C2}),\ (\beta_{A1} \wedge \beta_{A2},\ \beta_{C1} \wedge \beta_{C2}), (\gamma_{A1} \wedge \gamma_{A2}, \gamma_{C1} \wedge \gamma_{C2})$ (4)
4. $N_{Z1} \cap N_{Z2} \Leftrightarrow [(\alpha_{A1} \wedge \alpha_{A2},\ \alpha_{C1} \wedge \alpha_{C2}),\ (\beta_{A1} \vee \beta_{A2},\ \beta_{C1} \vee \beta_{C2}), (\gamma_{A1} \vee \gamma_{A2}, \gamma_{C1} \vee \gamma_{C2})$ (5)
5. $(N_{Z1})^C = [(\gamma_{A1}, \gamma_{C1}), (1-\beta_{A1}, 1-\beta_{C1}), (\alpha_{A1}, \alpha_{C1})$ (Complement of N_{Z1}) (6)
6. $N_{Z1} \oplus N_{Z2} = [(\alpha_{A1} + \alpha_{A2} - \alpha_{A1}\alpha_{A2}, \alpha_{C1} + \alpha_{C2} - \alpha_{C1}\alpha_{C2}), (\beta_{A1}\beta_{A2}, \beta_{C1}\beta_{C2}), (\gamma_{A1}\gamma_{A2}, \gamma_{C1}\gamma_{C2})$ (7)
7. $N_{Z1} \otimes N_{Z2} = [(\alpha_{A1}\alpha_{A2}, \alpha_{C1}\alpha_{C2}), (\beta_{A1} + \beta_{A2} - \beta_{A1}\beta_{A2}, \beta_{C1} + \beta_{C2} - \beta_{C1}\beta_{C2}), (\gamma_{A1} + \gamma_{A2} - \gamma_{A1}\gamma_{C2}, \gamma_{C1} + \gamma_{C2} - \gamma_{C1}\gamma_{C2})$ (8)
8. $\varepsilon N_{Z1} = [(1-(1-\alpha_{A1})^\varepsilon, 1-(1-\alpha_{A1})^\varepsilon), (\beta_{A1}^\varepsilon, \beta_{C1}^\varepsilon), (\gamma_{A1}^\varepsilon, \gamma_{C1}^\varepsilon)$ (9)
9. $(N_{Z1})^\varepsilon = [\ (\alpha_{A1}^\varepsilon, \alpha_{C1}^\varepsilon), (1-(1-\beta_{A1})^\varepsilon, 1-(1-\beta_{C1})^\varepsilon), (1-(1-\gamma_{A1})^\varepsilon, 1-(1-\gamma_{C1})^\varepsilon)$ (10)

The defuzzification process aims to convert these fuzzy values into a single crisp value for clearer interpretation and decision-making; the defuzzification process of

$N_{Z1} = [\alpha_1(A,C), \beta_1(A,C), \gamma_1(A,C)] = [(\alpha_{A1}, \alpha_{C1}), (\beta_{A1}, \beta_{C1}), (\gamma_{A1}, \gamma_{C1})$, using Equation (11):

$$DEF(N_{Z1}) = \frac{2 + \alpha_{A1}\,\alpha_{C1} - \beta_{A1}\,\beta_{C1} - \gamma_{A1}\,\gamma_{C1}}{3}\ for\ DEF(N_{Z1})\ \epsilon\ [0,1 \quad (11)$$

Example illustration1: We have two numbers NZN be expressed as: N_{Z1} = [0.7,0.9),(0.2,0.1),(0.3,0.2) and N_{Z2} = [(0.5,0.7),(0.4,0.3),(0.2,0.1), ε = 0.6, an example of Equations (7) - (11) are calculated as follows:

$N_{Z1} \oplus N_{Z2} =$ 9(0.7,0.9),(0.2,0.1),(0.3,0.2) ⊕ [(0.5,0.7),(0.4,0.3),(0.2,0.1)
= [(0.85,0.97),(0.12,0.07),(0.06,0.02)

$N_{Z1} \otimes N_{Z2} =$
[(0.7,0.9),(0.2,0.1),(0.3,0.2)⊗[(0.5,0.7),(0.4,0.3),(0.2,0.1)=[(0.35,0.63),(0.56,0.37),(0.46,0.28)

εN_{Z1} =0.6·[(0.7,0.9),(0.2,0.1),(0.3,0.2)=[(0.42,0.54),(0.12,0.06),(0.18,0.12

$(N_{Z1})^\varepsilon$ =([(0.7,0.9),(0.2,0.1),(0.3,0.2))0.6=[(0.7487,0.8748),(0.1429,0.0859),(0.2004,0.1348)

$$DEF(N_{Z1}) = \frac{2 + 0.7 \cdot 0.9 - 0.2 \cdot 0.1 - 0.3 \cdot 0.2}{3} = 0.85$$

Definition 3 (Du et al., 2021): **Weighted Aggregation Arithmetic Mean (NZNWAAM) and Weighted Aggregation Geometric Mean (NZNWAGM)**

Consider $N_{Zi} = [\alpha_i(A,C), \beta_i(A,C), \gamma_i(A,C)] = [(\alpha_{Ai}, \alpha_{Ci}), (\beta_{Ai}, \beta_{Ci}), (\gamma_{Ai}, \gamma_{Ci})]$, (i = 1, 2, 3, ... n) as a set of NZN. Let NZNWAA: $\Omega^n \longrightarrow \Omega$. This formulation facilitates the combination of multiple NZNs, offering a thorough depiction of consolidated information. It proves especially valuable in decision-making scenarios requiring the merging of uncertain and inconsistent data. The formal definition of the NZNWAA equation is presented in Equation (12), which captures the collective behavior of the given set of neutrosophic Z-numbers through weighted averaging. This method ensures that each component of the NZN is considered proportionally according to its significance in the aggregation process (Du et al., 2021b), as presented in Equation (12):

$$\mathrm{NZNWAA}(N_{Z1}, N_{Z2}, \dots, N_{Zn}) = \sum_{i=1}^{n} \varepsilon_i N_{Zi} \quad (12)$$

$$= [(1 - \prod_{i=1}^{n}(1 - \alpha_{Ai})^{\varepsilon_i}, 1 - \prod_{i=1}^{n}(1 - \alpha_{Ci})^{\varepsilon_i}), (\prod_{i=1}^{n} \beta_{Ai}{}^{\varepsilon_i}, \prod_{i=1}^{n} \beta_{Ci}{}^{\varepsilon_i}), (\prod_{i=1}^{n} \gamma_{Ai}{}^{\varepsilon_i}, \prod_{i=1}^{n} \gamma_{Ci}{}^{\varepsilon_i})$$

In which $\varepsilon_i (i = 1, 2, 3, \dots n)$ was defined as a weight of N_{Zi} under the condition $0 \le \varepsilon_i \le 1$ and $\sum_{i=1}^{n} \varepsilon_i = 1$

Similarly, by employing Equations (8) and (10) from Definition 2, the Weighted Aggregation Geometric Mean (NZNWAGM) equation for NZNs can be established.

Allow $N_{Zi} = [\alpha_i(A, C), \beta_i(A, C), \gamma_i(A, C)] = [(\alpha_{Ai}, \alpha_{Ci}), (\beta_{Ai}, \beta_{Ci}), (\gamma_{Ai}, \gamma_{Ci})], (\mathrm{i} = 1, 2, \dots \mathrm{n})$. This defines the capability to aggregate a group of NZNs, represented as NZNWGA: $\Omega^n \longrightarrow \Omega$. Representation of NZNWGA, as presented in Equation (13):

$$\mathrm{NZNWGA}(N_{Z1}, N_{Z2}, \dots, N_{Zn}) = \prod_{i=1}^{n} (N_{Zi})^{\varepsilon_i} \quad (13)$$

$$= [(\prod_{i=1}^{n} (\alpha_{Ai})^{\varepsilon_i}, \prod_{i=1}^{n} (\alpha_{Ci})^{\varepsilon_i}), (1 - \prod_{i=1}^{n}(1 - \beta_{Ai})^{\varepsilon_i}, 1 - \prod_{i=1}^{n}(1 - \beta_{Ci})^{\varepsilon_i}), 1 - \prod_{i=1}^{n}(1 - \gamma_{Ai})^{\varepsilon_i}, 1 - \prod_{i=1}^{n}(1 - \gamma_{Ci})^{\varepsilon_i})$$

In which $\varepsilon_i (i = 1, 2..n)$ was defined as the weight of N_{Zi} when $0 \le \varepsilon_i \le 1$ and $\sum_{i=1}^{n} \varepsilon_i = 1$

Example Illustration 2:

NZ1 = [(0.7,0.6),(0.3,0.2),(0.4,0.3)

NZ2 = [(0.5,0.7),(0.4,0.3),(0.5,0.4)

NZ3 = [(0.8,0.9),(0.2,0.1),(0.3,0.2)

Given corresponding weights ε_i={0.4,0.3,0.3}

The weighted aggregation arithmetic mean of these NZNs calculated by NZNWAA (12) and NZNWGA (13) equations are determined as follows:

$\mathrm{NZNWAA}(N_{Z1}, N_{Z2}, N_{Z3})$ = [(0.7444,0.8331),(0.2797,0.2105),(0.3985,0.3012)

$\mathrm{NZNWGA}(N_{Z1}, N_{Z2}, N_{Z3})$ = [(0.6476,0.7169),(0.4114,0.2992),(0.5129,0.3924)

Definition 4 (Ye, 2021)**: Measures of distance and similarity for NZN sets**

Researchers have increasingly emphasized the similarity and distance between sets, as they are valuable instruments for facilitating decision-making (Zavadskas et al., 2017).

Allow $N_{Z1} = \{N_{Z11}, N_{Z12} \dots, N_{Z1n}\}$ and $N_{Z2} = \{N_{Z21}, N_{Z22} \dots, N_{Z2n}\}$, where $N_{Z1k} = [\alpha_{1k}(A, C), \beta_{1k}(A, C), \gamma_{1k}(A, C)] = [(\alpha_{A1k}, \alpha_{C1k}), (\beta_{A1k}, \beta_{C1k}), (\gamma_{A1k}, \gamma_{C1k})]$, and $N_{Z2k} = [\alpha_{2k}(A, C), \beta_{2k}(A, C), \gamma_{2k}(A, C)] = [(\alpha_{A2k}, \alpha_{C2k}), (\beta_{A2k}, \beta_{C2k}), (\gamma_{A2k}, \gamma_{C2k})]$ to be two NZNs, under the condition of giving any integer as $\vartheta \ge 1$. The corresponding weights assigned to the n pairs of NZN $w_k = (w_1, w_2, \dots w_n), \sum_{k=1}^{n} w_k = 1$. Following this, Equation (14) is used to calculate the generalized distance between N_{Z1} and N_{Z2}:

$$D_{w\vartheta}(N_{Z1}, N_{Z2}) = \frac{1}{2}\left\{ \sqrt[\vartheta]{\frac{1}{3}\sum_{k=1}^{n} w_k(|\alpha_{A1k} - \alpha_{A2k}|^{\vartheta} + |\beta_{A1k} - \beta_{A2k}|^{\vartheta} + |\gamma_{A1k} - \gamma_{A2k}|^{\vartheta})} + \sqrt[\vartheta]{\frac{1}{3}\sum_{k=1}^{n} w_{k(|\alpha_{C1k} - \alpha_{C2k}|^{\vartheta} + |\beta_{C1k} - \beta_{C2k}|^{\vartheta} + |\gamma_{C1k} - \gamma_{C2k}|^{\vartheta})}} \right\} \quad (14)$$

When $\vartheta = 1$, the generalized distance formula is simplified to the Hamming distance formula, which was D_{w1} as shown in Equation (15):

$$D_{w1}(N_{Z1}, N_{Z2}) = \frac{1}{6}\left\{ \sum_{k=1}^{n} w_k(|\alpha_{A1k} - \alpha_{A2k}| + |\beta_{A1k} - \beta_{A2k}| + |\gamma_{A1k} - \gamma_{A2k}|) + \sum_{k=1}^{n} w_k(|\alpha_{C1k} - \alpha_{C2k}| + |\beta_{C1k} - \beta_{C2k}| + |\gamma_{C1k} - \gamma_{C2k}|) \right\} \quad (15)$$

When $\vartheta = 2$, the generalized distance formula is D_{w2}, as shown in Equation (16):

$$D_{w2}(N_{Z1}, N_{Z2}) = \frac{1}{2}\left\{\sqrt{\frac{1}{3}\sum_{k=1}^{n} w_k(|\alpha_{A1k} - \alpha_{A2k}|^2 + |\beta_{A1k} - \beta_{A2k}|^2 + |\gamma_{A1k} - \gamma_{A2k}|^2)} + \sqrt{\frac{1}{3}\sum_{k=1}^{n} w_k(|\alpha_{C1k} - \alpha_{C2k}|^2 + |\beta_{C1k} - \beta_{C2k}|^2 + |\gamma_{C1k} - \gamma_{C2k}|^2)}\right\} \quad (16)$$

Example Illustration 3: Consider a pair of two NZN numbers:

$N_{Z1} = \{[(0.8,0.8),(0.15,0.15),(0.2,0.2), [(0.6,0.8),(0.35,0.15),(0.4,0.2)\}$

$N_{Z2} = \{[(0.6,0.4), (0.35,0.65), (0.4,0.6)], [(0.2,0.2), (0.85,0.85), (0.8,0.8)\}$

Under the condition of corresponding weights $\varepsilon_i = (0.65, 0.35)$, Hamming and Euclidean distance was calculated by applying Equations (15)-(16) :

Hamming Distance:

$D_{w1}(N_{Z1}, N_{Z2}) = \frac{1}{6}\{[0.65 \cdot (|0.8 - 0.6| + |0.15 - 0.35| + |0.2 - 0.4|) + 0.35 \cdot (|0.6 - 0.2| + |0.35 - 0.85| + |0.4 - 0.8|)] + [0.65 \cdot (|0.8 - 0.4| + |0.15 - 0.65| + |0.2 - 0.6|) + 0.35 \cdot (|0.8 - 0.2| + |0.15 - 0.85| + |0.2 - 0.8|)]\} = \mathbf{0.3925}$

Euclidean Distance:

$$D_{w2}(N_{Z1}, N_{Z2}) = \frac{1}{2}\left\{\sqrt{\frac{1}{3}\left[0.65 \cdot \left(|0.8 - 0.6|^2 + |0.15 - 0.35|^2 + |0.2 - 0.4|^2\right) + 0.35 \cdot \left(|0.6 - 0.2|^2 + |0.35 - 0.8\right.\right.} + \sqrt{\frac{1}{3}\left[0.65 \cdot \left(|0.8 - 0.4|^2 + |0.15 - 0.65|^2 + |0.2 - 0.6|^2\right) + 0.35 \cdot \left(|0.8 - 0.2|^2 + |0.15 - 0.85|^2\right.\right.}$$

= 0,4093

3.3 NZN DELPHI Method

In a scenario with k experts evaluating n factors, each rates the significance using a linguistic scale converted into NZN numbers via NZN sets. Expert weights, based on education and experience, enhance analysis precision. The calculation is shown below:

Step 1: The expert's weights.

Expert weights will be determined using NZNs, consisting of two key elements: A, representing the expert's qualifications based on education and experience, and C, indicating the certainty level based on the research team's familiarity with the expert. These NZN values, reflecting evaluations of experience and credentials, are combined into an exact score using Equation (11). **Table 3** presents the assessments given by the experts alongside the corresponding linguistic scales (P. H. Nguyen et al., 2024).

Table 3. Experts evaluation scale

Education (A)	Experience (A)	Linguistic scale (C)	NZN	Code
Doctor	Over 20 years	Very high	(0.8,0.15,0,2)	VH
Master	10 – 20 years	High	(0.6,0.35,0.4)	H
Bachelor	5 – 10 years	Medium	(0.4,0.65,0.6)	M
Under Bachelor	Under five years	Low	(0.2,0.85,0.8)	L
		Very low	(0,1,1)	VL

As an illustration, Expert 3 holds a bachelor's degree and over 20 years of relevant professional experience. This expert is well-acquainted with the authors, which implies high confidence in their evaluation (VH). As a result, the weighted score for this expert based on their experience will also be (VH; VH), while the evaluation corresponding to their qualifications will be (H; VH). Their evaluations will be defined as NZNs: [(0.4,0.8),(0.65,0.15),(0.6,0.2)] for experience and [(0.8,0.8),(0.15,0.15),(0.2,0.2)] for qualifications.

The two assessments presented as NZN numbers will be aggregated using Equation (7). The resulting value will then be transformed into a crisp score through Equation (11) to derive the evaluation value. In the aforementioned illustration, the calculation is as follows:

[(0.7, 0.9) , (0.4 , 0.2) , (0.5 , 0.3)] ⊕ [(0.6 , 0.7) , (0.3 , 0.2) , (0.4 , 0.1)] = [(0.88 , 0.97) , (0.12 , 0.04) , (0.2 , 0.03)]

Equation (11) was used to convert NZN [(0.88,0.97),(0.12,0.04),(0.2,0.03)] to a crisp score, and the result obtained is 0.9476.

Determine the assessment scores for k experts, generating k distinct result EK: $ek_j = \{ek_1, ek_2, \dots ek_k\}$. The weight of expert EW: $ew_j = \{ew_1, ew_2, \dots ew_k\}$ is calculated as Equation (17) below:

$$ew_j = \frac{ek_j}{\sum_{j=1}^{k} ek_j} \quad (17)$$

Step 2: Construction of expert weight evaluation matrix

To determine the relevance of n factors, experts provide initial evaluations using linguistic descriptors. These assessments are then converted into NZN numbers, generating a matrix $\otimes EM = \left[em_{ij}\right]_{nxk}$, where n refers to the number of factors involved and k represents the experts' numbers. Linguistic scales and their corresponding NZN representations are detailed in Table 4 (Abdullah et al., 2021; Kutlu Gündoğdu & Kahraman, 2019) .

Table 4. NZN Delphi linguistic significant scale

Important level	Code	Membership		
		α	**β**	**γ**
Very low	VL	0	1	1
Low	L	0.2	0.85	0.8
Medium	M	0.4	0.65	0.6
High	H	0.6	0.35	0.4
Very high	VH	0.8	0.15	0.2

The expert's weighted evaluation matrix $\otimes EMW = \left[emw_{ij}\right]_{nxk}$ is created using Equation (18) as below.

$$emw_{ij} = em_{ij} \otimes ew_j \quad (18)$$

In condition of $i = 1, 2, 3, \dots n$ and $j = 1, 2,3, \dots k$; $ew_j = \{ew_1, ew_2, \dots ew_k\}$ is the j of weight

Step 3: Factors validation and Threshold calculations

A panel of k experts evaluates each factor. By implementing Equation (12), their assessments are merged to form comprehensive NZN evaluations for m factors. These aggregated evaluations are then converted into crisp values using Equation (11), producing n EV score: $ev_i = \{ev_1, ev_2, \dots ev_n\}$. To determine the threshold, Equation (19) is applied as:

$$\delta = \frac{\sum_{i=1}^{n} ev_i}{n} \quad (19)$$

Once the threshold is calculated, a factor i is accepted if it meets the criteria $ev_i \geq \delta$. In contrast, if $ev_i < \delta$, the factor is rejected.

3.4 NZN DEMATEL Method

Consider k experts, each assigned weights ew, tasked with evaluating the interrelationships among n factors. The initial assessments, provided in linguistic terms, are then transformed into NZN values. **Table 5** presents the rating scale alongside the corresponding NZN conversions (Abdullah et al., 2021).

Table 5. NZN DEMATEL linguistic influence scale

Influence level	Code	Membership		
		a	**b**	**c**
Equal influence	EI	0	1	1
Week influence	WI	0.2	0.85	0.8
Fair influence	FI	0.4	0.65	0.6
Very influence	VI	0.6	0.35	0.4
Absolute influence	AI	0.8	0.15	0.2

The evaluations were converted into NZN numbers and analyzed using the DEMATEL method. The computation steps are detailed in the following section.

Step 1: Forming the Direct Relationship Matrix $\otimes$ D

The mutual influence evaluations among the n factors (where factor i impacts factor j), provided by k experts and denoted as d_{ij}^{k} , are converted into NZN values using the expert weights, ew_t. These evaluations are then aggregated using Equation (12) to generate the direct influence matrix $\otimes D = [\otimes d_{ij}]_{nxn}$, where:

$$d_{ij} = \text{NZNWAA}\left(d_{ij}^{1}, d_{ij}^{2}, \dots, d_{ij}^{k}\right) = \sum_{t=1}^{k} ew_t d_{ij}^{k} \tag{20}$$

In which $i = 1, 2, \dots n$, $j = 1, 2, \dots n$, t = 1, 2, …k; $\otimes d_{ij} = \left[\left(d_{ij}^{\alpha_A}, d_{ij}^{\alpha_C}\right), \left(d_{ij}^{\beta_A}, d_{ij}^{\beta_C}\right), \left(d_{ij}^{\gamma_A}, d_{ij}^{\gamma_C}\right)\right]$. Note that the diagonal elements are 0, i.e., $\otimes d_{ij} = 0$ (with i = j).

Step 2: Normalizing the Direct Relationship Matrix $\otimes$ D*

The matrix $\otimes D = [\otimes d_{ij}]_{nxn}$ is normalized into $\otimes D^* = [\otimes d_{ij}^*]_{nxn}$ according Equation (21):

$$d_{ij}^* = (\theta_A, \theta_C). d_{ij} = \left[\left(\theta_A d_{ij}^{\alpha_A}, \theta_C d_{ij}^{\alpha_C}\right), \left(\theta_A d_{ij}^{\beta_A}, \theta_C d_{ij}^{\beta_C}\right), \left(\theta_A d_{ij}^{\gamma_A}, \theta_C d_{ij}^{\gamma_C}\right)\right] \tag{21}$$

In which $\otimes d_{ij}^* = \left[\left(d_{ij}^{*\alpha_A}, d_{ij}^{*\alpha_C}\right), \left(d_{ij}^{*\beta_A}, d_{ij}^{*\beta_C}\right), \left(d_{ij}^{*\gamma_A}, d_{ij}^{*\gamma_C}\right)\right]$

$$\theta_A = Min\left\{\frac{1}{\sum_{j=1}^{n} d_{ij}^{\alpha_A}}; \frac{1}{\sum_{j=1}^{n} d_{ij}^{\beta_A}}; \frac{1}{\sum_{j=1}^{n} d_{ij}^{\gamma_A}}\right\} \tag{22}$$

$$\theta_C = Min\left\{\frac{1}{\sum_{j=1}^{n} d_{ij}^{\alpha_C}}; \frac{1}{\sum_{j=1}^{n} d_{ij}^{\beta_C}}; \frac{1}{\sum_{j=1}^{n} d_{ij}^{\gamma_C}}\right\}$$

Step 3: Constructing the total influence matrix ⊗T

The normalized direct relationship matrix ⊗T derives the total influence matrix. This matrix accounts for both direct and indirect influence paths by aggregating impacts over an infinite range, spanning from minimal to maximal levels of influence. The detailed computation process is described below:

$$\otimes \text{T} = [\otimes t_{ij}]_{nxn}, \quad i = j = 1, 2, \dots n \tag{23}$$

$$\otimes t_{ij} = \left[\left(t_{ij}^{\alpha_A}, t_{ij}^{\alpha_C}\right), \left(t_{ij}^{\beta_A}, t_{ij}^{\beta_C}\right), \left(t_{ij}^{\gamma_A}, t_{ij}^{\gamma_C}\right)\right]$$

$$\begin{aligned} \otimes T &= \otimes N^* + \otimes N^{*2} + \dots + \otimes N^{*\infty} \\ &= \otimes T(I + \otimes N^* + \otimes N^{*2} + \dots + \otimes N^{*\infty-1}) \\ &= \otimes D^*(I - \otimes N^{*\infty})(I - \otimes N^*)^{-1} = \otimes N^*(I - \otimes N^*)^{-1} \end{aligned} \tag{24}$$

In which $\otimes T^{\infty} = [0]_{nxn}$ with I as the identification matrix

Matrix *⊗T*' elements as NZNs are converted to crisp NZNs using Equation (11), creating a matrix $\otimes T^* = [\otimes t_{ij}^*]_{nxn}$

Step 4: Construct an Influence Network Relation Map (INRM) to assess the interdependencies among development projects.

$\otimes D$ is obtained by summing the values in each column of the total influence matrix $\otimes T^*$, while $\otimes R$ is calculated by summing the values in each row of $\otimes T^*$.

$$\otimes D = [\otimes D_i]_{nx1} = (\otimes D_1, \otimes D_2, \dots, \otimes D_{i,} \dots, \otimes D_n) \tag{25}$$

$$[\otimes D_i]_{nx1} = \left[\sum_{j=1}^{n} \otimes t_{ij}^*\right]_{nx1} \tag{26}$$

$$\otimes R = [\otimes R_i]_{1xn} = (\otimes R_1, \otimes R_2, \dots, \otimes R_{j,}, \dots, \otimes R_n)^T \tag{27}$$

$$[\otimes R_j]_{1xn} = \left[\sum_{i=1}^{n} \otimes t_{ij}^*\right]_{1xn} = [\otimes R_i]_{nx1}^T \tag{28}$$

Note: "The superscript T" denotes the transpose of the matrix.

The measure of influence strength imparted and received is symbolized by $\otimes D_i + \otimes R_i$. The net influence is calculated as $\otimes D_i - \otimes R_i$. A higher $\otimes D_i + \otimes R_i$ value suggests that criterion i exerts a substantial influence on the evaluation system. If $\otimes D_i - \otimes R_i > 0$ (positive), criterion i significantly affects others. Conversely, if $\otimes D_i - \otimes R_i < 0$ (negative), it indicates that criterion i is predominantly influenced by other factors.

The total effect of each indicator on the evaluation system is given by $\otimes D_i + R$ and the weight of the indicator's impact is calculated using Equation (29):

$$\phi_i = \frac{(Di + R_i)}{\sum_{i=1}^{n}(D_i + R_i)} \tag{29}$$

4. Results and Discussions

4.1. Results of NZN Delphi

A set of 47 factors was compiled through an extensive literature review and expert consultations. The survey was structured into two parts and designed to be completed within 30 minutes. The first section focused on gathering demographic details such as industry affiliation, job title, education level, and years of professional experience. In the subsequent section, participants were asked to evaluate their level of agreement with various criteria and express the certainty of their responses based on their expertise and confidence. Invitations were emailed, and the questionnaire was accessible only after consent. Conducted in English via Jotform, the data collection took place over three months, from May to August 2024. Sixteen experts representing both industry and academia participated in this study.

Following the guidelines of Veugelers et al. (2020), a panel of 10 to 18 experts is recommended to achieve a consensus among participants. Table 2 presents the detailed profiles of the participating experts, while Table 4 illustrates how each expert assessed the significance of the critical criteria using NZN Delphi linguistic scales outlined in **Table 6**.

Table 6. NZN Delphi results

	NZN Weight	Crisp Weight	Validate
SC1	(0.6342;0.6149);(0.326;0.3391);(0.3658;0.3851)	0.7129	Accept
SC2	(0.5459;0.6781);(0.4149;0.2684);(0.4541;0.3219)	0.7042	Accept
SC3	(0.4986;0.6651);(0.4744;0.2817);(0.5014;0.3349)	0.6767	Accept
SC4	(0.5801;0.7304);(0.3938;0.216);(0.4199;0.2696)	0.7418	Accept
E01	(0.5092;0.7044);(0.4809;0.2418);(0.4908;0.2956)	0.6991	Accept
E02	(0.5612;0.7232);(0.4158;0.2247);(0.4388;0.2768)	0.7303	Accept
E03	(0.6673;0.7052);(0.2822;0.2444);(0.3327;0.2948)	0.7678	Accept
E04	(0.5826;0.6502);(0.3853;0.2969);(0.4174;0.3498)	0.7061	Accept
E05	(0.3356;0.6749);(0.689;0.2759);(0.6644;0.3251)	0.6068	Reject
PE1	(0.4793;0.7407);(0.4872;0.206);(0.5207;0.2593)	0.7065	Accept
PE2	(0.2872;0.5123);(0.7341;0.4683);(0.7128;0.4877)	0.4852	Reject
PE3	(0.379;0.7019);(0.618;0.2441);(0.621;0.2981)	0.6433	Reject
PE4	(0.5391;0.4545);(0.4247;0.5507);(0.4609;0.5455)	0.5866	Reject
PE5	(0.615;0.6783);(0.3475;0.2681);(0.385;0.3217)	0.7334	Accept
PE6	(0.4052;0.6639);(0.6157;0.2831);(0.5948;0.3361)	0.6316	Reject
PE7	(0.4725;0.6555);(0.4773;0.2937);(0.5275;0.3445)	0.6626	Reject
PE8	(0.5654;0.7061);(0.3936;0.2401);(0.4346;0.2939)	0.7257	Accept
PE9	(0.5065;0.7046);(0.4613;0.2415);(0.4935;0.2954)	0.6999	Accept
PE10	(0.4479;0.7099);(0.5043;0.2382);(0.5521;0.2901)	0.6792	Accept
PI1	(0.4838;0.4329);(0.4829;0.5713);(0.5162;0.5671)	0.5469	Reject
PI2	(0.5282;0.4329);(0.4406;0.5713);(0.4718;0.5671)	0.5698	Reject
PI3	(0.4106;0.7019);(0.572;0.2441);(0.5894;0.2981)	0.6576	Reject
PI4	(0.4231;0.7091);(0.5512;0.239);(0.5769;0.2909)	0.6668	Reject
PI5	(0.5578;0.6035);(0.4121;0.3555);(0.4422;0.3965)	0.6716	Accept
PI6	(0.5786;0.6648);(0.3882;0.282);(0.4214;0.3352)	0.7113	Accept
PI7	(0.597;0.6111);(0.3617;0.3496);(0.403;0.3889)	0.6939	Accept
PI8	(0.3977;0.5163);(0.6138;0.4665);(0.6023;0.4837)	0.5426	Reject
PI9	(0.6317;0.5777);(0.323;0.3836);(0.3683;0.4223)	0.6952	Accept
PI10	(0.3977;0.5163);(0.6138;0.4665);(0.6023;0.4837)	0.5426	Reject

PI11	(0.5684;0.6661);(0.3974;0.2872);(0.4316;0.3339)	0.7068	Accept
PI12	(0.5431;0.6031);(0.4325;0.3571);(0.4569;0.3969)	0.6639	Reject
PI13	(0.517;0.6358);(0.4596;0.3193);(0.483;0.3642)	0.6687	Accept
PI14	(0.2305;0.5914);(0.7983;0.3772);(0.7695;0.4086)	0.5069	Reject
PI15	(0.6636;0.6165);(0.2879;0.3467);(0.3364;0.3835)	0.7268	Accept
PI16	(0.5403;0.6051);(0.4187;0.3545);(0.4597;0.3949)	0.6657	Reject
PI17	(0.5121;0.6535);(0.4478;0.301);(0.4879;0.3465)	0.6769	Accept
PI18	(0.5209;0.7049);(0.4486;0.2412);(0.4791;0.2951)	0.7059	Accept
SI1	(0.3505;0.6673);(0.6663;0.2858);(0.6495;0.3327)	0.6091	Reject
SI2	(0.4406;0.661);(0.5551;0.291);(0.5594;0.339)	0.6467	Reject
SI3	(0.5737;0.7092);(0.3937;0.2388);(0.4263;0.2908)	0.7296	Accept
SI4	(0.617;0.6512);(0.3391;0.2998);(0.383;0.3488)	0.7222	Accept
SI5	(0.5636;0.6548);(0.4055;0.2946);(0.4364;0.3452)	0.6996	Accept
SI6	(0.5214;0.6747);(0.4536;0.2801);(0.4786;0.3253)	0.6897	Accept
SI7	(0.606;0.6263);(0.3545;0.3319);(0.394;0.3737)	0.7049	Accept
SI8	(0.5083;0.6218);(0.4678;0.3352);(0.4917;0.3782)	0.6578	Reject
SI9	(0.5492;0.6215);(0.4158;0.3347);(0.4508;0.3785)	0.6772	Accept
SI10	(0.6943;0.6176);(0.2576;0.3443);(0.3057;0.3824)	0.7411	Accept

The comprehensive results of the NZN Delphi technique are displayed in Table 5. Factors scoring higher than the threshold (0.668) were accepted, reflecting strong expert agreement on their significance in influencing consumer behavior sustainably. Those factors below the threshold were deemed less impactful and rejected for further consideration. All of the social and cultural factors were accepted. SC4 and SC1 received the highest validation scores, with 0.7418 and 0.7129, respectively, because they reflect current consumer trends where affordability and social media pressures drive purchasing decisions. SC2 gets a score immediately, followed by SC1 (0.7042). SC3 scored 0.6767, barely passing the threshold, suggesting its moderate influence in the context of sustainable purchasing.

For the Pricing and Affordability dimension, all factors except E05 were accepted, with E03 receiving the highest score of 0.7678, underscoring that price sensitivity remains a dominant barrier to sustainable fashion adoption. Next are factors E02 (0.7303), E04 (0.7061), E01 (0.6991), E05 (0.6068). The rejection of E05 indicates that experts saw this as more of a business concern than a direct factor influencing sustainable purchasing decisions.

The Policy and Education dimension showed mixed results. The Policy and Education dimension showed mixed results. While factors like PE5 and PE8 were strongly validated, with scores of 0.7334 and 0.7257, followed by PE1 (0.7065), PE9 (0.6999), PE10 (0.6792), factors such as PE2 (0.4852) and PE3 (0.6433), PE4 (0.5866), PE6 (0.6316), PE7 (0.6626) were rejected. PE2 and PE3 were rejected, indicating that while the lack of standards and subsidies for unsustainable products are important, they do not have an immediate or direct influence on consumer behavior compared to cultural and educational factors. PE4, PE6, and PE7 were rejected because these factors are more relevant to regulatory and corporate practices than individual consumer choices.

In the Perception and Image dimension, factors PI1 (0.5469), PI2 (0.5698), PI3 (0.6576), PI8 (0.5426), PI10 (0.5426), PI12 (0.6639), PI14 (0.5069), and PI16 (0.6657) were all rejected with scores below the threshold of 0.668. These factors were likely deemed less critical or redundant than more substantial barriers, such as economic constraints and trend-following behavior, which overlap with accepted factors like E02 and E03. In contrast, factors such as PI5 (0.6716), PI6 (0.7113), PI7 (0.6939), PI9 (0.6952), PI11 (0.7068), PI13 (0.6687), PI15 (0.7268), PI17 (0.6769), and PI18 (0.7059) were accepted, as they scored above the threshold. These factors highlight the importance of fashion trends, personal involvement, perceptions of quality, and durability in shaping consumer behavior, as well as the impact of income levels and skepticism regarding sustainability claims. These scores point to deep-rooted social and psychological influences on fashion consumption, making these factors critical obstacles to embracing sustainable fashion.

Finally, the Supply Chain and Industry Practices dimension strongly validated factors like SI3 and SI10, which scored 0.7296 and 0.7411, respectively. SI4 (0.7222), SI5 (0.6996), SI6 (0.6897), SI7 (0.7049), and SI9

(0.6772) were accepted because they reflect critical issues directly impacting the affordability, availability, and perception of sustainable fashion. These elements underscore the ethical and operational challenges preventing consumers from embracing sustainable fashion more widely. Conversely, SI1 (0.6091), SI2 (0.6467), and SI8 (0.6578) were rejected, as experts likely saw them as secondary issues with less direct impact on consumer behavior compared to more pressing barriers like cost, promotion, and greenwashing concerns. These rejected factors, while relevant, were not viewed as immediate deterrents to sustainable purchasing decisions.

4.2. Results of NZN DEMATEL Technique

4.2.2. NZN DEMATEL Results of Main Dimensions

Table 7. The NZN DEMATEL results of the main dimensions

	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
SC	35.5217	8.1087	0.185214	4	Cause
E0	35.1841	-7.7555	0.183453	5	Effect
PE	42.6309	13.3693	0.222282	1	Cause
PI	42.2226	-13.8778	0.220153	2	Effect
SI	36.2285	0.1553	0.188899	3	Cause

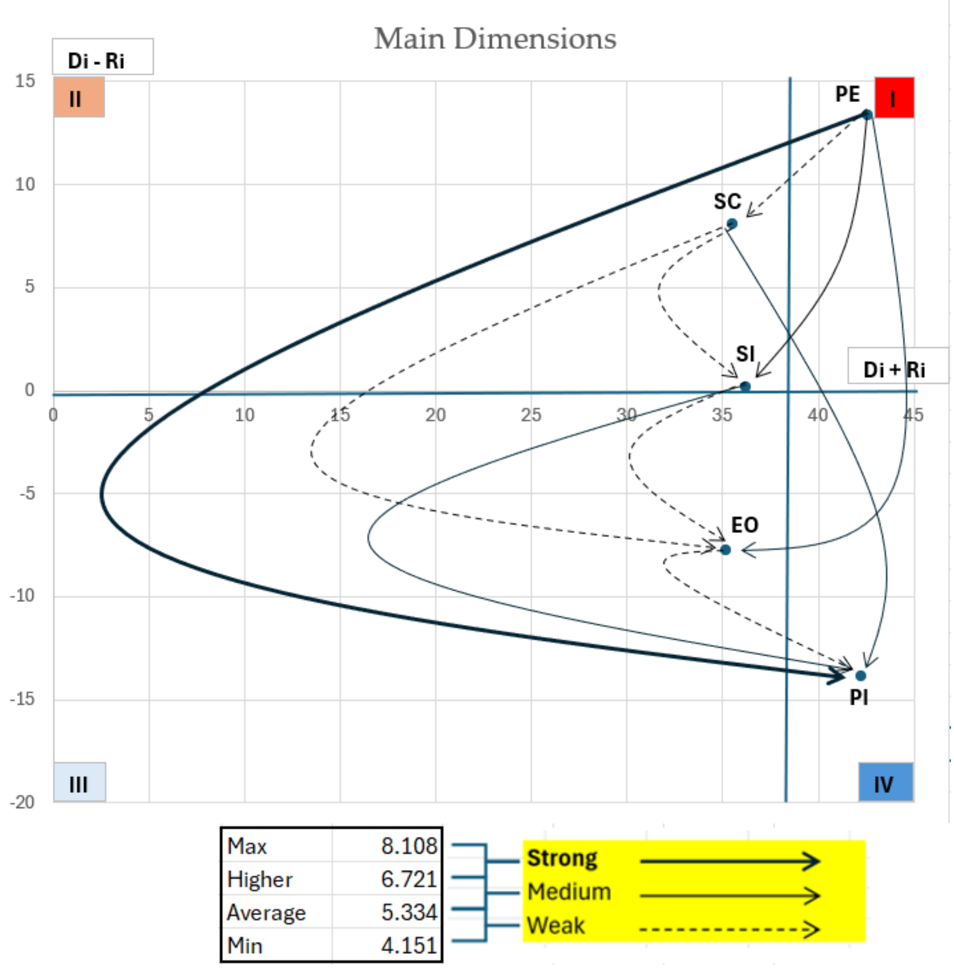

Figure 2. Impact-Relation Map Main Dimension.

The DEMATEL analysis findings, as presented in Table 7 and Figure 2, provide a comprehensive depiction of the interactions among the principal dimensions influencing sustainable consumption within the fashion industry. Notably, Policy and Education (PE) emerges as the most dominant causal factor, exhibiting the highest combined (Di+Ri) score and a positive (Di–Ri) score, situating it within quadrant I. This underscores PE's pivotal role in promoting sustainable practices. Additionally, Social and Cultural (SC) factors, illustrated in Figure 2, hold the position as the second most influential causal component, impacting all dimensions except PE. Supply Chain and Industry Practices (SI) are the third most significant factor, showcasing substantial causal influence.

On the other hand, perception and image (PI) and pricing and affordability (E0) are identified as effect factors, with low (Di−Ri) values, indicating that the causal variables largely shape them. PI is positioned in quadrant IV, meaning multiple factors impact it but do not directly drive change. E0 is located in quadrant III, reflecting its independent nature and lower prominence in the system. PE, SC, and SI primarily influence both PI and E0. Enhancing PE and SC will lead to broader improvements in sustainable fashion consumption, as they serve as the foundational drivers of change across the system.

4.2.2. NZN DEMATEL Results of Sub Dimensions

4.2.2.1 NZN DEMATEL Results of Social and Culture

Table 8. The NZN DEMATEL results of social and cultural factors

	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
SC	35.5217	8.1087	0.185214	4	Cause
E0	35.1841	-7.7555	0.183453	5	Effect
PE	42.6309	13.3693	0.222282	1	Cause
PI	42.2226	-13.8778	0.220153	2	Effect
SI	36.2285	0.1553	0.188899	3	Cause

The NZN DEMATEL analysis highlights the relationships among the factors in the Social and Cultural Factors dimension, as shown in **Table 8**. SC1 (Emergence of Affordable Fashion) and SC3 (Fashion as a Status Symbol) are noted as the primary causal factors, as shown by the positive (Di−Ri) values and placement in the first quadrant of the analysis. This quadrant signifies that these factors influence other factors and are highly important within the system, reaffirming their significance in driving sustainable purchasing behavior. SC1, with the highest (Di+Ri) value of 0.2644, emerges as the most influential factor, emphasizing its role in shaping consumer choices through affordability. SC3 similarly plays a key role, with a weight of 0.2548, reinforcing the cultural value of fashion as a status symbol.

Further analysis reveals that SC3 influences SC1, SC2 (Sustainable Fashion Stereotypes), and SC4 (Social and Media-Induced Wardrobe Updates), though varying degrees. SC3 has the most decisive impact on SC4, indicating a significant role in driving frequent wardrobe updates through social media pressures. Its influence on SC2 is moderate, shaping perceptions around sustainable fashion but to a lesser extent. The effect on SC1 is weaker, suggesting that while status-driven consumption is linked to affordability, the two factors operate somewhat independently.

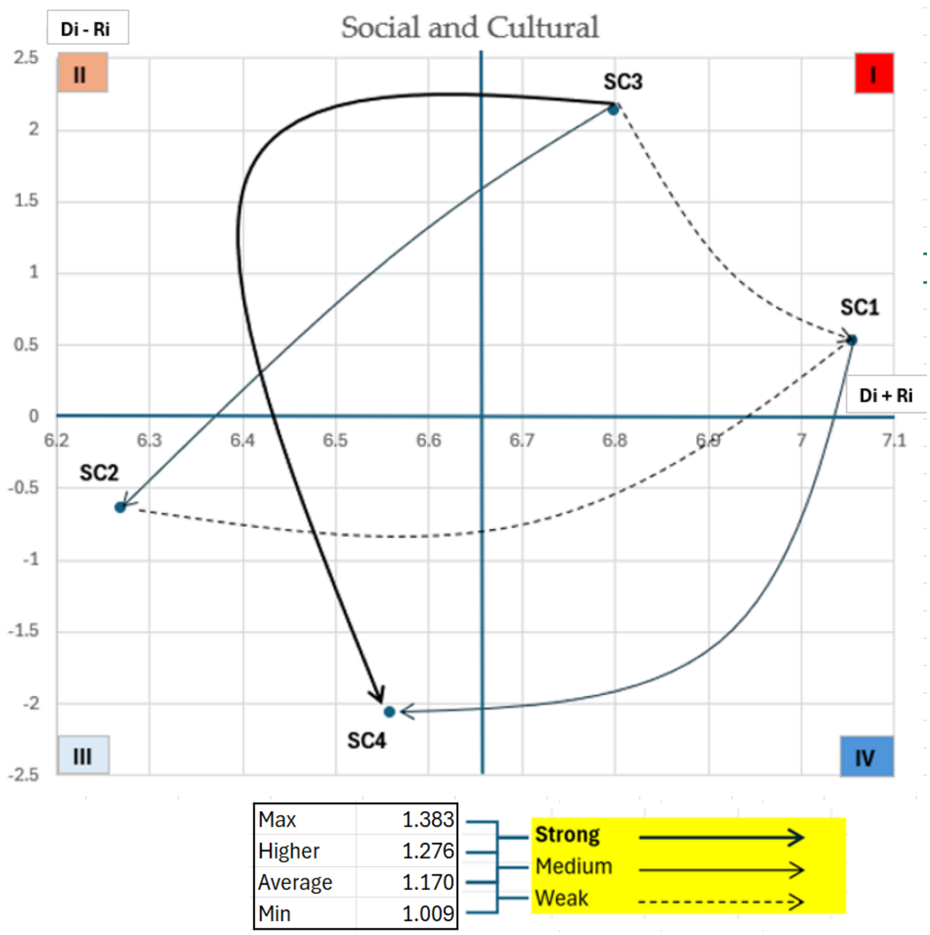

Figure 3. Impact-Relation Map Social and Culture Dimension.

Conversely, SC2 and SC4 are classified as effect factors, with negative (Di−Ri) values and weights of 0.2350 and 0.2458, respectively. These factors are influenced by SC1 and SC3, reflecting the broader social and cultural dynamics. SC2 is shaped by affordability and status, while social media-driven consumption patterns heavily influence SC4.

4.2.2.2 NZN DEMATEL Results of Pricing and Affordability

Table 9. The NZN DEMATEL results of pricing and affordability factors

Factor	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
E01	4.9669	1.3677	0.268952	1	Cause
E02	4.6107	-1.2253	0.249664	3	Effect
E03	4.0575	-1.3523	0.219709	4	Effect
E04	4.8325	1.2099	0.261675	2	Cause

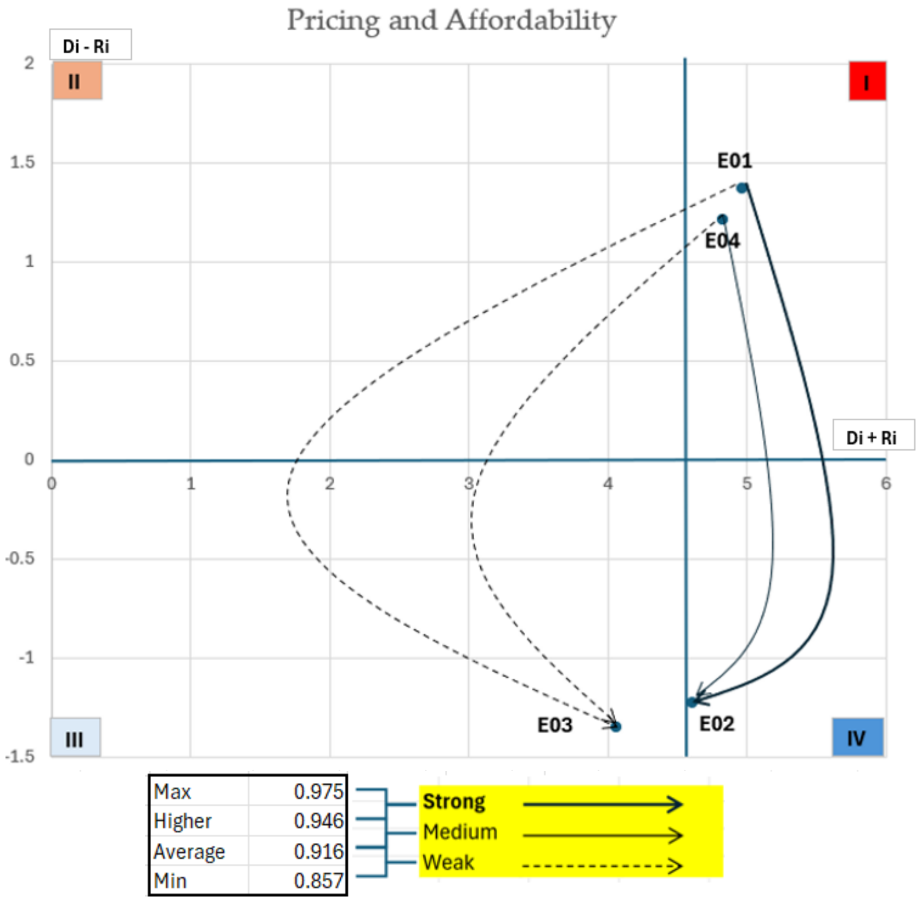

Figure 4. Impact-Relation Map Pricing and Affordability Dimensions

The Pricing and Affordability dimension, as outlined in **Table 9**, identifies key causal and effect factors shaping consumer behavior toward sustainable fashion. E01 (Economic Growth Impact on Consumption), with a weight of 0.2690, and E04 (Balancing Sustainability and Profitability), with a weight of 0.2617, are highlighted as the most influential causal factors, both positioned in quadrant I, underscoring their critical role in driving sustainable fashion through economic and profitability mechanisms. The results show that E01 and E04 exhibit similar "strong influence" curves, indicating that both factors significantly influence the system. E01, with the highest (Di−Ri) value, plays a pivotal role in shaping how economic conditions impact consumer purchasing power and choices sustainably. E04, closely following, influences the balance between sustainable production and profitability, highlighting businesses' tension in offering sustainable options at competitive prices. Conversely, E02 (High Prices of Sustainable Fashion) with a weight of 0.2497 and E03 (Consumer Budget Constraints) with a weight of 0.2197 are identified as effect factors, with negative (Di−Ri) values.

Figure 6 visually represents these relationships, with E01 and E04 positioned as driving forces in the Pricing and Affordability dimension, exerting influence over the cost-related factors E02 and E03. The placement of E01 and E04 in Quadrant I reaffirms their role as core factors driving change, while E02 and E03 respond to these broader economic and pricing pressures.

4.2.2.3 NZN DEMATEL Results of Policy and Education

Table 10. The NZN DEMATEL results of policy and education factors

Factor	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
PE1	7.1168	1.791	0.223152	2	Cause
PE5	6.9082	1.4698	0.216611	3	Cause
PE8	7.2482	1.5136	0.227272	1	Cause

PE9	5.2804	-2.2076	0.16557	5	Effect
PE10	5.3386	-2.5668	0.167395	4	Effect

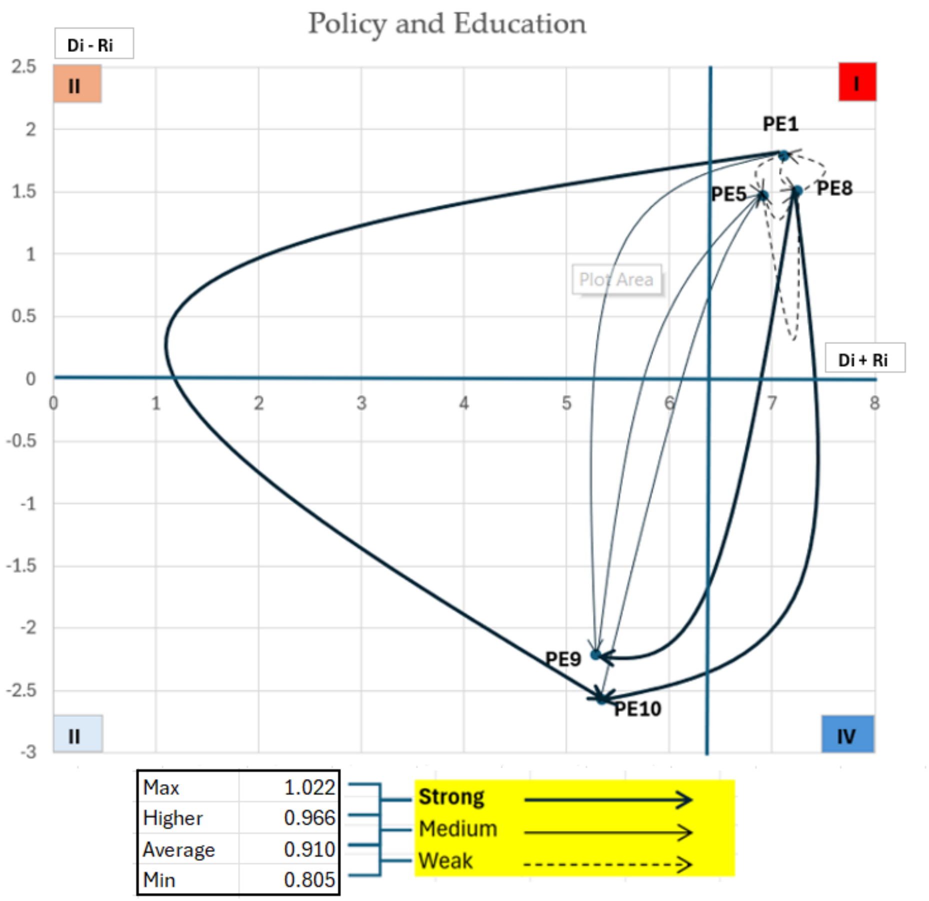

Figure 5. Impact-Relation Map Policy and Education Dimension

The Policy and Education dimension comprises five factors, as shown in **Table 10**, providing insights into the relationships among the five factors, highlighting both cause and effect factors. PE1 (Social and Cultural Norms Against Sustainability) with a weight of 0.2232, PE5 (Educational Campaigns on Sustainable Consumption) with a weight of 0.2166, and PE8 (Subsidies for Unsustainable Products) with a weight of 0.2273, are identified as the primary causal factors, positioned in quadrant I of the DEMATEL matrix. They are referred to as the "core factors" or "intertwined givers," characterized by both high prominence and strong connections to other factors, signifying that they are key drivers of the system. Among these, PE8 holds the highest influence, as indicated by its (Di+Ri) value of 0.2273, signaling its substantial role in shaping the policy and education landscape, particularly in affecting market incentives that drive unsustainable purchasing behavior.

Conversely, PE9 (Lack of Standards for Sustainable Fashion) with a weight of 0.1656 and PE10 (Limited Education Level of a Consumer Segment) with a weight of 0.1674 are positioned in quadrant IV, also known as "impact factors" or "intertwined receivers." That indicates this factor has high prominence but low relation, meaning other factors significantly influence them but are not easily improved through direct intervention. With negative (Di−Ri) values of -0.1656 for PE9 and -0.1674 for PE10, these factors are strongly impacted by the dynamics driven by the causal factors in quadrant I, particularly PE8, PE1, and PE5. These factors reflect broader systemic issues, such as unclear sustainability standards and insufficient consumer education, which respond to the influence of core policy drivers but do not independently generate change.

Figure 4 further illustrates the directional influence among these factors, showing how PE8 and PE1 considerably impact the entire system, particularly on PE9 and PE10. The prominence of PE8 as a major driver with the highest (Di−Ri) value indicates that addressing subsidies for unsustainable products would have a ripple effect throughout the system, leading to improvements in sustainability standards and consumer education levels. Similarly, PE1 and PE5, with their positions in quadrant I, act as key influencers in shaping cultural norms and the effectiveness of educational campaigns.

4.2.2.4 NZN DEMATEL Results of Perception and Image

Table 10. The NZN DEMATEL results of perception and image factors

Factor	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
PI5	10.7206	0.8268	0.120187	1	Cause
PI6	10.6544	1.0242	0.119445	2	Cause
PI7	9.3695	-0.9781	0.10504	8	Effect
PI9	9.3876	-0.6852	0.105243	7	Effect
PI11	10.5658	0.8372	0.118451	3	Cause
PI13	9.45	-0.7094	0.105942	5	Effect
PI15	10.3525	0.9737	0.11606	4	Cause
PI17	9.2526	-0.7614	0.103729	9	Effect
PI18	9.4464	-0.5278	0.105902	6	Effect

Table 10 uncovers important cause-and-effect relationships between the factors within the Perception and Image dimension. PI5 (Influence of Fashion Trends), PI6 (Degree of Consumer Involvement in Fashion), PI11 (Impact of Income Levels on Fashion Choices), PI15 (Materialistic Consumer Behavior), and PI18 (Skepticism Towards Sustainability Claims) are recognized as causal factors based on their positive (Di−Ri) values. Among these, PI5 holds the highest (Di+Ri) value, making it the most influential factor. However, PI6 exerts a more substantial overall influence on other factors, particularly PI7, PI9, and PI13, indicating that improving PI6 would lead to significant shifts in consumer perception and behavior.

Conversely, PI7, PI9, PI13, and PI17 are categorized as effect factors with negative (Di−Ri) values, indicating that the causal variables shape them. Notably, factors such as PI5, PI11, PI6, and PI15 are positioned in the first quadrant, signifying their role as core drivers in the system, while PI18, PI13, PI9, PI17, and PI7 are located in the fourth quadrant, marking them as impact factors, heavily influenced by other variables but difficult to address directly.

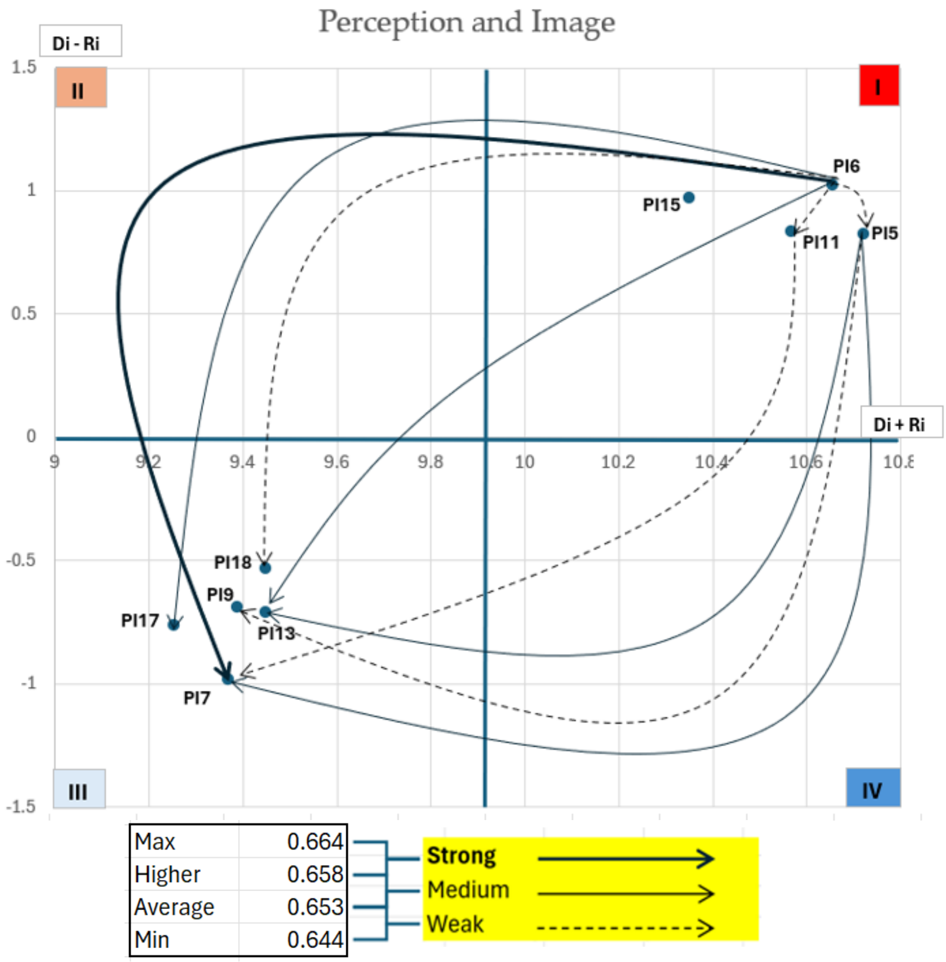

Figure 6. Impact-Relation Map Perception and Image Dimension

Additional illustrations of the correlations are shown in **Figure 6**, which demonstrates that although PI15 is more independent, PI6 and PI5 have a significant effect on the environment. In terms of fostering sustainable purchasing behavior, this underlines how important it is to concentrate on PI6 as a critical driver of change within the Perception and Image dimension inside the organization.

4.2.2.5 NZN DEMATEL Results of Supply Chain and Industry Practices

Table 11. The NZN DEMATEL results of supply chain and industry practices factors

Factor	Crisp Di+Ri	Crisp Di-Ri	Weight	Rank	Classification
SI3	9.1112	0.625	0.150426	2	Cause
SI4	8.0217	-0.6817	0.132439	6	Effect
SI5	7.9853	-1.0465	0.131838	7	Effect
SI6	9.0793	0.5953	0.1499	3	Cause
SI7	9.12	0.5484	0.150572	1	Cause
SI9	8.2573	-0.6521	0.136328	5	Effect
SI10	8.9944	0.6116	0.148498	4	Cause

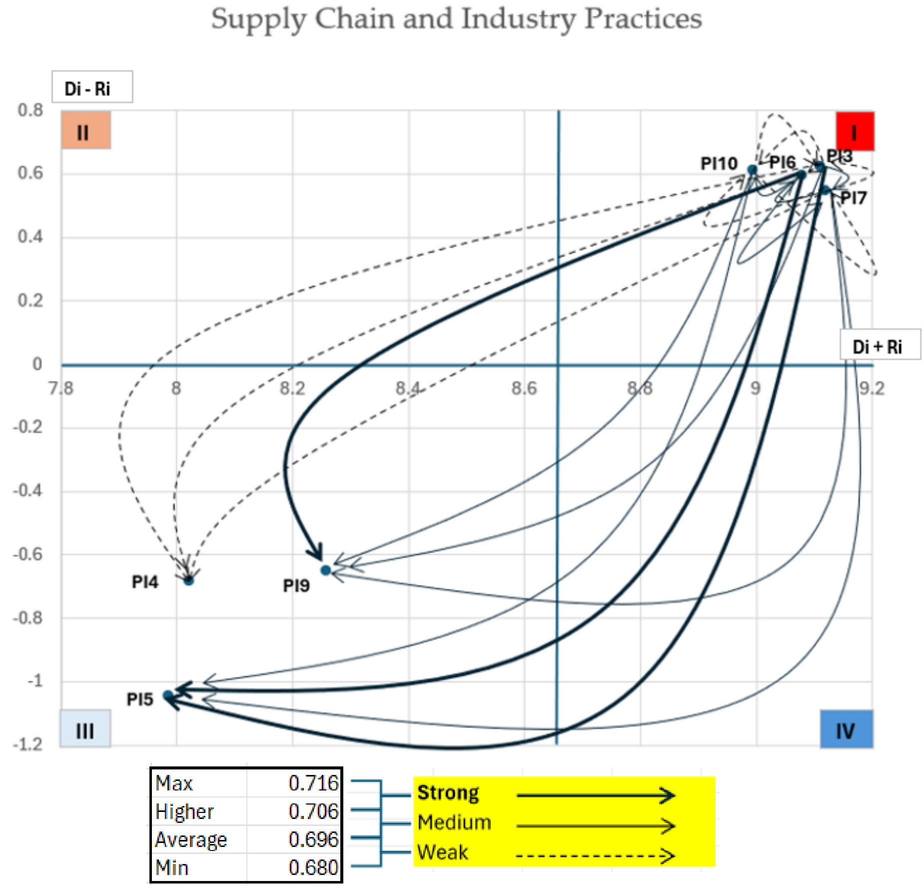

Figure 7. Impact-Relation Map Supply Chains and Industry Practices Dimension

The DEMATEL analysis for the Supply Chain and Industry Practices dimension, as outlined in **Table 11**, highlights the causal relationships among the seven factors. SI3 (Fair Wages and Working Conditions Challenges), SI6 (Financial Constraints and Scalability Concerns), SI7 (Technological Challenges in Production), and SI10 (Shift in the Fashion Industry Toward Circular Economy) are designated as causal factors based on their positive (Di−Ri) values. Among these, SI7 emerges as the most influential, with SI3 and SI6 following closely behind in impact. These factors are located in quadrant I, indicating their role as core drivers within the system, possessing high prominence and strong relations with other variables.

In contrast, SI4 (Greenwashing Practices in the Industry), SI5 (Limited Promotion of Sustainable Brands), and SI9 (High Production Costs) are categorized as effect factors, as reflected by their negative (Di−Ri) values. These factors are positioned in quadrant III, meaning they have lower prominence and relation and are influenced by the causal factors. Figure 7 demonstrates that SI4, SI5, and SI9 are significantly impacted by the core causal factors, particularly SI7 and SI3, both directly and indirectly.

The findings underscore the pivotal role of SI7, which serves as the primary catalyst in shaping supply chain practices and promoting sustainable behavior. Additionally, SI3 and SI6 significantly contribute to the impact of other factors. Prioritizing these essential elements is crucial for driving innovation and enhancing sustainability in the fashion industry.

4.3 Discussions

Employing a novel methodological framework by integrating Neutrosophic Z-number theory into the Delphi-DEMATEL approach. Unlike traditional methods, this integration allows for a more robust handling of uncertainty and reliability in expert evaluations, enabling a deeper analysis of causal relationships among barriers to sustainable consumption. The NZN Delphi study has identified key barriers and enablers for sustainable fashion adoption in Vietnam, highlighting the significant influence of social and cultural factors on consumer behavior. In Vietnam, affordability and social status are primary drivers of purchasing decisions, often taking precedence over sustainability concerns. This dynamic reflects a deeper conflict between immediate consumer priorities and long-term sustainability objectives, a pattern that is not unique to Vietnam but resonates across various emerging markets. As highlighted by Blas Riesgo et al. (2023), economic barriers and skepticism toward green claims similarly hinder progress in Spain, suggesting a global relevance to these findings. This reflects a broader trend of conspicuous consumption driven by social norms, a phenomenon not unique to Vietnam but observed across various emerging markets (Min Kong & Ko, 2017; Singh et al., 2024; Thi et al., 2019). The influence of social media on fashion trends and consumer behavior seems stronger in Vietnam than in other Southeast Asian nations (Gazzola et al., 2020; Nayak, Akbari, et al., 2019). Social media further amplifies these influences, exerting a more pronounced impact on fashion trends and consumer behavior in Vietnam than neighboring Southeast Asian nations (Gazzola et al., 2020; Nayak, Akbari, et al., 2019). This aligns with Hong Lan & Watkins (2023), who underscore the dual role of social media in both perpetuating fast fashion and promoting sustainable alternatives, emphasizing its potential as a strategic tool for change. It suggests underscoring the necessity of leveraging digital platforms to craft narratives that align with consumer aspirations while promoting sustainability, a strategy that has proven effective in other contexts.

Although the Delphi process identified critical factors influencing sustainable fashion consumption, excluding some elements does not diminish their broader significance. Previous research predominantly focuses on barriers like high costs and technological constraints, but a holistic understanding of Vietnam requires considering sociocultural and economic factors unique to this market. For instance, consumer skepticism towards sustainability claims, compounded by the prevalence of greenwashing, is a significant barrier, as Vietnamese consumers often question the authenticity of brands' environmental claims (Adamkiewicz et al., 2022). Moreover, the prevalence of consumer skepticism, driven by widespread greenwashing, presents a significant challenge. Incorporating advanced transparency mechanisms, such as blockchain for supply chain traceability, as recommended by Mizrachi & Alon (2022), could provide a robust solution to enhance consumer confidence and accountability among industry stakeholders. This aligns with global calls for enhanced supply chain transparency as a foundation for building trust, particularly in emerging markets where regulatory oversight may be less stringent.

Applying the NZN DEMATEL method has provided nuanced insights into the complex interactions between key factors influencing sustainable fashion in Vietnam. One of the most significant insights from this study is identifying the Policy and Education dimension as the dominant causal factor. This finding underscores the transformative potential of well-designed policies and educational interventions in driving sustainable practices. Sehnem et al. (2024) advocate for embedding sustainability education within institutional frameworks, particularly in emerging economies, to cultivate a deeper societal understanding of sustainability principles. These results echo calls for targeted policy measures and community-centric educational campaigns to foster sustainable purchasing habits (Martín-Sánchez et al., 2022). In the Vietnamese context, where cultural values and economic realities significantly shape consumer behavior, integrating educational interventions that resonate with local perspectives can substantially enhance consumer awareness and involvement in sustainable fashion. This finding is particularly noteworthy as it diverges from previous studies primarily focused on economic or technological factors. For instance, Niinimäki et al. (2020) emphasized the role of technological innovation in driving sustainable fashion, while our study indicates that in the Vietnamese context, policy and education may be more powerful tools for driving change. Moreover, as Bick et al. (2018) highlighted, addressing labor and environmental injustices through policy reforms is timely and essential for advancing sustainability in the textile sector. To implement this effectively, policymakers should consider developing curricula on sustainable fashion for schools and universities, creating public awareness campaigns about the environmental impact of fast fashion, and establishing incentives for businesses adopting sustainable practices.

According to the findings of our DEMATEL investigation, the Pricing and Affordability component demonstrates that economic factors have a considerable effect on the behavior of consumers with regard to sustainable fashion. This is the second most significant discovery that was made by the research. "Economic Growth Impact on Consumption" and "Balancing Sustainability and Profitability" are two elements that play crucial roles in making sustainable fashion accessible in Vietnam, where income levels and economic stability are significant drivers of purchasing power. In this context, the phrase "economic growth impact on consumption" is particularly relevant. This conclusion is consistent with the findings of earlier research that assert that affordability and economic stability are necessary for environmentally responsible practices in emerging countries (Villa Todeschini et al., 2017). However, our research further identifies the specific relationship between economic growth and sustainable consumption in the Vietnamese context. To address this, strategies could include developing policies and business models that enhance the affordability of sustainable fashion, such as through subsidies or tax incentives, encouraging local brands to develop affordable, sustainable product lines, and promoting sharing economy models in the fashion industry, such as clothing rentals or swaps.

The classification of Social and Cultural elements as the third most significant influence underscores the substantial effect of societal norms and social media on consumer decisions. Sandvik & Stubbs (2019) emphasize the power of cultural values and media platforms in normalizing sustainable behaviors, a finding that aligns with our analysis. Forging partnerships with social media influencers to advocate for sustainable fashion in Vietnam could serve as a game-changing strategy. Compared to previous studies, such as (Min Kong & Ko, 2017) focusing on the impact of social media on fast fashion consumption in China, our research provides a unique perspective on how sociocultural factors interact with other aspects of sustainability in the Vietnamese context. The Supply Chain and Industry Practices dimension highlights systemic challenges within the industry, suggesting a need for comprehensive reforms to align industry operations with sustainability goals. There is a correlation between this finding and a study by Khurana & Ricchetti (2015), who emphasized the importance of restructuring fashion supply chains to achieve sustainability. To address these challenges, industry stakeholders could develop marketing campaigns to change perceptions of sustainable fashion, collaborate with social media influencers to promote sustainable fashion choices and invest in research and development of sustainable production technologies.

Our sub-dimension analysis reveals that factors such as "Fashion as a Status Symbol" and "Consumer Involvement in Fashion" are crucial in driving consumer engagement and shaping attitudes towards sustainable fashion. The strong influence of these factors on "Social and Media-Induced Wardrobe Updates" highlights how societal expectations and social media can drive unsustainable consumption patterns. Compared to McNeil and Moore (2015) research on the conflict between personal values and sustainable behavior in fashion, our findings emphasize the specific role of social status in the Vietnamese context. This underscores the necessity of deploying tailored advertisements that promote mindful consumption and confront the dominant culture of fast fashion. Potential intervention strategies include the creation of marketing campaigns that emphasize the unique characteristics and prestige of sustainable fashion, the persuasion of luxury brands to embrace and advocate for sustainable practices, and the instruction of consumers on the enduring value of investing in high-quality, sustainable apparel. This finding correlates with the study on eco-friendly apparel.

Examining the Perception and Image dimension highlights the significance of fashion trends and consumer engagement in influencing attitudes toward sustainable fashion. The predominance of fashion trends in Vietnam, frequently propelled by social media and peer influence, indicates that integrating sustainable fashion with current trends might substantially enhance public acceptance. Compared to Henninger's research (2016) about the role of social media in sustainable fashion consumption, our findings emphasize the importance of tailoring communication strategies to the specific cultural context of Vietnam. It is essential to implement educational initiatives that not only increase consumer engagement but also address economic inequities in order to cultivate a shift in consumer behavior that is durable. Developing interactive platforms to educate consumers about the consequences of their fashion choices, collaborating with educational institutions to incorporate sustainable fashion education into the curriculum, and creating community events that encourage garment exchanges and reuse are all potential approaches that may be taken.

Our DEMATEL analysis for the Supply Chain and Industry Practices dimension reveals significant challenges, including technological barriers, financial constraints, and ethical labor concerns. These factors directly impact the efficiency of production processes, ethical practices, and overall cost management. This echoes previous research highlighting the importance of technological adaptation and financial resources in fostering sustainable practices across industries (Karaosman et al., 2015). In comparison to Nayak & Panwar et al. (2019) on sustainable practices in Vietnamese fashion and textiles SMEs, our findings provide a more comprehensive view of how these challenges interact and influence the entire fashion ecosystem in Vietnam. Addressing these core challenges could lead to a more sustainable and transparent industry. Strategies might include facilitating technology transfer and knowledge sharing within the industry, developing financial support mechanisms for sustainable upgrades in production processes, and implementing industry-wide standards for ethical labor practices and environmental sustainability.

This study's integration of the NZN Delphi and DEMATEL techniques offers a thorough knowledge of the relationships among numerous aspects influencing sustainable fashion in Vietnam. Our results, derived from the systematic identification of key features, provide significant insights for regulators, industry leaders, and marketers to formulate more effective strategies that promote sustainable practices in consumer fashion consumption. This study not only augments existing information on sustainable fashion but also establishes a foundation for future research employing integrated decision-making procedures to tackle intricate socio-environmental issues within the fashion sector.

5. Conclusions

5.1. Conclusions

This research delivers an in-depth exploration of the challenges to sustainable consumption within the Vietnamese fashion sector, employing an integrated methodology that merges Neutrosophic Z-number sets with Delphi and DEMATEL approaches. By assessing 47 barriers across five main, the study sheds light on the complex interplay that hinders sustainable fashion adoption. The results reveal that Policy and Education (PE) emerge as the most impactful causal elements driving sustainable consumption, underlining the necessity for comprehensive policy structures and educational initiatives. Furthermore, Social and Cultural Factors (SC) and Supply Chain and Industry Practices (SI) are vital in influencing consumer behavior and attitudes, reinforcing the importance of targeted measures to advance sustainable practices.

5.2. Theoretical Implications

This research contributes significantly to the literature on sustainable consumption by integrating NZN with the Delphi and DEMATEL techniques, offering a novel framework for analyzing complex consumer behaviors and decision-making processes. Using NZN sets introduces a sophisticated method for representing uncertainty, indeterminacy, and falsity in expert judgments, effectively addressing critical limitations inherent in traditional MCDM models. By incorporating reliability alongside the three dimensions of truth, indeterminacy, and falsity, this framework provides a more nuanced and robust means of sustainably capturing the ambiguity and complexity often associated with consumer perceptions and behaviors.

A notable theoretical contribution of this research lies in its ability to map causal relationships comprehensively across multiple dimensions: Social and Cultural Factors, Pricing and Affordability, Policy and Education, Perception and Image, and Supply Chain and Industry Practices. Unlike previous studies that typically emphasize singular dimensions, this study highlights the interdependencies between these factors, offering a holistic perspective on the barriers and drivers of sustainable consumption. Identifying key causal factors, such as the transformative role of policy interventions and the persistent challenge of affordability, underscores the interconnected nature of these issues, advancing the understanding of how systemic and behavioral factors influence sustainable consumption patterns.

The integration of NZN with Delphi and DEMATEL methodologies establishes a new benchmark for robustness in causal analysis. This approach enhances the reliability and depth of insights derived from multi-dimensional studies by systematically addressing complex systems' inherent uncertainties and ambiguities. The findings validate the applicability of the NZN framework in consumer behavior research and suggest that this method could be extended to other domains where complex and interrelated factors influence decision-making.

Additionally, this research makes a significant contribution by tailoring its analysis to the unique socio-economic and cultural context of Vietnam, a setting often underrepresented in sustainability studies. By confirming and expanding upon known barriers, such as skepticism towards sustainability claims and high costs, while introducing novel insights—such as the influential role of social media and the impact of targeted policy incentives—the study exemplifies the value of a context-sensitive approach. These findings not only address gaps in the existing literature but also provide actionable insights for stakeholders seeking to advance sustainable consumption in Vietnam. Furthermore, the framework developed in this study serves as a foundation for future research, particularly in regions with similar socio-cultural dynamics, offering a replicable model for examining sustainable consumption challenges in diverse contexts.

5.3. Managerial Implications

To address the pressing challenges of sustainable consumption within the fashion industry, policymakers and industry leaders must pioneer comprehensive strategies that drive substantial changes in production processes and consumer behavior. A critical starting point lies in formulating dynamic policies that transcend mere advocacy for environmental stewardship, actively reshaping economic systems to prioritize sustainability. Incentives such as tax reductions for green enterprises and financial support for adopting eco-friendly materials are essential to lower the barriers to entry for sustainable practices. These measures not only encourage businesses to transition toward greener operations but also foster a cultural shift that integrates sustainability into mainstream economic and social frameworks.

Education is pivotal in bridging the gap between consumer awareness and actionable behavior. Comprehensive educational campaigns emphasizing the socio-environmental impacts of fashion consumption can cultivate informed and responsible consumer habits. Incorporating sustainability into school curricula early on can embed environmental consciousness as a core societal value. Public awareness initiatives should complement formal education by demystifying the detrimental effects of fast fashion and emphasizing the long-term economic and environmental benefits of sustainable consumption habits. These efforts can nurture a generation that intrinsically values sustainability, positioning it as a non-negotiable component of everyday life rather than an optional ideal.

On the supply chain front, transparency and accountability are indispensable. Implementing technologies such as blockchain can revolutionize supply chain traceability, ensuring that sustainability claims are verifiable and trustworthy. Transparent supply chains enable consumers and stakeholders to make informed decisions, fostering trust in sustainable brands. Moreover, the transition to circular economy models is imperative. Prioritizing the reuse, recycling, and upcycling of materials reduces waste and promotes a continuous resource utilization loop. The fashion industry must also collaborate actively with technologists, designers, and environmental scientists to drive innovation in sustainable materials and production techniques. Collaborative efforts can lead to groundbreaking advancements that minimize the environmental footprint of fashion production without compromising quality or style, positioning sustainable fashion as an accessible standard rather than an exclusive alternative.

Ultimately, the integration of these strategies requires a multi-faceted and coordinated approach. Legislative support, educational enhancement, technological innovation, and industry-wide collaboration must work in tandem to create a robust framework for sustainability. By addressing these dimensions holistically, the fashion industry can transition to a more sustainable future that is innovative, inclusive, and resilient. Such an approach ensures that all stakeholders—policymakers, businesses, and consumers—actively engage in the dialogue and action toward achieving a sustainable fashion ecosystem.

5.4. Limitations and Future Works

Despite its valuable insights, this study is subject to several limitations. One notable limitation is the reliance on expert opinions in the Delphi approach, which inherently involves a degree of subjectivity. Although incorporating the Neutrosophic Z-number theory mitigates this subjectivity, it may still affect the robustness and objectivity of the conclusions. Additionally, the study's focus on the Vietnamese fashion sector may restrict the generalizability of its findings to other markets with different cultural, economic, and social dynamics. The cross-sectional nature of the data provides only a snapshot of consumer behaviors and attitudes at a specific time, limiting its ability to capture temporal changes or trends in sustainable fashion consumption.

Another limitation is the lack of exploration into concrete solutions or interventions to address the identified barriers. While the study successfully highlights key obstacles to sustainable fashion, it stops short of providing actionable strategies or evaluating the effectiveness of specific policy measures or industry initiatives. Future research should address these gaps by broadening the scope and employing complementary methodologies.

Subsequent studies could expand to include additional developing markets, allowing for a comparative analysis of barriers and drivers across diverse cultural and economic contexts. Longitudinal studies would provide deeper insights into how consumer attitudes and behaviors evolve, particularly in response to targeted interventions such as public awareness campaigns, policy changes, or shifts in industry practices. Furthermore, integrating Neutrosophic Z-number theory with established behavioral models could offer a more nuanced understanding of the key psychological and contextual factors driving sustainable fashion purchases.

Future research should also explore the role of digital technology in advancing sustainability in the fashion sector. For instance, examining the impact of technologies like blockchain for supply chain transparency, artificial intelligence for personalized consumer engagement, or e-commerce platforms for promoting sustainable choices could yield practical insights. Additionally, evaluating the effectiveness of policy measures such as environmental taxes, subsidies for sustainable products, or stricter greenwashing regulations would enhance the practical relevance of future studies. By addressing these limitations and exploring these new dimensions, future research could significantly advance the understanding of how to promote sustainable practices in the fashion industry, both in Vietnam and globally.

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