Framework for Sustainable Packaging Design

Thesis Submitted
in Partial Fulfilment of the Requirements for the
Degree of

DOCTOR OF PHILOSOPHY

in

DESIGN

by

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DECEMBER' 2025

I would like to dedicate this work to my family, friends, and teachers—the foundation of every success I've achieved." "With deepest gratitude to my parents, siblings, friends, and teachers, whose belief in me made this journey possible."

“This belongs to all of us."

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere appreciation to my supervisors, **Prof. Ranganath M. Singari** and **Dr. Sumer Singh**, for their invaluable mentorship and continuous encouragement throughout my PhD journey. Their profound expertise, insightful feedback, and unwavering support have been instrumental in shaping the direction of this research. Their patience and constructive guidance have helped me refine my ideas and navigate the challenges of this academic endeavour.

I extend my sincere thanks to the Department of Design, Delhi Technological University, India for providing the resources and facilities that made this research possible. I am thankful to Head, DOD **Prof. R.C Singh** & DRC Chairperson **Prof. Roli Purwar** for their continuous motivation and support. I am also grateful to my colleagues—**Dr. Ravindra Singh, Mr. Partha Pratim Das, Mr. Varun Singh, and Mr. Neeraj Rathee, as well as the administrative staff,** for their assistance and support throughout various stages of my work. I also wish to acknowledge my **fellow Research Scholars** especially **Ms. Shraddha Pundir, Ms. Yashika Kumari, Ms. Awani Sankritya, Ms. Anuradha Raizada, Ms. Simran Vats, Md. Tayyab, Mr. Shahid, Mr. Utkarsh and Md. Meraj** in the Department of Design, whose dedication to excellence has continually inspired me to strive for higher standards in my own work.

I am honoured to have received insights from the **Industry experts, Entrepreneurs and Academic Researchers** who generously shared their time and expertise during the framework development phase. Their contributions brought practical depth and real-world relevance to this study, and I am grateful for their willingness to engage with my work and provide valuable feedback. Apart from this, I would also like to thank my academic friend **Dr. Deepshikha Jha** for her continuous and unconditional support during my research work.

On a personal note, I owe immense gratitude to my family for being my constant pillars of support and for your endless encouragement. especially my **Parents Shri Hari Singh & Smt. Usha and my In-laws,** whose dreams I hope to honour through this achievement. **My better half Mr. Varun Bansal** and **my siblings – Mr. Dinesh Singh and Ms. Monika Singh, my sister & Brother in law Mr. Pranjal Garg and Ms. Eshita Singh and all the kids in the family** have shown me unconditional love and support throughout this journey.

Finally, I dedicate this thesis to my daughter, **Vaani**, whose presence in my life serves as a daily reminder of the importance of pursuing excellence and working toward a better future. Her joy and innocence have been my inspiration through both the challenging and rewarding moments of this academic pursuit. She will always be my continuous inspiration to work in future.

This research would not have been possible without the collective support of all these wonderful individuals. I am truly grateful for their contributions to this journey.

Taruna Singh

CANDIDATE'S DECLARATION

I, **Taruna Singh**, hereby certify that the work presented in this thesis, entitled "**Framework for sustainable Packaging Design**," submitted in partial fulfilment of the requirements for the award of the **Degree of Doctor of Philosophy** in **Design at Delhi Technological University**, is an original and authentic record of my research. This work was carried out under the supervision of **Dr. Ranganath M. Singari** and **Dr. Sumer Singh** during the period from **August 2020 to December 2025.**

I further declare that the content of this thesis has not been submitted for the award of any other degree at this or any other institution.

Candidate's Signature

This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis and the statement made by the candidate is correct to the best of our knowledge.

Signature of Supervisor **Signature of Joint-Supervisor**

CERTIFICATE BY THE SUPERVISOR(s)

This is to certify that **Taruna Singh**, Roll No. - 2K20/PHDDES/01 has conducted the research work presented in this thesis, entitled "**Framework for sustainable packaging Design**," for the award of the **Doctor of Philosophy** from the Department of Design, Delhi Technological University, Delhi, under our supervision. The thesis embodies the results of original research, and the candidate has carried out the studies independently. The contents of this thesis have not been submitted as the basis for the award of any other degree to the candidate or to any other individual from this or any other University/Institution.

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ABSTRACT

Addressing the sustainability challenges of packaging waste has become an alarming global need. A neglected yet important environment issue is the function of packaging in reducing the amount of content losses. There is a large gap between real life design implementation and sustainability intentions despite industry commitments to sustainable packaging solutions. The focus here lies on design attributes of packaging that can be utilized to conserve resources effectively and minimize the environmental impact. This Thesis fills this gap by determining the priority list of the key design attributes for Sustainable Packaging Design (SPD) and creating an inclusive framework to enable their practical implementation. Using a mixed-methods research design incorporating systematic literature review, expert interviews (n=30), with Kano method analysis, the study initially established the key design attributes driving effective sustainable packaging innovation. The findings indicated the key design attributes blocks of effective SPD.

Drawing on these findings, this dissertation offers the Sustainable Packaging Initiate - Innovate Design (SPIID) framework—a new methodological tool for bringing theoretical sustainability principles to tangible design specifications. The SPIID framework is a three phased: Initiate – Integrate - Innovate and 5- steps, interconnected process. This three-phase framework (Initiate, Integrate, Innovate) is introduced, enabling the strategic integration of design attributes that elevate sustainable packaging performance. Each phase employs specific tools and methodologies for resolving the critical design attributes found and dealing with the inherent trade-offs between sustainability goals and functional needs. To test the SPIID framework, an assessment via Expert group sessional insights (n=30) validated the framework's utility, usability, and applicability to varied packaging contexts. Practitioners from the industry, academics and entrepreneurs most appreciated the framework's methodical process of dealing with sustainability trade-offs and its ability to encourage cross-functional collaboration between design, engineering, and sustainability groups in their decision-making process.

This study contributes to three important areas in the field. First, it provides a holistic basis for understanding critical design attributes affecting successful sustainable packaging innovation using design thinking. Second, it presents a tested framework that closes the gap between theoretical principles of sustainability and practical using design thinking. Third, it presents evidence-based findings on the effectiveness of integrated design strategies in tackling intricate sustainability issues in packaging. The SPIID methodology provides designers, and sustainability experts with a structured approach for creating packaging solutions that reconcile environmental, economic, and functional factors. Areas of future research are the extension of the framework to new packaging technologies, creation of digital tools to facilitate its use, and its extension to cover more comprehensive circular economy concepts in product-packaging systems.

Keywords: sustainable packaging design (SPD), design attributes, Design thinking, packaging innovation, decision-making, design process

LIST OF PUBLICATIONS

Journal Publications:

1. Singh, T., Singari, R. M., & Singh, S. (2025). *Comprehensive study of design attributes for sustainable packaging design: Analytical techniques and expert validation. International Journal of Innovation Studies, 9*(1), 1101–1115. https://doi.org/10.xxxxxx/ijis.2025.9.1.1101

2. Singh, T., Singari, R. M., & Singh, S. (2025). *Advancing sustainable packaging: A unified approach integrating industry, innovation, and consumer*. *International Development Planning Review, 24*(1), 527–541. https://doi.org/10.xxxxxx/idpr.2025.24.1.527

Conference Presentations:

1. **Singh, T.** (2024, December 17-18). *Certificate of presentation: Fostering sustainable packaging design: A collaborative framework involving industry, local innovation, and customers*. 2nd International Conference on Sustainability, Entrepreneurship, Equity, & Digital Strategies (SEEDS 2024), Middlesex University Dubai.
2. **Singh, T.** (2024, March 14-15). *Certificate of presentation: Intertwining sustainability and packaging design: A review*. International Conference 2024 on Intertwining Sustainability with Mission Life: Fashion, Entrepreneurship, and Cultural Integration in Harmony, National Institute of Fashion Technology (NIFT), Gandhinagar.
3. **Singh, T.** (2023, December 14-16). *Certificate of presentation: Exploring opportunities in sustainable packaging design industry: A review study*. 4th Asian Conference on Ergonomics and Design, Humanizing Work and Work Environment & BRICSplus HFE Conference 2023, Indian Institute of Management (IIM) Mumbai.

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CHAPTER 1

INTRODUCTION

For decades, the environmental agenda has been about tackling packaging waste. Society has always debated and discussed it as a primarily environmental challenge. The environment is severely impacted by the production, distribution and consumption of food and drinks. It is an often neglected environmental issue how packaging can reduce the amount of food losses. Focusing on packaging attributes enables preservation of resources and reduction of environmental impact of food packaging systems. A service perspective is often considered to understand how consumers interact with packaging. The study analyses how sustainable design principles have integrated with packaging design attributes through the application of design thinking methodologies to optimise performance outcomes. This research investigates how sustainability considerations can be systematically incorporated into a packaging design framework to enhance both performance and environmental impact. By employing design thinking as a structured approach, this research targets identification and analysis of the correlation between SPD attributes and packaging performance, contributing to a better sustainable packaging.

1.1 BACKGROUND

Packaging design is a multidisciplinary field that encompasses the creation of the exterior of a product, serving multiple critical functions beyond mere aesthetics. Recent studies show that packaging design is a sophisticated system that combines form, function, and communication to benefit both businesses and consumers. The basic definition of packaging design goes beyond how it looks to include strategic factors including consumer psychology, brand communication, and functional needs. Research shows that people are affected by the design of packaging, and studies depict that about 73% of buying choices are made at the point of sales. This shows how important good packaging design is in stores (Kovačević et al., 2022). A number of theoretical frameworks discusses the understanding packaging design from an academic perspective. According to the optimal-arousal hypothesis, the manner in which packaging is designed can affect how people think and feel which can affect their motivation to buy (Chen et al., 2022). This theory says that packaging design is a complicated stimulus that needs to find the right balance between being new and being familiar in order to get the most people to pay attention to it. Packaging design plays a very important role in how brands communicate with customers. Research shows that packaging is a way for brands to communicate with customers, and that making packaging more appealing is strongly related to how likely customers are to buy something. Adding creative components to packaging design has been demonstrated to make people think more deeply, which makes them more likely to buy something (Wang et al., 2023).

The contemporary global packaging landscape confronts an unprecedented confluence of environmental, economic, and social challenges that necessitate a fundamental transformation from traditional linear packaging models towards sustainable, circular economy-integrated design approaches. The global sustainable packaging market, valued at USD 283.37 billion in 2024, is projected to reach USD 552.45 billion by 2033, growing at a CAGR of 7.70%, reflecting both the urgency and commercial viability of sustainable packaging solutions. Packaging design for decades has proven environmentally unsustainable, since the early 1950s, over 8.3 billion tonnes of plastic has been created, with approximately 60% ending up in landfills or the natural environment, and nearly 8 million tonnes of plastic entering oceans annually. This environmental crisis has led to a revolution in how packaging is designed, with a focus on protecting the environment, using resources wisely, and following the principles of a circular economy. 79% of customers have changed the way they buy things because of social responsibility, inclusivity, or environmental effect Capgemini Research Institute (2020). This shows how consumer behaviour is changing towards / a better, more sustainable situation. This shift represents more than a fleeting trend; it signifies a fundamental realignment of consumer values towards sustainability consciousness. Recent research by Shorr Packaging's 2025 Sustainable Packaging Consumer Report (Jan 2025) demonstrates that 90% of consumers are more likely to purchase from brands prioritising sustainable packaging, with 54% of respondents reporting deliberate choices of products with sustainable packaging in the past six months.

There are several different ways that the academic literature defines sustainable package design. At its core, sustainable package design is about making packaging that has the least effect on the environment while yet protecting the product, appealing to consumers, and being cost-effective. This definition is in keeping with the triple bottom line method, which takes into account environmental, social, and economic factors while making packaging.

Recent studies show that designing packaging that is good for the environment is part of a complicated system of competing priorities and tensions between sustainability and other goals. It is hard for the industry to find a balance between environmental benefits and practical concerns like protecting products, extending their shelf life, and meeting consumer needs (Smith et al., 2023). These tensions show how important it is to have advanced design methods that can handle several conflicting goals.

The circular economy paradigm gives us a way to think about how to create packaging that is good for the environment. This method stresses how important it is to make packaging solutions that enable recycling, reuse, and regeneration instead of linear consumption patterns. Research shows that to make packaging work in a circular economy, we need to make big changes to how we choose materials, design structures, and prepare for the end of life (Johnson et al., 2022). Research consistently demonstrates that sustainable packaging alternatives often fail to match the functional performance of conventional packaging materials. Customers are not impressed by the design and functionality of the paper-based packages studied, with the main functions of packaging identified as protection, communication, and facilitation of handling, and participants felt the paper-based packaging did not meet most of these criteria (Lindh et al., 2021). This fundamental issue highlights the challenge facing sustainable packaging adoption: balancing environmental benefits with basic protective functions. The global shift toward sustainable packaging represents one of the most significant transitions in today's packaging industry. However, despite increasing environmental awareness and regulatory pressures, many sustainable packaging solutions in the market face critical challenges related to functionality, product protection, durability, and consumer cost perceptions. This analysis examines the current state of sustainable packaging through the lens of scientific research, highlighting the disconnect between environmental goals and practical performance requirements.

The issue extends beyond individual material properties to system-wide challenges. Commercial success of these films developed at a lab scale is still challenging due to unsatisfactory mechanical, barrier, thermal, and optical properties than synthetic films (Mohan & Kumar, 2024). This research-to-market translation gap indicates that while laboratory developments show promise, real-world applications often reveal performance inadequacies.

Despite research showing mixed attitudes toward price premiums, consumer perception of sustainable packaging costs represents a significant market barrier. Price, quality, and convenience are still consumers' top product buying criteria, while environmental impact continues to be one of the lowest-ranked factors (McKinsey, 2023). This hierarchy of consumer priorities places sustainable packaging at a disadvantage when cost differences exist.

However, willingness-to-pay studies reveal complex consumer behaviour patterns. 82% of respondents would be willing to pay more for sustainable packaging, up four points from 2022, and eight points since 2021, signalling that even with a worsening economic situation; the environment remains a consumer priority (Trivium Packaging, 2023). This apparent contradiction between stated preferences and actual purchasing behaviour suggests that cost remains a practical barrier despite stated environmental concerns.

Some consumers are willing to pay on average 9.7% more for goods that meet specific environmental criteria, including locally sourced, made from recycled or eco-friendly materials (PwC, 2024). However, this willingness may not translate into actual purchases due to economic pressures and competing priorities. Consumers are not willing to pay more for green packaging because the price of products correlated with the low consumer budget and the lack of information (Popescu et al., 2022).

Recent research indicates a vast gap between consumer values declared and buying behaviour. Meanwhile, about 82% of world consumers indicate readiness to pay extra for sustainable packaging – up by eight percentage points since 2021 – buying behaviour indicates price sensitivity still substantially influences consumer purchasing (Trivium Packaging, 2023). This value-action divide presents a challenging environment for companies to balance environmental stewardship with market competition and consumer price sensitivity.

To solve these research problems, There is a need to develop methods from psychology, design thinking, marketing, material science, and environmental studies that cross disciplines. Researchers can help find effective solutions that reconcile environmental goals with business goals and customer goals by better understanding the factors that affect how people think about sustainability costs in packaging.

Contemporary packaging paradigms are strategic sustainability levers that span industrial sectors and go beyond traditional protective purposes. Significant advancements in the creation of biodegradable materials and the integration of the circular economy have been demonstrated empirically. Systematic literature studies, however, show that implementation strategies are disjointed and lack thorough design frameworks. Importantly, current research shows that design thinking approaches—more especially, user empathy mapping—are conspicuously lacking in the development of sustainable packaging. a gap that fundamentally compromises stakeholder-centered design outcomes and cross-cultural applicability (Norman & Verganti, 2014).

Adoption of sustainable packaging is still limited by financial constraints and insufficient integration of human-centred design, even with technology breakthroughs. By using evidence-based inclusive design techniques that methodically incorporate user empathy mapping into frameworks for developing sustainable packaging, this study fills in these empirically found gaps. The suggested methodology creates a conceptual framework for balancing stakeholder interests and the development of Packaging solutions that can sustain various practical uses.

The research identifies design experts perspective as a transformative tool for understanding stakeholder experiences, preferences, and constraints across different demographic, economic, segments. By integrating design thinking into SPD, this study proposes to bridge the gap between environmental optimization and real-world usability, creating solutions that are simultaneously sustainable and inclusive. Despite growing interest in SPD, significant research gaps remain that require doctoral-level investigation. The relationship between sustainable design strategies and consumer preferences remains poorly understood, with limited empirical evidence regarding optimal design approaches. The long-term environmental impacts of emerging sustainable materials require comprehensive lifecycle assessments that extend beyond current short-term studies.

1.2 MOTIVATION OF THE STUDY

The growing worldwide environmental crisis has made packaging waste one of the most important issues for sustainability. Every year, we make more than 300 million tons of plastic garbage, and packaging makes up 40% of that. The packaging waste is now a big part of ocean pollution, landfill overflow, and resource depletion. The conventional approach of take, make, and throw away is not sustainable at its core and needs to be changed in a systematic way. The packaging industry faces a significant challenge: it must develop environmentally sustainable solutions while ensuring product functionality, affordability, and consumer acceptability. Sustainable solutions often give up important attributes like barrier qualities and physical strength, which leads to more waste and safety concerns. This leads to challenges with sustainability, as packaging that is good for the environment might make other environmental concerns worse. The reason for this study is the big gap between what is needed for the environment and what is possible in the development of sustainable packaging. More than 80% of consumers say they would be prepared to pay more for eco-friendly packaging, yet the market shows that this isn't the case. Many sustainable alternatives fail to meet functional requirements, suffer performance limitations, or carry prohibitive costs that prevent widespread adoption.

The COVID-19 pandemic has intensified packaging consumption through increased e-commerce and hygiene requirements, creating unprecedented need for sustainable solutions that meet performance and environmental criteria without compromising public health. This research is motivated by the potential to bridge theory and practice through evidence-based framework development. By systematically identifying sustainable packaging attributes and developing a comprehensive design framework, this study aims to provide actionable guidance for better decision-making methodology using design thinking.

1.3 PROBLEM STATEMENT AND RESEARCH AIM

1.3.1 PROBLEM STATEMENT: Surmounting the cost perception barriers to adopting sustainable packaging is a key frontier in the larger process of moving toward a more environmentally friendly consumption habit. Through filling the noted research lacunae, authors can provide valuable insights that facilitate bridging the gap between consumer environmental values and consumption behaviors, thereby facilitating the uptake of sustainable packaging solutions by different market segments. This study thoroughly analyses the literature on the most recent advancements in package design in connection with sustainability. There is a need to identify important attributes that must be considered while starting a new SDP. For packaged goods, there is a need for a comprehensive and well-coordinated conceptual design framework that addresses sustainability, cost-effectiveness, and protection throughout the entire supply chain, from raw material extraction to disposal, and from manufacturer to final consumer. It will look into design methods and innovation for environmentally friendly packaging and encourage the use of inclusive design that satisfies consumer demands.

1.3.2 RESEARCH AIM:

Based on a comprehensive literature review, it is apparent that any product requires packaging, whether it is a tangible product, food, pharmaceutical, or any other object. Packaging has a key role to play in sustainable development and to support the marketing of the products. However, the packaging industry also has opportunities to explore other functions around sustainability.

The protection of the ecological environment and sustainable development has become the most pressing issues facing countries worldwide in the 21st century. Based on this situation, various fields increasingly emphasise energy conservation and the protection of nature. The traditional packaging materials and design obviously cannot meet this requirement. So, it is spurred to fully consider environmental design packaging with select packaging materials, explore a new model and method. Therefore, there is a need to thoroughly study the basic demands of the holistic SPD solution, which provides full consideration to the sustainability in mind, and could act as an intervention to shift consumers' behaviour in an environmentally and socially beneficial way.

The absence of unified design frameworks has led to inconsistent sustainability definitions and evaluation criteria across market sectors and regions. Packaging designers frequently lack clear guidance on prioritising competing sustainability requirements, resulting in arbitrary decision-making that may not align with actual environmental impact reduction or consumer needs. Contemporary approaches prioritize isolated design attributes, with developers highlighting singular traits like as biodegradability or recyclability, neglecting broader implications. This narrow method leads to problems in enhancing one portion of sustainable parameters affecting other aspects, which influences functional parameters. The mismatch between theoretical research and practical implementation indicates fundamental obstructions to making sustainability proof of concepts into suitable purposes. On one hand where academic research often investigates new materials and innovative methods, it many a times does not solve important aspects which include scalability potential, economic suitability, and supply chain incorporation essentials, which reduces practicality and feasibility to a great extent

A very important area to understand during this thesis is to identify the wide variety of consumer needs and varying market situations. To study factors in Indian context where large customer base influences economic and other factors that influence their purchasing decisions. This is not a systematic approach, which reveals a system level barrier where the adoption is not spread out evenly and smoothly across the ecosystem but is heavily fragmented. Holistic frameworks are absent that include the factors of environment, customer needs and new materials altogether from design to delivery phases to achieve a complete solution thus failing to benefit the environment as it should. Also, to develop designer's methods from achieving its full potential and achieving environmental sustainability though potential solutions. This highlights successful collaboration between researchers, engineers, designers and businesses from conception to delivery and End-of-life (EOL) considerations.

1.4 RESEARCH OBJECTIVES

In this thesis, 03 objectives were finalized to be worked upon**:**

Objective_01: Identification of the Attributes of Sustainable Packaging Design

The foremost step of the process will be to study and select design attributes pertaining to sustainable packaging which are versatile in nature. The aim of this research is to systematically identify and analyse the essential attributes that define truly SPD, which enhances its performance. These attributes extend beyond simple biodegradability or material structure to encompass a comprehensive range of environmental, social, and economic factors that collectively determine packaging sustainability.

Objective_02: Development of the Framework to Develop Sustainable Packaging

Multi-disciplinary methods and various stakeholder ideologies has been summarised into a cohesive and holistic design process to develop a rigorous framework for SPD. The sole aim of the present research is to strategize the method that will enable designers, manufacturers and businesses employ a systematic decision making method to design suitable and performance-based SPD solutions.

Objective_03: Study of the effectiveness of Sustainable Packaging Design Framework

The evaluation of SPD framework impact needs development of rigorous assessment parameters. The objective of this research goal lays foundation for assessment matrix, validation tests and feedback generation to evaluate if the framework developed achieves its goals of designing, maintaining performance thus ensuring sustainability. Comparative studies will also be employed in validation of the framework. To test and validate the SPIID framework, the attributes were generated form theoretical research and these were assessed against practical (real-world) SPD examples. This was specifically carried out to eliminate any gap between academic research and real world practices to ensure commercially viable SPD solutions.

1.5 SCOPE OF THE STUDY

Present research aims at encouraging practices during the conception stage to allow designers to design inclusive interventions. This design practice must emerge out of SPD attributes based on user requirements, performance-enhancing design attributes and types of materials involved to make eco-friendly packaging, which is also suitable for mass production and uses.

Present research also addresses and important factor pf SPD methodologies particularly suitable for India's diverse market segments which vary according to cultural diversity, economics, performance requirements across customer base. The research emphasises that SPD interventions must go beyond eco-friendliness and also be commercially viable, cost effective, and culturally appropriate and have functional suitability at the same time.

The SPD framework also lays emphasis on various competing factors that drive decision making such as – minimal materials usage, minimal wastage, EOL consideration, logistics, cost-effectiveness, minimal environmental pressures, functionality, market suitability, durability and varying product performances. This method highlights that sustainability will be achieved by a cohesive consideration of social, economic and environmental factors.

The present research will probe the gaps encountered in implementing SPD framework, its economics and efficiency in context of India by underlining essential SPD attributes via a conceptual framework. The research methodology relies on both quantitative and qualitative assessment of the performance matrix and customer preferences, respectively, while studying designers' constraints as well. This ensures that the resultant framework addresses needs of all stakeholders involved in the decision making process while upholding performance, functional and aesthetic parameters. This comprehensive approach aims to target the diverse customer base that India presents with respect to socio-cultural and economic paradigms.

1.6 Overview of the Thesis

This thesis addresses a critical oversight in contemporary sustainable packaging research: the systematic exclusion of design thinking methodologies, particularly user empathy, from sustainable packaging development processes. While technical solutions have advanced considerably, the human-centered design dimension remains underdeveloped, resulting in environmentally sound products that fail to resonate with diverse user groups, economic contexts, and cultural requirements.

The research identifies user empathy mapping as a transformative tool for understanding stakeholder experiences, preferences, and constraints across various aspects of design. By integrating design thinking into SPD, this study proposes to bridge the gap between environmental optimization and real-world usability, creating solutions that are simultaneously sustainable and inclusive. A brief overview of the thesis is shown below in Figure 1.1.

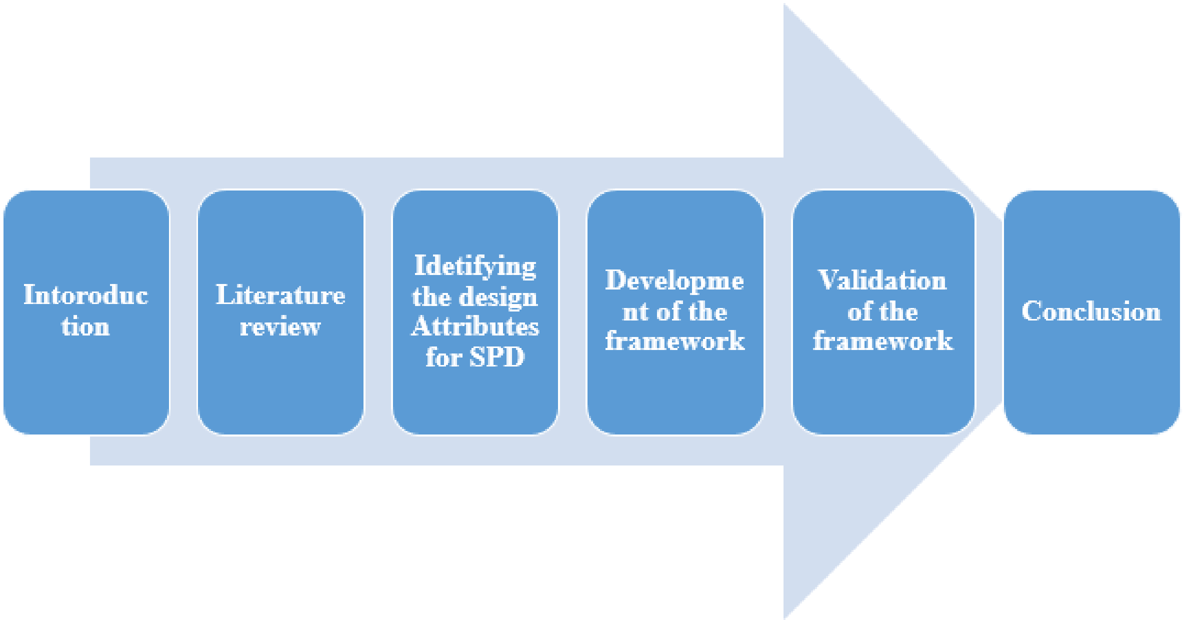

Figure 1.1: Flow chart of the overview of the thesis

Chapter 1: Introduction: This chapter addresses the traditional usage of packaging design. It also briefly discusses the development of various strategies and methodologies that have been developed to corporate sustainability commitments. It also discusses the fragmented implementation approaches lacking holistic frameworks, limited integration of user experience considerations, absence of design thinking methodologies, missing systematic user empathy mapping, poor understanding of cross-cultural requirements, and insufficient frameworks balancing environmental and economic objectives across diverse stakeholder contexts. Industry practices focus on material performance, structural integrity, and manufacturing scalability.

CHAPTER 3: LITERATURE REVIEW: The Literature Review chapter establishes foundational context by tracing the packaging industry's evolution from traditional protective functions to sustainability-focused paradigms. It examines environmental imperatives including climate change, pollution, and waste crises driving industry transformation. The chapter analyses regulatory frameworks, market dynamics, and consumer behaviour patterns influencing sustainable packaging adoption.

CHAPTER 3: METHODOLOGY: In this research, a mixed-methods approach is used, integrating qualitative and quantitative methods to examine attributes that lead to SPD. Through online surveys, discussions, and interviews, this method provides a thorough assessment of both subjective user opinions and objective performance measures. The list of attributes were prepared after a thorough literature review by the Systematic Literature Review (SLR) approach described by Tranfield et al. (2003). A short list of selected attributes was then pilot testing with 35 Designers to understand weather the attributes are aligned with sustainability or not. The positive results further guided towards the final survey which was conducted with Kano methodology. A quantifiable data was produced by using this method which resulted into a priority list of the design attributes. Later, these attributes were used to create a conceptual framework to design SPIID framework. SPIID framework can be utilized to develop SPD which can sustain various market conditions as discussed earlier. This framework was then validated by using Relative importance index (RII).

CHAPTER 4: IDENTIFICATION OF THE ATTRIBUTES OF SUSTAINABLE PACKAGING DESIGN: Identification of SPD attributes began with a comprehensive review of existing literature on sustainable packaging, examining peer-reviewed journals, industry reports, and design guidelines. This allowed us to compile an initial list of potential SPD attributes across environmental, social, and economic dimensions. Method used in this chapter is Kano model (Kano et al., 1984) resulting into priority list of design attributes

CHAPTER 5: DEVELOPMENT OF FRAMEWORK FOR SPD (SPIID): This chapter introduces a comprehensive methodology for developing a holistic framework to develop SPD solutions. The author's addresses the inherent uncertainty in early design phases by incorporating SPD attributes. By integrating this SPIID model into conventional packaging design processes, we effectively address challenges related to sustainability requirement prioritisation and design uncertainty. The SPD model for sustainable packaging evolves through three phases Initiate, Integrate and Innovate, which is elaborated in detail throughout this chapter. The aim is to create a conceptual framework to allow any researcher or designer involved in an SPD process to follow logical, consistent procedural steps.

CHAPTER 6: STUDY OF THE EFFECTIVENESS OF SUSTAINABLE PACKAGING DESIGN FRAMEWORK: The comparison of the SPD survey is the key milestone in verifying the holistic framework obtained through this work. The survey tactfully created to assess sustainable packaging examples against the previously obtained framework attributes. A purposively selected expert panel comprising 30 domain specialists was assembled across three professional categories: industry practitioners (n=10) with implementation experience, entrepreneurs (n=10) with commercial development focus and academic researchers (n=10) with theoretical expertise.

CHAPTER 7: CONCLUSION & FUTURE SCOPE: This framework contributes importantly to theory and practice of sustainable packaging by shifting away from silo approaches towards an integrated model that acknowledges inter-relatedness of design characteristics. It offers a shared language and evaluation methodology to various stakeholders along the packaging value chain, enabling collaboration for sustainability.

CHAPTER 2

LITERATURE REVIEW

The domain of packaging design with increased focus on SPD has transformed significantly in the last decade, owing to regulations, SDGs and largely due to consumer preferences. The present chapter on literature review examines the state of the art in SPD with a focus on the following: design attributes, theoretical frameworks, challenges in implementation and consumer preferences. The state-of-the-art literature review amalgamates studies from recent scientific literature to set up a theoretical foundation for the development of comprehensive design frameworks for sustainable packaging.

The packaging industry, globally, has reached a critical juncture facing challenges from environmental degradation, which demands rapid transformations from conventional paradigms towards a more holistic design strategy with increased focus on sustainability. The present packaging scenario, valued at USD 283.37 billion in 2024, is projected to reach USD 552.45 billion by 2033. This means a conjecture of economics, industrial manufacturing, consumer preferences, and environmental strategies and stewardship to shape the global sustainability landscape (Straits Research, 2024). This significant growth orientation, which is characterised by a compound annual growth rate of 7.70%, signifies urgent requirements for sustainable packaging solutions and the emergence of commercial suitability of sustainable design methodologies that go beyond traditional profit-maximisation strategies.

The packaging design industry has been operating upon linear economic models which employ the "take-make-dispose" methodology, where materials are primarily utilised from natural sources extensively, converted into packaging materials, used for a short time for containment and protection purposes, and finally disposed as waste with little consideration for EOL (end of life) impacts on environment or resource extraction methods. This straightforward methodology, while economically viable for short-term gains, has affected the environment with consequences that are appalling and need immediate attention. Since the early 1950s, over 8.3 billion tonnes of plastic have been manufactured across the globe, with almost 60% of plastic manufactured has been eventually disposed in landfills or circulated amidst natural environment, leading to altercation of natural ecosystem and biodiversity concerns across the ecosystem - terrestrial or marine (United Nations Environment Programme, 2023). The enormity of this natural emergency is additionally magnified by the almost 8 million tonnes of plastic waste that enter the marine system every year, creating enormous gyres of waste and introducing micro-plastic contamination in marine food systems, with a significant impact on human health and the integrity of the ecosystem.

Consumer preferences at present show a deep transformation in purchase decision-making activities, with 79% of consumers being active in iterating their buying and consumption patterns according to the CSR initiatives, SDGs and inclusive business operations (Capgemini Research Institute, 2024). This shift in behaviour surpasses superficial marketing trends, denoting a foundational repurposing of consumer values with respect to sustainability consciousness that highlights long-term environmental strategies over quick convenience-based or cost-based deliberations. Contemporary research carried out within diverse demographics indicates that 90% of the users would purchase products that commit to environmental sustainability with genuineness, and 54% select products or drive product purchase decisions based on sustainable packaging attributes within the preceding six months (Shorr Packaging, 2025). This data reveals that SPD solutions have transformed from a niche area or niche opportunities to increasing commercial imperatives that may channelize consumer buying preferences and loyalty towards brand building.

2.1 Evolution of Sustainable Packaging Research

The advancement of packaging design demonstrates an incredible journey from the earliest survival needs of human beings to a modern-day, elaborate, and refined technology-driven lifestyle. Archaeological evidence suggests that packaging emerged when early nomadic societies required methods to protect, store, and transport food and goods (Rypax, 2022), beginning with natural materials like leaves, animal skins, and gourds. Scientific research traces the development from Chinese mulberry bark wrapping in the first century B.C. to the Industrial Revolution's mechanised production (Ohio State University Extension), which fundamentally transformed packaging from handmade to mass-produced solutions. Contemporary studies emphasise packaging design as the fundamental stepping-stone toward a circular economy (Paparoidamis et al., 2022), with researchers investigating how design rules and guidelines can achieve sustainability. Recent scientific perspectives recognise packaging through a socio-technical lens, understanding plastics and materials within their broader networks and societal relations rather than as isolated technological solutions (Gabrys et al., 2020). Modern packaging science has evolved to incorporate intelligent monitoring systems, biodegradable materials, and digital integration, reflecting what researchers describe as "a convergence of digital technology, sustainability, and consumer engagement" that addresses both preservation needs and environmental responsibility. The relationship between packaging and sustainability has caused the evolution of literature towards the minimisation of environmental damage. The task of packaging professionals is becoming more demanding, as they need to collect information from distinct topics to stay up to date (Sastre et al., 2022). This complexity has necessitated systematic approaches to understanding and organizing the diverse aspects of sustainable packaging research. A brief figure of evolution of Packaging Design can be seen in figure 2.1.

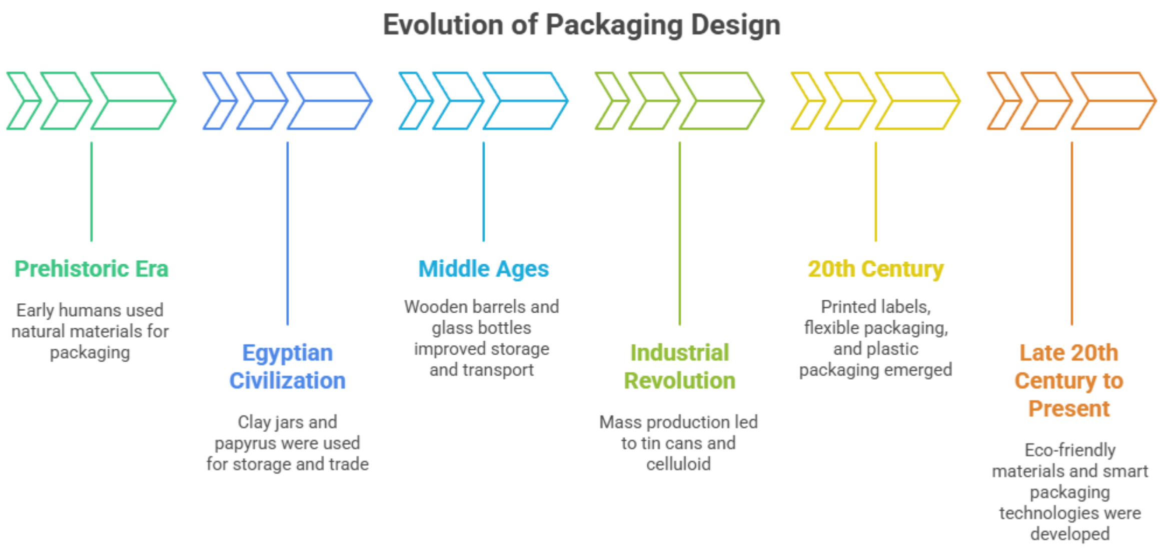

Figure 2.1: Evolution of Packaging Design

The transition toward SPD necessitates the comprehensive integration of circular economy principles that fundamentally reconceptualise material flows, product lifecycles, and waste management systems within industrial processes. Circular economy frameworks, established upon three foundational principles of eliminating waste and pollution, maintaining materials and products in circulation at their highest value, and regenerating natural systems, provide systematic methodologies for developing packaging solutions that operate within planetary boundaries while maintaining commercial viability (Ellen MacArthur Foundation, 2024). The implementation of these principles requires a sophisticated understanding of material science, manufacturing processes, supply chain dynamics, consumer behaviour patterns, and regulatory frameworks that collectively influence the feasibility and effectiveness of sustainable packaging interventions. Design for Circularity methodologies recognize that approximately

80% of environmental impacts associated with packaging systems are determined during the design phase, emphasizing the critical importance of integrating sustainability considerations throughout the conceptualization, development, and implementation processes rather than attempting to retrofit environmental considerations into existing linear design frameworks (Zhou et al., 2024).

Life Cycle Assessment methodologies have emerged as the predominant analytical framework for quantifying environmental impacts associated with packaging systems, providing standardised approaches for evaluating resource consumption, energy utilisation, emissions generation, and waste production across all phases of packaging lifecycles from raw material extraction through end-of-life management scenarios. However, the addition of circular economy methodologies into conventional LCA principles brings about substantial complexities that pose a challenge to traditional systems' paradigms, operational unit definitions, and impact allotment methods. Recent research has defined the importance of Circular Economy Life Cycle Assessment integration that expands system boundaries to incorporate several use cycles, adds circular allocation procedures, and reports on the versatile quality changes that may happen through multiple reuse and recycling processes (Tunçok-Çeşme et al., 2024). These procedural developments enable enhanced quantification of environmental benefits linked with circular packaging systems while defining potential trade-offs and unintended outcomes that may be a result of sustainable design paradigms.

The design of new biomaterials demonstrates rapid transformation in the domain of SPD, which offers immense opportunities to replace traditional petroleum-based materials with renewable, biodegradable options, which maintain functional characteristics while terminating contamination in the environment. Mycelium-based materials, extracted from the root structure of mushroom-forming fungi, depict immense potential as sustainable packaging alternatives that may be generated within 7 days using agricultural waste substrates and eventually decompose completely within 45 days under a home composting environment (Ecovative Design, 2024). These biomaterials demonstrate mechanical characteristics similar to expanded polystyrene foam while removing contamination of the environment linked with traditional synthetic packaging materials. Likewise, seaweed-based packaging solutions demonstrate the high growth attributes and ample accessibility of marine algae to generate biodegradable films and repositories that need no agricultural land, freshwater resources, or synthetic fertilisers for generation while vigorously processing carbon dioxide during cultivation processes (Notpla, 2024).

The magnitude at which biomaterial alternatives needs be scaled brings both opportunities and challenges for large-scale implementation within present packaging supply systems. Market predictions indicate that mycelium-based products could reach global market values crossing $32 billion by 2025, which indicates significant commercial potential for these novelty materials (Jones et al., 2024). However, the successful intervention of biomaterials into the mainstream packaging domain needs a more holistic evaluation of manufacturing scalability, cost competitiveness, supply chain logistics, performance consistency, and consumer acceptance patterns. Present research indicates that while biomaterial alternatives perform well in environmental performance metrics, achieving functional parity with traditional materials beyond dynamic packaging applications, it emphasises continued intervention in material science and technology, processing methods, and application or context-specific optimisation processes.

Technological amalgamation presents a critical aspect of SPD evolution, with AI (artificial intelligence), ML (machine learning), IOT (Internet of Things) capabilities, and block chain technologies, which lead to extreme optimisation of packaging systems in versatile performance variables. Machine learning algorithms assess large datasets of material characteristics, supply chain systems, and environmental impacts, which can optimise packaging material usage, reduce waste generation by up to 24% while simultaneously decreasing transportation charges incurred by 5% through enhanced packaging productivity (MIT Technology Review, 2024). Smart packaging technologies incorporating embedded sensors enable real-time monitoring of product quality, environmental conditions, and packaging performance throughout supply chain processes, providing data-driven insights that support continuous improvement in sustainability metrics while reducing food waste and product spoilage. Block chain integration facilitates complete supply chain transparency, creating immutable records of material sourcing, manufacturing processes, and end-of-life management that enable verification of sustainability claims and support consumer confidence in environmentally responsible products.

Consumer behaviour research reveals significant demographic variations in sustainable packaging preferences and willingness to pay premium prices for environmentally responsible alternatives. Generational analysis demonstrates that 49% of Generation Z consumers and 47% of Millennial consumers express willingness to pay higher prices for sustainable packaging, compared to 41% of Generation X and 37% of Baby Boomer consumers, indicating that younger demographic segments represent primary target markets for sustainable packaging innovations (Shorr Packaging, 2025). However, successful sustainable packaging implementation requires a careful balance between environmental performance, functional effectiveness, and economic accessibility to ensure broad market adoption across diverse demographic segments. Research indicates that minimal packaging approaches are valued by 61% of consumers, suggesting that sustainability and functionality must be harmoniously integrated rather than positioned as competing priorities.

The regulatory landscape surrounding sustainable packaging continues evolving rapidly, with governments worldwide implementing comprehensive Extended Producer Responsibility frameworks, plastic waste reduction mandates, and circular economy promotion policies that fundamentally alter the economic incentives associated with packaging design decisions. The European Union's Packaging and Packaging Waste Directive, updated in 2024, mandates recyclability goals, stops many single-use packaging uses, and calls for notable advancement toward circular economy targets (European Commission, 2024). Likewise, regulatory developments across North America, Asia-Pacific, and other countries generate a persistent global need for sustainable packaging accessibility and adoption while affecting market dynamics that support long-term investment in sustainable packaging infrastructure and technology.

Corporate sustainability guidelines demonstrate another driving force that enhances sustainable packaging adoption, with multinational corporations including Unilever, Nestlé, Coca-Cola, and Procter & Gamble establishing time-bound procedures to achieve 100% recyclable, reusable, or compostable packaging by 2025-2030 (Corporate Sustainability Reports, 2024). These guidelines, driven by the amalgamation of regulatory compliance standards, an increase in consumer demand, and corporate social responsibility targets, create a fundamental market demand for sustainable packaging solutions while generating economic incentives for novelty and technological advancement within the sustainable packaging domain.

2.2 Packaging Design and Its Aspects

Although there has been significant advancements in sustainable packaging R&D (research and development), several significant knowledge gaps exist that reduce the effectiveness of current methods and reduce the calibrated progress towards complete sustainable packaging strategies. The present literature depicts persistent fragmentation across boundaries of materials science, environmental engineering, consumer preferences, economics, and policymaking - functioning mostly in seclusion instead of generating integrated methods that address the multidisciplinary aspects of sustainable packaging opportunities and challenges (Lau et al., 2024). This fragmentation leads to interventions that do well in a specific technical domain but fail in large-scale applicability and scalability for successful applications.

The systematic article classification system was carefully organised as per unique domains of competence, with these classifications being rigorously evaluated based on the precise academic groups officially submitted and validated by the respective journals' editorial boards and peer review committees. This systematic approach ensured that each publication was mapped within its appropriate scholarly domain, maintaining the integrity of the categorisation process and reflecting the editorial expertise of subject matter specialists. Microsoft Excel® electronic spreadsheet software was systematically used as the primary data management tool to classify, record, organise, and track study participants and their corresponding publications across each identified research article. This helped facilitate efficient data entry, sorting, and analysing the data, enabling the maintenance of comprehensive records of participant demographics, publication details, and cross-referencing information in a structured and accessible format.

Following the initial publication and subsequent indexing in various prominent digital academic libraries and repositories—including but not limited to Scopus, Web of Science, PubMed, IEEE Xplore, and ScienceDirect—the collected journals underwent a secondary classification process. This additional categorisation step involved the systematic grouping of publications into five broadly defined general topic areas or thematic clusters, which were established to facilitate cross-disciplinary analysis and identify emerging patterns or research gaps across different but related fields of study. The categorisation into 08 general topic areas represents a strategic consolidation approach designed to create meaningful thematic clusters that transcend traditional disciplinary boundaries while maintaining analytical coherence. These five categories were deliberately selected to balance comprehensiveness with manageable scope, ensuring that the diverse range of publications could be effectively grouped without oversimplification or excessive fragmentation that might obscure important crosscutting themes and interdisciplinary connections. Table 1 show shows the classification of literature review topics.

Table 2.1: Categorization of Literature Review

S.No	**Categorization**
1	Packaging and Aesthetics
2	Packaging following LCA
3	Packaging and E-Commerce
4	Packaging and Circular Economy
5	Packaging design focusing on material & innovation
6	Packaging Design Distribution & supply chain
7	Packaging Design and sustainability
8	Existing Frameworks

2.2.1 Packaging and Aesthetics

The graphic and structural components of design, such as its form, colour, size, and typography are referred to as its packaging design (Underwood, 2003). These components could act as subliminal cues that might attract attention and imply product qualities through associations. Compared to clear cues like price, brand, or promises, these implicit design signals are not immediately consciously detected and acknowledged as informative by the client. Therefore, the subconscious aspect of decision-making is more strongly correlated with packaging design (Silayoi & Speece, 2004).

Colours are an important aspect of a packaging design (Ampuero & Vila, 2006; Ares & Deliza, 2010; Hutchings, 2003). They are the package aspects that respond the quickest, and they have grown to be one of the most crucial visual design components (Swientek, 2001). The ability to distinguish the backdrop colour from the other package components, researchers will look solely at the impact of colour (Marshall et al., 2006).

In the food sector, colour has a significant role (Hutchings, 2003; Deliza et al., 2003; Piqueras-Fiszman & Spence, 2011). This is the reason why producers should use food packaging to grab customers' attention and pique their desire to buy, to create sensory and hedonic expectations for the product that are in line with its actual performance attributes (Ares & Deliza, 2010). Design styles have a great evocative effect for customers, and companies frequently employ them to express certain connections of concepts as colour frequently enters human decision-making and discourse. Due to the various interpretations given to colours in various circumstances, distinct connotations of colour may surface. Red, for instance, connotes a negative conclusion when competence is being assessed and both good and negative outcomes are conceivable.

There are many different colour associations that explain the influence of colour, in which a certain colours are interpreted as a symbol or a sign. In addition to shape, colour is the most crucial component of a package and is a key component of logos and product packaging for example red for Coca-Cola red, blue for IBM blue, purple for Cadbury, and so on (Hynes, 2009). According to colour and form have a substantial impact on customers' associations, predicted preferences, and desire to buy. According to a recent study on the effect of product package colours on customers' purchasing decisions under time constraints, a customer's purchasing decision is largely influenced by the colour scheme rather than the amount of time available (Javed & Javed, 2015). To entice customers in their decision-making, however, all package components—including colour and shape—must be blended. When applied to a product's packaging, the appropriate choice of package colour, backdrop picture, wrapper design, and unique concepts will foster a cheerful sensation in customers' minds (Ghosh, 2016).

The literature review for this aspect of packaging design references spans two decades (2001-2016) and encompasses interdisciplinary research examining the psychological and behavioural impacts of packaging design elements on consumer decision-making processes. The literature predominantly focuses on colour psychology and visual design components in packaging, with significant emphasis on food industry applications and consumer perception studies. Research methodologies employed across these studies include conjoint analysis, word association techniques, experimental designs, and case study approaches, demonstrating both quantitative and qualitative research traditions in packaging and consumer behaviour research. The references collectively establish a robust theoretical foundation for understanding how packaging design elements—particularly colour, shape, and visual aesthetics—function as subliminal communication tools that influence consumer preferences, purchase intentions, and brand associations across diverse product categories and demographic segments.

Present research depicts an increased amalgamation between sustainability attributes and aesthetic specifications in packaging design, as companies more and more realise that environmental responsibility must be seamlessly incorporated with visual aesthetics to effectively influence consumer purchase decisions. Research shows that consumer expectations for sustainable packages go beyond environmental functionality to include aesthetic attributes, with consumers/participants specifically mentioning, "the design should be very attractive and stand out from other less sustainable packages" (Ketelsen et al., 2020). Study examining sustainable design methods depicts that visual sustainability in packaging positively influences purchase decisions via both cognitive specifications (product gentleness and power) and emotional attributes (moral contentment), with gender differences modulating these relationships (Steenis et al., 2018). Cognitive research employing electroencephalogram (EEG) technology depicts that paper packaging with significant sustainability claims better engages consumers in comparison to plastic alternatives, though effective implementation requires meticulous execution to retain consumer purchase motivation for decision making and brand building for consistency (Nielsen IQ, 2023). Consumer studies using conjoint analysis demonstrates that aesthetic assessments are crucial in sustainable product assessments, with form continuing as one of the most fundamental characteristics, though the relative importance of design versus sustainability attributes changes by product category and consumer environmental awareness as stated in Sustainable Paper-Based Packaging: A Consumer's Perspective - PMC (Boz et al., 2020). This amalgamation of sustainability and aesthetics depicts a unique perspective that SPD solutions must satisfy both functional and emotional consumer needs to achieve large-scale commercial success.

2.2.2 Packaging Design and Life Cycle Assessment

Life Cycle Assessment (LCA) is a way to look at the environmental effects of packaging design over its whole lifecycle, from getting the raw materials to making it, shipping it, using it, and getting rid of it at the end of its life (ISO 14040, 2006). The LCA approach helps designers and manufacturers figure out how their products affect the environment in a statistical way and find ways to make them better in areas like carbon footprint, water use, energy use, and trash generation. LCA-informed packaging design uses environmental performance parameters as a basic design criterion that affects material selection, structural optimization, and EOL (end-of-life) assessment (Sastre et al., 2022). This is different from traditional design methods that focus on aesthetic or functional factors.

In the packaging for food field, the LCA method helps us understand how packaging improvements can help reduce food waste. Research shows that reducing packaging materials by 10% can increase food waste by 15-25%, which has a negative effect on the environment because making food is more harmful to the environment than making packaging (Grönman et al., 2013; Han et al., 2018). This occurrence leads to a systems thinking intervention to packaging design where environmental enhancement may consider the entire product-packaging system rather than packaging in isolation. Design methodologies such as active packaging technologies and modified atmosphere packaging depict positive LCA profile by enhancing shelf life and reducing food waste, despite higher material complexities and production energy essentials (Coffigniez et al., 2021).

Structural design enhancement through LCA-guided methods focuses on achieving greater protection productivity with least material utilisation, using tools such as finite element analysis and protective packaging modelling to employ required thickness, geometry, and reinforcement requirements (Meherishi et al., 2021). Transportation effects, generally representing 10-15% of complete packaging environmental stressors, can be majorly minimised through design methods that increase packing density, reduce weight-to-volume ratios, and lead to efficient logistics arrangements (Morgan et al., 2022). Advanced LCA modelling incorporating supply chain optimisation demonstrates that packaging redesign can achieve 20-30% reductions in transportation-related emissions through improved stacking productivity and reduced secondary packaging requirements.

The literature review for LCA-informed packaging design spans three decades (1990-2023) and encompasses multidisciplinary research integrating environmental science, materials engineering, industrial ecology, and packaging technology. The literature predominantly focuses on quantitative environmental impact assessment methodologies, with significant emphasis on food packaging applications, comparative material studies, and end-of-life scenario modelling. Research methodologies employed across these studies include attributional and consequential LCA approaches, Monte Carlo uncertainty analysis, sensitivity testing, and hybrid LCA-economic assessment techniques, demonstrating the evolution from simple impact quantification to sophisticated decision-support frameworks. The references collectively establish a comprehensive knowledge base for understanding how LCA methodology can guide packaging design decisions toward environmental optimisation while maintaining functional performance requirements across diverse product categories and market contexts.

Contemporary LCA research demonstrates increasing integration with circular economy principles and digital technologies, as companies recognize that traditional linear assessment approaches must evolve to address complex material flows and emerging packaging innovations. Studies indicate that circular design strategies such as design for recyclability, material substitution, and packaging-as-a-service models can achieve 40-60% reductions in environmental impacts when properly implemented, though success depends heavily on supporting infrastructure and consumer behaviour patterns (Paparoidamis et al., 2022). Advanced LCA methodologies incorporating artificial intelligence and machine learning enable real-time optimization of packaging design parameters based on environmental performance criteria, supply chain constraints, and market requirements (Civancik-Uslu et al., 2019).

2.2.3 Packaging Design and E-commerce

The globe is living in a unique historical moment right now. In reality, the fourth industrial revolution—also referred to as "the digital revolution"—is bringing about significant changes in the early 21st century. The term "e-commerce" describes the exchange of products and services using electronic media, such as the Internet and other digital platforms, between buyers and sellers. E-commerce has made our lives more comfortable in terms of purchases that we do in our day-to-day life. However, the issue of packaging waste that results—especially from over packaging—poses significant threats to both human health and the sustainability of the environment. E-commerce packaging represents a paradigmatic shift from traditional retail-oriented design, where packaging must simultaneously fulfil multiple critical functions including product protection during shipping, brand communication in digital environments, and enhanced customer experience through unboxing moments (Escursell et al., 2021). Dissimilar to traditional retail packaging created for shelf enhancement and POS (point-of-sale) visibility, e-commerce packaging functions within a large and complicated logistical ecosystem where dimensional productivity, damage avoidance, and cost enhancement become main design drivers while maintaining brand building in an verily congested digital marketplace (Sarkis et al., 2021). These functional attributes lay stress on innovative design methodologies that stabilise protective activities with material productivity, shipping cost factors, and environmental sustainability factors.

Dimensional enhancement stands out as the most important design attribute in e-commerce packaging, as shipping costs are mostly calculated based on dimensional weight rather than actual weight, making economic incentives for compact, efficient packaging dimensions (Van Loon et al., 2015). Research depicts that enhanced packaging design can reduce shipping costs by 15-30% through increased space utilization and lessened dimensional weight measurements, while at the same time reducing material usage and environmental effects

(Mangiaracina et al., 2019). The problem of right-sizing packaging for versatile product portfolios has led to the design of automated packaging systems and algorithm-driven box selection methods that match optimal packaging dimensions to specific product measurements in real-time (Boysen et al., 2019).

Damage avoidance in e-commerce packaging needs an elaborate understanding of distribution stressors, handling dynamics, and multiple touchpoint effects in the complicated supply chains that lead to last-mile delivery networks (Zhou et al., 2022). Comparative research concludes that e-commerce products deal with 3-5 times more handling stressors and impact forces in comparison to conventional retail distribution, laying stress on enhanced protective design strategies, including reinforcement of edges, filling voids, and several layers of protective systems (Khouja et al., 2021). Sustainability attributes in e-commerce packaging face several novel problems due to the predominance of single-use functions, more and more packaging volumes per transaction, and complex end-of-life contexts, which may involve diverse geographic disposal systems (Escursell et al., 2021). Life cycle assessment studies of e-commerce packaging reveal that while individual package environmental impacts may be higher due to protective requirements, the elimination of retail infrastructure, reduced transportation to physical stores, and optimised logistics networks can result in net environmental benefits at the system level (Mangiaracina et al., 2019). Innovative solutions, including reusable packaging systems, biodegradable void fill materials, and packaging consolidation strategies, demonstrate potential for 20-40% reductions in packaging-related environmental impacts, though implementation success depends heavily on consumer participation and reverse logistics infrastructure development.

Waste from e-commerce packaging is particularly problematic in light of the COVID-19 epidemic and the rising popularity of online shopping. This leads to the formation of a significant amount of e-commerce packaging trash, as well as resource utilisation and CO2 emissions that go into the manufacture of packaging. Three main elements contributed to this: the rise of the Internet and the digital transition; health and safety concerns; and the e-commerce industry's increased comfort, variety, and affordability (Tiwari S, Singh P, 2011 and Xie G, Huang L et al., 2021). The e-commerce packaging business has to promote the notion of a circular economy as long as such unsustainable packaging techniques persist and pose a danger to the idea of sustainable development. Examining packaging systems from the standpoint of the circular economy would also aid in the development of creative restorative and regenerative models that need less financial and technological resources than other approaches, such as redesigning packaging and creating new packaging materials.

2.2.4 Packaging and Circular Economy

The intersection of packaging design and circular economy principles fundamentally challenges the traditional linear "take-make-dispose" paradigm by reimagining packaging as a continuous resource flow within closed-loop systems (Ellen MacArthur Foundation, 2019). This transformative approach repositions packaging design from end product thinking to systems-level optimization, where materials maintain their highest value through multiple use cycles, biodegradation pathways, or infinite recyclability scenarios. Rather than viewing packaging as inevitable waste, circular design principles establish frameworks for eliminating waste through intelligent material selection, modular design architectures, and regenerative end-of-life planning that contributes positively to natural and technical nutrient cycles (McDonough & Braungart, 2002).

Important to circular packaging design is the conceptualisation of designing out waste or EOL materials at the sourcing points through tactical material choices and innovations in configurations that underline circularity indicators such as recyclability rates, biodegradability timelines, and renewable content percentages (Linder & Williander, 2017). Mono-material design methodologies exemplify this process by removing complex material combinations, those complex recycling processes, enabling simpler sorting and processing while maintaining functional performance necessities. Research shows that mono-material flexible packaging can achieve recycling rates of 85-95% compared to 25-40% for multi-layer barrier films, though trade-offs exist in barrier performance and shelf-life protection that require innovative interventions such as barrier coatings and alternative preservation technologies (Hahladakis & Iacovidou, 2018).

Adopting bio-based and biodegradable materials leads to another main touch-point of circular packaging design, though material selection needs meticulous consideration of EOL end-of-life facilities and environmental effect trade-offs (Rossi et al., 2021). Polylactic acid (PLA) and polyhydroxyalkanoates (PHA) show positive circularity aspects through industrial composting processes, yet their environmental advantages depend heavily on waste collection systems, composting facility closeness, and energy-based production processes that may offset biodegradability benefits. Emerging research in seaweed-based packaging, mushroom mycelium interventions, and agricultural waste outcomes offers potentially superior circularity aspects by employing waste streams as feedstock while providing end-of-life benefits through soil enhancement and carbon sequestration.

Design for disassembly methodologies lead to circular material cycles by making it easier to separate various parts for proper end-of-life processing. However, implementing these methods requires careful balancing of functional integration and circularity optimisation (Moreno et al., 2017). Some new solutions are water-soluble adhesives that dissolve when washed, mechanical separation systems that work when the temperature or pH changes, and modular designs that make it easy to upgrade or replace pieces. These methods are especially useful in big packaging systems like beverage containers with labels, closures, and barrier layers, where each material portion can follow optimal circular cycles.

Business model innovation turns out as equally important as technical design in achieving circular packaging systems, with strategies such as packaging-as-a-service, deposit-return systems, and collaborative reuse networks creating economic incentives for circularity (Antikainen & Valkokari, 2016). Reusable packaging programs display significant environmental advantages when consumer involvement rates exceed 75% and logistics distances remain below 500 kilometres, though success relies heavily on convenience aspects, consumer education, and reverse logistics facilities (Coelho et al., 2020). Digital technologies, including block-chain tracking, IoT sensors, and AI-powered sorting systems, enable sophisticated circular packaging operations by providing real-time visibility into material flows, contamination levels, and optimisation advantages.

Recent research in circular packaging design spans multiple disciplines, including materials science, industrial ecology, behavioural economics, and digital technology integration, reflecting the systems-level complexity required for successful implementation (Kalmykova et al., 2018). Methodological approaches range from life cycle assessment and material flow analysis to consumer behaviour research and business model explorations, displaying the requirements for holistic evaluation frameworks that capture technical, economic, social, and environmental aspects of circular systems. The multi-disciplinary nature of this research field creates both advantages for intervention and problems in standardisation, measurement, and implementation in versatile industry sectors and regulatory ecosystems.

Current advancements in circular packaging design increasingly focus on digitalisation and artificial intelligence applications that lead to the versatile optimisation of circular material flows based on real-time data inputs and predictive modelling capabilities. Machine learning algorithms analyse packaging return rates, contamination patterns, and consumer behaviour data to optimise circular system performance while minimising operational costs and environmental impacts (Bag et al., 2021). Block chain-enabled material passports provide unprecedented transparency in material composition, supply chain provenance, and end-of-life instructions, though widespread adoption faces challenges related to interoperability standards, data privacy concerns, and implementation costs across complex value networks (Kouhizadeh et al., 2021). Advanced simulation modelling enables virtual testing of circular packaging systems before physical implementation, reducing development risks while optimising performance across multiple circularity indicators, including material productivity, energy consumption, and economic viability (Kristensen & Mosgaard, 2020).

2.2.5 Packaging design study with focus on material & innovation

Material innovation leads to bringing transformative possibilities that go far beyond conventional performance statistics to include sustainability, functionality, and smart responses to environmental and consumer preferences (Yam et al., 2005). The significant shift from conventional petroleum-based polymers toward bio-based alternatives, smart materials, and hybrid composites depicts a major reimagining of packaging as an active, responsive action point between products and their ecosystems rather than passive containment interfaces (Rhim et al., 2013).

Advanced barrier technologies depict the most significant innovation prospects in packaging materials, with nanocomposite systems that achieve barrier improvements of 100-1000% over conventional materials through strategic incorporation of clay platelets, carbon nanotubes, and metallic nanoparticles (Duncan, 2011). These Nano-enhanced materials enable dramatic thickness reduction while maintaining or enhancing protective performance, resulting in material reduction of 20-40% and corresponding reductions in environmental effect and production costs. However, critical limitations severely restrict practical implementation: nanoparticle migration concerns raise food safety questions with limited long-term toxicity data available (Bouwmeester et al., 2009), manufacturing costs remain 200-500% higher than traditional materials due to specialized processing requirements (Sorrentino et al., 2007), and recycling infrastructure cannot accommodate nanocomposite materials due to contamination risks and sorting difficulties (Kuchta et al., 2018). Regulatory approval processes for nano-enhanced packaging require extensive safety testing that can take 5-10 years and cost millions of dollars, making commercial suitability questionable for many purposes.

Biopolymer innovations have advanced beyond simple starch and cellulose extractions to include modern engineered media extracted from marine algae, agricultural waste streams, and microbial fermentation processes (Siracusa et al., 2008). Polyhydroxyalkanoates (PHAs) produced through bacterial fermentation show mechanical characteristics comparable to conventional plastics while offering complete biodegradability in marine environments, conveying critical concerns about plastic pollution in aquatic chains (Chen, 2009). Although major practical disadvantages limit adoption, the production costs of PHA remain 3-5 times higher than traditional plastics due to expensive fermentation processes and low yields (Koller et al., 2017). Barrier properties decline largely under high humidity conditions, making them not viable for many food applications (Plackett et al., 2003), and processing temperatures must be strictly controlled to prevent thermal decline, requiring specialised equipment and proficiency (Bugnicourt et al., 2014). Additionally, composting infrastructure for biodegradable plastics exists in less than 15% of global markets, meaning these media often end up in conventional waste streams where they provide no environmental advantages (Brodhagen et al., 2017).

Smart packaging materials embedded with responsive technologies create dynamic packaging systems that monitor product condition, communicate with consumers, and adapt their properties based on environmental changes or product requirements (Vanderroost et al., 2014). Time-temperature indicators utilising thermos-chromic materials provide visual feedback about cold chain integrity, while oxygen-sensitive inks change colour to indicate package breach or product deterioration. Furthermore, complex manufacturing processes requiring electronics integration are incompatible with existing high-speed packaging lines, necessitating substantial infrastructure investments.

Edible packaging represents a revolutionary approach to material innovation that completely eliminates packaging waste by transforming the package itself into a consumable component of the product system (Janjarasskul & Krochta, 2010). Protein-based edible films derived from whey, collagen, and plant proteins provide excellent barrier properties while offering nutritional value and complete digestibility. However, fundamental limitations prevent widespread adoption**;** moisture sensitivity causes rapid degradation under normal storage conditions with shelf life typically limited to 2-4 weeks compared to months for conventional packaging (Hassan et al., 2018). Taste and texture issues create consumer acceptance problems with studies showing rejection rates of 60-80% for edible packaging (Campos et al., 2011), and food safety concerns arise from potential bacterial growth on protein-rich edible films requiring preservatives that compromise the "natural" positioning (Dhall, 2013). Production costs remain 400-800% higher than conventional packaging due to specialised ingredients and processing requirements.

Emerging innovations in programmable materials introduce unprecedented functionality through shape-memory polymers, self-healing materials, and stimulus-responsive systems that adapt their properties based on temperature, humidity, or chemical exposure (Lendlein & Kelch, 2002). Shape-memory packaging materials can be programmed to change form during distribution, creating compact shipping configurations that expand to optimal display formats upon reaching retail environments. Significant practical constraints include that shape-memory polymers require precise temperature control during manufacturing and storage, with activation temperatures often incompatible with normal distribution conditions (Hu et al., 2012). Self-healing mechanisms lose effectiveness after 3-5 healing cycles and cannot repair large punctures or tears common in packaging applications (Urban, 2012), and manufacturing complexity increases production costs by 300-600% while requiring specialised equipment and training (Behl & Lendlein, 2007). Additionally, unpredictable activation in real-world conditions can cause premature shape changes, leading to packaging failures and product damage.

Nanocellulose materials demonstrate exceptional potential, offering renewable sourcing, outstanding mechanical properties, barrier enhancement capabilities, and complete biodegradability while serving as platforms for incorporating functional additives (Licciardello, 2017). However, critical implementation barriers persist, which is that production costs remain 5-10 times higher than conventional materials due to energy-intensive processing requirements (Rol et al., 2019). Moisture sensitivity limits applications in humid environments, with mechanical properties degrading by 50-70% under high humidity conditions (Dufresne, 2013), and scaling production to industrial volumes faces technical challenges with current manufacturing capacity less than 1% of global packaging demand (Moon et al., 2011). Furthermore, nanocellulose processing requires significant water consumption (10-15 litres per kilogram) and energy input, raising questions about overall environmental benefits.

Contemporary manufacturing and infrastructure challenges further compound material innovation limitations. Existing packaging machinery cannot accommodate many innovative materials without substantial modifications costing $500,000-$2 million per production line (Marsh & Bugusu, 2007). Supply chain infrastructure lacks storage and handling capabilities for moisture-sensitive bio-based materials requiring climate-controlled environments (Jiménez et al., 2012), and quality control systems designed for conventional materials cannot adequately assess innovative material properties, leading to inconsistent performance and safety concerns (Guillard et al., 2018). In addition, regulatory guidelines have not been found to address innovative media, leading to approval delays of 3-7 years and which require extensive testing protocols that favour established conventional media (Bott et al., 2019).

Economic suitability concerns display a major roadblock to innovative media adoption: cost premiums of 150-800% over traditional media create immense price hurdles for a heavily price-dependent consumer goods market (Gironi & Piemonte, 2011). Return on investment calculations show payback periods of 7-15 years that exceed typical business planning horizons (Hottle et al., 2013), and market demand for premium sustainable packaging remains limited to small practices, leading to less than 5% of total packaging usage (Lindh et al., 2016). These economic actualities, together with technical disadvantages and infrastructural facility constraints, describe why innovative packaging media remain mostly confined to research labs and small-scale context-specific applications rather than becoming a primary source of packaging and logistical ecosystem.

2.2.6 Packaging Design and its impact on Distribution & supply chain

Distribution-centric packaging design depicts a major juncture where protective functionality, logistical productivity, and economic optimisation meet to lead to global trade dynamics, yet simultaneously creates complex challenges that significantly impact supply chain performance and environmental sustainability (Azzi et al., 2012). Distribution packaging must bear the mechanical stressors, environmental changes, and handling irregularities which are common in modern multi-modal transportation networks, which span thousands of kilometres and multiple touchpoints with multiple stakeholders, dissimilar to consumer-first packaging designs that focus more on aesthetic appeal and brand building and communication (García-Arca et al., 2014). This specific design domain needs enhanced research of distribution physics, supply chain economics, and system-level optimisation while manoeuvring major limitations, including standardisation requirements, cost pressures, and infrastructure constraints that may compromise optimal design interventions.

Protective Performance Optimisation stands out as the basic need for distribution packaging, where designers must balance material productivity with respect to damage reduction across multiple transportation touch points and modes, including truck, rail, maritime, and airfreight systems that subject packages to multiple stressors and environmental changes (Singh et al., 2008). Recently developed testing protocols simulate real-world distribution stressors through drop testing, vibration analysis, compression evaluation, and climate cycling to optimise protective packaging configurations while reducing material usage and dimensional needs (Brandenburg & Lee, 2001). However, critical performance disadvantages persist about standardized testing procedures often fail to duplicate complicated real-world stressors at multiple touch points, with laboratory test results showing 40-60% variance from real world distribution damage rates (Saha & Khare, 2018). Protective packaging optimisation for one transportation mode may create vulnerabilities in others, requiring over-engineering that increases costs by 15-30% (Molina-Besch, 2016), and emerging last-mile delivery challenges, including automated sorting systems and doorstep delivery, create new stress contexts not solved by conventional testing procedures (Zhou et al., 2022).

Dimensional Standardisation and productivity represent another critical design parameter where packaging dimensions must optimise space utilisation across diverse transportation and storage systems while accommodating varying product configurations and consolidation requirements (McKinnon & Ge, 2006). Efficient packaging design can reduce transportation costs by 10-25% through improved load factors and reduced dimensional weight calculations, while poor dimensional optimisation creates cascading inefficiencies throughout supply chains (Hellström & Saghir, 2007). Although basic limitations reduce optimisation of existing transportation facilities, which include container dimensions, pallet standards, and warehouse. Rack systems create rigid configurational limitations that avoid suitable packaging sizing for many products (Olsson & Larsson, 2009). Conflicting regional standards (European pallets vs. North American pallets) lay stress on sub-optimal adjustments when working for global markets, which increase packaging costs by 8-15% (García-Arca & Prado-Prado, 2008). The need to include several product variants within single packaging systems often leads to significant void space and material waste, with research demonstrating 20-40% unused space in average e-commerce shipments (Packaging Strategies, 2021).

Cold Chain Integration demonstrates several limitations where packaging must maintain product integrity across temperature-controlled distribution networks while integrating with specialised refrigerated transportation and storage systems (Mercier et al., 2017). Temperature-sensitive products, including pharmaceuticals, biologics, and fresh foods, require sophisticated thermal packaging solutions that maintain specific temperature ranges throughout distribution cycles lasting days or weeks. Critical constraints may include passive thermal packaging systems show significant performance degradation beyond 72-96 hours, limiting distribution range and employing expensive expedited shipping for lengthier routes (Singh et al., 2018). Active cooling systems incorporated with packaging increase complexity and costs by 200-500% while requiring specialized handling and disposal procedures (Rodrigue & Rodrigue, 2019), and thermal packaging materials including phase change materials and insulation foams often contradict with sustainability objectives due to limited recyclability and high environmental impact of its manufacturing processes (James et al., 2017). Additionally, cold chain monitoring systems face integration challenges with existing logistics networks, with sensor accuracy varying ±2-5°C under real-world conditions potentially compromising product safety (Ruiz-Garcia et al., 2009).

Automation compatibility is becoming more important as distribution centres adopt automated sorting, handling, and packaging systems that require packaging designs optimised for machine recognition, handling, and processing (Rushton et al., 2014). Packaging must include machine-readable codes, uniform dimensions, and predictable handling characteristics while maintaining protective performance and cost productivity. Significant technical barriers exist**:** automated systems require packaging dimensional tolerances of ±2-3mm compared to ±10-15mm for manual systems, increasing manufacturing costs and quality control requirements (Faber et al., 2020). variable product weights and centre-of-gravity positions within packages create handling difficulties for robotic systems with failure rates of 5-15% requiring manual solutions (Bogue, 2016), and packaging graphics and labelling must include multiple scanning technologies (barcode, QR code, RFID) while retaining aesthetic appeal and regulatory compliance, increasing design complexity and printing costs by 20-35% (Wang et al., 2021). Furthermore, automation systems developed for traditional packaging cannot accommodate innovative sustainable media with different mechanical characteristics, creating barriers to environmental improvement guidelines.

Reverse Logistics and Returns Processing create additional packaging design challenges where packages must facilitate product return, refurbishment, and remarketing processes while maintaining cost productivity and sustainability objectives (Rogers & Tibben-Lembke, 2001). E-commerce growth has dramatically increased return rates to 25-30% in many categories, requiring packaging solutions that enable multiple use cycles and easy opening/resealing capabilities. Implementation challenges includes packaging designed for returns must balance tamper-evidence with reusability, often requiring specialized closures that increase costs by 15-25% (Sarkis et al., 2021). Return shipping labels and documentation must be integrated without compromising original packaging aesthetics or functionality, creating design conflicts and space constraints (Genchev et al., 2011), and reverse logistics infrastructure often lacks capabilities for processing sustainable packaging materials, with returned bio-based packages frequently ending up in conventional waste streams negating environmental benefits (Govindan et al., 2015). Additionally, contamination from returned products can compromise packaging recyclability, requiring separate processing streams that increase costs and complexity.

Supply Chain Visibility and Traceability demand packaging integration with digital tracking systems that enable real-time monitoring of product location, condition, and custody throughout complex multi-stakeholder distribution networks (Bosona & Gebresenbet, 2013). New packaging advancements must accommodate RFID tags, sensors, and communication devices while maintaining cost productivity and physical protection necessities. Critical limitations persist in RFID tag integration, which increases packaging costs by $0.10-$0.50 per unit while providing limited read accuracy in challenging environments, including metal containers and liquid products (Landt, 2005). Sensor integration for condition monitoring faces power consumption limitations with battery life reducing assessment duration to 7-30 days based on sampling regularity (Abad et al., 2009). Data incorporation across several supply chain stakeholders needs standardised protocols that are not updated with interoperability problems creating information gaps and reducing visibility benefits (Shukla et al., 2011). Furthermore, privacy and security concerns with respect to supply chain data sharing create hesitation among partners to fully implement tracking systems, reducing their efficacy.

Sustainability Integration within Distribution generates a rift between environmental goals and supply chain performance needs, as sustainable packaging materials often depict inferior protective activities, increased costs, and compatibility issues with existing facilities (Molina-Besch et al., 2019). The shift towards sustainable packaging must be balanced against the environmental effects of enhanced product damage, transportation irregularities, and supply chain disturbances. Structural limitations about bio-based packaging materials show 20-50%

performance reduction under high humidity conditions common in maritime shipping, requiring over-packaging that negates environmental advantages (Siracusa et al., 2008). Recyclable mono-materials often do not possess barrier properties needed for lengthier distribution cycles, limiting applications to short supply chains and reducing market viability (Hahladakis & Iacovidou, 2018), and sustainable packaging disposal requires specialized infrastructure not available in many global markets, with sustainable packages often processed as traditional waste due to system constraints (Hopewell et al., 2009). Additionally, life cycle assessments show that transportation productivity improvements often outweigh packaging material sustainability benefits, creating clashes between local environmental goals and global optimisation goals (Williams & Wikström, 2011).

These multi-dimensional challenges show why distribution and supply chain deliberations often dominate packaging design decisions despite growing pressure for sustainability, consumer appeal, and intervention. The complicated interdependencies between protective performance, logistical productivity, economic limitations, and environmental objectives require sophisticated optimization approaches that frequently result in compromise solutions rather than optimal outcomes for any single objective.

2.2.7 Packaging Design and Sustainability

The convergence of packaging design and sustainability dimensions has significantly changed industrial objectives from purely functional considerations toward comprehensive environmental strategies that include material selection, production methods, distribution channels, and end-of-life assessment across all product ecosystems (Verghese et al., 2015). Current sustainability frameworks require packaging designers to navigate complex trade-offs between environmental defence, economic suitability, and functional production while dealing with diverse stakeholder expectations including regulatory compliance, consumer choices, and corporate responsibility guidelines. Although despite significant investment in research and development, sustainable packaging initiatives continue to face major implementation non-fulfilment, economic limitations, and specific knowledge gaps that reduce their efficacy and large-scale adoption across global markets.

Material sustainability depicts the requisite deliberations in environmentally conscious packaging design, where renewable resource utilisation, recycled content integration, and end-of-life biodegradability create channels for reducing environmental footprint while maintaining protective and marketing functions (Hottle et al., 2013). Bio-based materials derived from agricultural waste, marine algae, and forestry by-products demonstrate alternatives to petroleum-based polymers, although implementation faces significant technical and economic limitations. Polylactic acid shows optimal environmental aspects in controlled composting environments, but still demonstrates limited biodegradability in marine ecosystems and requires industrial composting facilities available in fewer than 20% of global markets (Brodhagen et al., 2017). The fundamental failure of bio-based materials lies in their performance limitations under real-world conditions, with moisture sensitivity causing 40-60% strength reduction in humid environments, temperature instability leading to premature spoilage during storage, and barrier property deficiencies requiring over-packaging that negates environmental benefits (Siracusa et al., 2008). Economic constraints incorporate production costs 200-500% higher than traditional materials, limited supply chain availability creating procurement problems, and quality irregularities that may add to rejection rates by 15-25% compared to established polymer systems (Gironi & Piemonte, 2011).

Energy consumption throughout packaging production, transportation, and disposal phases creates substantial environmental impacts that often exceed material-related effects, particularly for lightweight packaging systems where transportation productivity becomes the dominant sustainability factor (Williams & Wikström, 2011). Manufacturing energy requirements vary dramatically across material types, with aluminium packaging requiring 170-190 MJ/kg compared to 70-85 MJ/kg for conventional plastics and 20-30 MJ/kg for paperboard systems, though recycling energy benefits can offset initial production impacts over multiple lifecycle iterations (Franklin Associates, 2018). Critical failures in energy optimization include the renewable energy transition lag in packaging manufacturing, where 70-80% of production still relies on fossil fuel energy sources, inadequate energy recovery systems in waste processing facilities that waste 60-70% of embedded energy content, and transportation inefficiencies caused by sustainable packaging dimensional constraints that reduce load factors by 10-20% (McKinnon, 2015). Missing elements include comprehensive energy accounting methodologies that capture full supply chain impacts, integration of renewable energy requirements in sustainability standards, and dynamic energy optimization systems that adapt to grid energy source variations.

Waste generation and end-of-life management present perhaps the most visible sustainability challenges, where packaging materials constitute 30-40% of municipal solid waste streams in developed economies while creating environmental pollution concerns in marine and terrestrial ecosystems (Ellen MacArthur Foundation, 2016). Recycling infrastructure limitations significantly constrain material circularity objectives, with global recycling rates averaging 14% for plastics, 70% for aluminium, and 68% for paper and cardboard, though regional variations and contamination issues create substantial performance gaps (Geyer et al., 2017). The recycling system demonstrates systematic failures including contamination rates of 25-40% that render materials unrecyclable, downcycling processes that reduce material quality with each cycle limiting circularity to 2-3 iterations, and economic inefficiencies where recycling costs exceed virgin material costs by 20-50% in many markets (Hopewell et al., 2009). Missing infrastructure includes automated sorting systems capable of handling bio-based materials, contamination removal technologies for mixed waste streams, and economic mechanisms that internalize environmental costs to make recycling financially viable without subsidies.

Consumer behaviour patterns significantly influence packaging sustainability outcomes through purchasing decisions, usage practices, and disposal behaviours that can either amplify or negate environmental design intentions (Lindh et al., 2016). Research indicates that 65-75% of consumers express willingness to pay premiums for sustainable packaging, yet actual purchasing behaviour shows price sensitivity that limits premium acceptance to 5-15% above conventional alternatives (Nielsen, 2018). Consumer behaviour failures include the intention-action gap, where environmental concern does not translate to purchasing behaviour, incorrect disposal practices that contaminate recycling streams with error rates of 30-50%, and preference for convenience over sustainability, leading to rejection of reusable packaging systems that require behaviour change (Davenport et al., 2012). Disadvantages of relying on consumer participation include the need for extensive education programs costing $0.05-0.15 per package, variable compliance rates across demographic groups ranging from 20-80%, and the inability to guarantee proper end-of-life treatment regardless of package design optimization (Martinho et al., 2015). Missing elements include behavioural psychology integration in packaging design, real-time feedback systems that reinforce sustainable behaviours and incentive structures that align consumer convenience with environmental objectives.

Regulatory frameworks increasingly drive packaging sustainability through extended producer responsibility legislation, recycled content mandates, and single-use plastic restrictions that create compliance requirements while potentially limiting design flexibility and innovation opportunities (OECD, 2021). European Union packaging directives require 65% recycling rates by 2025 and mandate recycled content minimums of 25% for plastic bottles by 2025, increasing to 30% by 2030, though achievement depends on recycling infrastructure development and material quality standards (European Commission, 2019). Regulatory failures include fragmented standards across jurisdictions creating compliance costs of 10-20% of packaging budgets, enforcement mechanisms that lack technical feasibility assessment leading to unachievable targets, and time lag between regulation implementation and infrastructure development creating 5-10 year gaps (Packaging Europe, 2020). Missing regulatory elements include global harmonization of sustainability standards, technical feasibility requirements in regulation development, and dynamic adjustment mechanisms that account for technological and infrastructure constraints.

Life cycle assessment methodologies provide quantitative frameworks for evaluating packaging sustainability performance across multiple environmental impact categories including carbon footprint, water consumption, land use, and toxicity potential, though methodological limitations and data uncertainties can significantly influence results and decision-making (Guinée et al., 2011). Comparative LCA studies often reveal counterintuitive results where lightweight packaging with higher material environmental impact achieves superior overall sustainability performance through transportation productivity gains, while sustainable material substitutions may increase other impact categories such as eutrophication potential or land use requirements (Hellweg & Milà i Canals, 2014). LCA methodology failures include incomplete system boundary definitions that exclude 20-40% of relevant impacts, data quality issues with uncertainty ranges of ±50-100% for many impact categories, and temporal assumptions that do not account for technology evolution over product lifecycles (Christensen et al., 2009). Disadvantages include high assessment costs of $50,000-200,000 per comprehensive study, methodological complexity requiring specialized expertise, and result variability that creates decision-making uncertainty (Curran, 2012). Missing LCA elements include real-time data integration, dynamic modelling of changing energy and transportation systems, and standardised methodologies for emerging materials and technologies.

Innovation pathways for SPD increasingly focus on system-level solutions that integrate material optimisation, functional enhancement, and circular economy principles while leveraging digital technologies for supply chain optimisation and consumer engagement (Licciardello, 2017). Emerging approaches include active packaging systems that extend product shelf life through oxygen scavenging, moisture control, and antimicrobial action, potentially reducing food waste by 15-30% while using higher-impact packaging materials that achieve net environmental benefits through food preservation (Realini & Marcos, 2014). Innovation failures include the valley of death between laboratory research and commercial implementation, where 70-80% of sustainable packaging innovations never reach market due to scaling challenges, insufficient investment in pilot programs, and risk-averse corporate procurement practices (Pisano, 2015). Technology disadvantages include high development costs requiring 5-10 years and $10-50 million investment per innovation, performance unpredictability in real-world applications, and integration challenges with existing manufacturing and supply chain systems (Rogers, 2003). Missing innovation elements include systematic risk assessment frameworks for new technologies, public-private partnership models for scaling sustainable innovations, and open-source platforms for sharing development costs and knowledge across industry participants.

Economic viability challenges represent perhaps the most fundamental barrier to sustainable packaging adoption, where cost premiums, performance trade-offs, and market structure limitations create systematic disadvantages for environmental solutions (Porter & van der Linde, 1995). Sustainable packaging typically requires 150-400% higher initial investment in materials and manufacturing, 3-7 year payback periods that exceed typical business planning horizons, and ongoing operational complexity that increases management costs by 20-35% (Hottle et al., 2013). Market failures include the inability to capture environmental benefits in pricing, first-mover disadvantages where early adopters bear development costs without competitive advantages, and scale economy barriers where sustainable alternatives remain uneconomical below minimum production volumes of 10-50 million units annually (Rothenberg, 2007). Missing economic elements include environmental cost accounting systems, market mechanisms that reward sustainability performance and risk-sharing instruments that reduce adoption barriers for innovative solutions. These economic realities explain why sustainable packaging remains confined to premium market segments and regulatory-driven applications rather than achieving the broad market penetration necessary for meaningful environmental impact at global scale.

2.2.8 Existing Frameworks

There are a few existing frameworks that are available in literature for SPD, which establish a foundation for systemically addressing modern environmental and economic problems faced by the packaging sector. This framework includes circular material flow management principles to avoid waste via regenerative design, life cycle optimisation techniques for quantitative environmental impact analysis, and systems integration principles that orchestrate multi-stakeholder cooperation through value chains. Eco-effectiveness via innovation driving for integrating sustainable design into the system design by bringing materials strategically to the table and optimising for material health, and business model innovation components that generate value by following circular economy principles in Packaging-as-a-Service and take-back programs. The structured frameworks integrates special approaches - Design for Circular Packaging (DfCP) guidelines, Cradle-to-Cradle certification criteria, and linkage of Sustainable Development Goals. Methodology tools include Material Flow Analysis, Life Cycle Assessment software, digital tracing systems and Stakeholder mapping frameworks; however, implementation is limited due to complexity management, resource intensity levels and technology discrepancies. This holistic approach offers researchers and practitioners rational models and the fitting tools for creating sustainable packaging, which in turn will aid in the transition from a make-use-dispose economy to a circular one in packaging. Table 2 & 3 shows an overview of the existing framework for SPD.

Table 2.2: Existing Frameworks

Framework Component	**Core Principles**	**Key Components**	**Methodological Tools**	**Limitations**	**References**
Circular Material Flow Management	• Eliminate waste through regenerative design • Optimize material value retention • Decouple environmental impact from economic growth • Integrate biological and	• Mono-material design for simplified recycling • Bio-based alternatives (PLA, PHA, cellulose) • Recycled content integration • Material compatibility assessment •	• Material Flow Analysis (MFA) • Ellen MacArthur Foundation toolkit • Circularity indicators • Digital tracking systems • Blockchain for traceability	• Implementation complexity • Infrastructure requirements • Initial capital investment • Consumer behavior dependence • Technology gaps	Ellen MacArthur Foundation (2023) Lau et al. (2024) Wang et al. (2022)

	technical nutrient cycles	Contamination prevention design			
Life Cycle Optimization	• Cradle-to-grave environmental accountability • Quantitative impact minimization • Functional preservation with environmental enhancement • Temporal and spatial impact consideration	• Life Cycle Assessment integration • Carbon and water footprint quantification • Material flow analysis • Social impact assessment • Environmental performance metrics	• SimaPro/GaBi software • ISO 14040/14044 standards • Product Environmental Footprint (PEF) • Environmental Product Declaration (EPD) • ReCiPe impact method	• Data intensive requirements • Methodological complexity • Time and cost consuming • Uncertainty in results • Expert knowledge required	Sastre et al. (2022) Yokokawa et al. (2021) ISO 14040:2006
Systems Integration & Stakeholder Collaboration	• Holistic value chain coordination • Multi-dimensional sustainability (Triple Bottom Line) • Dynamic capability development • Feedback loop optimization	• Cross-industry collaboration platforms • Multi-stakeholder coordination • Supply chain integration • Consumer engagement systems • Policy alignment mechanisms	• Systems mapping tools • Stakeholder analysis frameworks • Causal loop diagrams • Impact assessment models • Scenario planning tools	• Complexity management difficulty • Analysis time requirements • Implementation coordination challenges • Resource intensity • Change resistance	Meadows (2008) Senge (1990) Checkland (1981)

Innovation-Driven Eco-Effectiveness	• Proactive environmental design integration • Material health and safety optimization • Renewable resource utilization • Technology-enabled transparency	• Design for disassembly • Modular design systems • Durability enhancement • Digital product passports • IoT monitoring systems	• C2C certification protocols • Material health assessment • Eco-design guidelines • Digital platforms • Performance testing protocols	• Performance trade-off challenges • Cost implication concerns • Technical constraint limitations • Market acceptance variability • Technology availability	European Commission (2021) Azzi et al. (2012) Santi et al. (2023)
Business Model Innovation	• Circular economy business model development • Value creation through sustainability • Service-oriented approaches • Collaborative consumption facilitation	• Packaging-as-a-Service (PaaS) • Take-back and refill programs • Deposit and return systems • Material leasing arrangements • Revenue from secondary streams	• Circular business model canvas • Value creation frameworks • Cost-benefit analysis tools • Financial modeling software • Partnership facilitation platforms	• Resource dependency risks • Capability development gaps • Market acceptance uncertainty • Investment requirements • Competitive response threats	Lau et al. (2024) Hart & Dowell (2011) Barney (1991)
Design for Circular Packaging (DfCP)	• Material selection optimization for circularity • Waste elimination	• Circular material specification • Design for disassembly principles •	• DfCP framework toolkit • Circularity assessment matrix •	• Limited standardization • Context dependency issues • Complexity	Zhang et al. (2023) Wang et al. (2022) Morashti et al. (2022)

	through design • Circularity assessment integration • End-of-life planning from design stage	Reuse optimization strategies • End-of-life scenario planning • Multi-material compatibility	Material compatibility checker • Design rule verification • Performance testing protocols	management challenges • Industry acceptance variability • Measurement consistency	
Cradle-to-Cradle (C2C)	• Eliminate waste concept entirely • Continuous material cycles • Eco-effectiveness over efficiency • Material health optimization • Renewable energy utilization	• Biodegradable packaging development • Infinitely recyclable material design • Non-toxic formulation requirements • Renewable energy sourcing • Compostable packaging solutions	• C2C certification protocol • Material health assessment • Renewable energy audits • Water stewardship evaluation • Quality score measurement	• Implementation challenge complexity • Limited material availability • Cost consideration implications • Technology requirement gaps • Scale-up difficulties	McDonough & Braungart (2002) C2C Products Innovation Institute (2021)
Sustainable Development Goals (SDG) Integration	• Triple bottom line integration • Global sustainability targets alignment • Integrated development approach •	• Responsible consumption patterns (SDG 12) • Climate action through packaging (SDG 13) • Innovation in sustainable	• SDG indicator framework • Impact measurement tools • Progress tracking systems • Partnership facilitation	• General guideline nature • Implementation gap challenges • Measurement complexity • Resource requirement	UN SDGs (2015) Lau et al. (2024) Sastre et al. (2022)

	Universal applicability • Partnership-based implementation	materials (SDG 9) • Partnership development (SDG 17) • Marine ecosystem protection (SDG 14)	platforms • Policy alignment mechanisms	intensity • Progress tracking challenges	

The implementation of sustainable packaging faces numerous technical challenges. The existing consumer research mostly examines generic consumer behaviours such as purchase intentions and willingness to pay for sustainable packaging; other pivotal aspects (e.g., consumer involvement in packaging design and stakeholder integration) lack empirical investigations (Lau et al., 2024). This research gap limits understanding of practical implementation requirements.

Performance limitations of sustainable materials often create barriers to adoption. Many bio-based and biodegradable materials exhibit inferior barrier properties, mechanical strength, or durability compared to conventional alternatives. These limitations require innovative approaches to material development and design optimization.

Table 2.3: Critical Success Factors:

Factor	Importance Level	Key Requirements
Leadership Commitment	High	• Executive sponsorship • Resource allocation • Long-term vision
Stakeholder Engagement	High	• Multi-party collaboration • Shared value creation • Trust building
Technology Integration	Medium-High	• Digital infrastructure • Interoperability • Scalability
Regulatory Support	Medium-High	• Policy alignment • Incentive structures • Standard harmonization
Consumer Adoption	Medium	• Education programs • Convenience factors • Value demonstration

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2.3 RESEARCH GAPS

A comprehensive systematic literature review reveals that packaging is a fundamental requirement across all product categories, whether tangible goods, food products, pharmaceuticals, or other consumer items. To solve the multi-dimensional aspects of sustainable packaging problems and unique systematic knowledge generation, the research gaps identified have been systematically categorized into five major groups as listed furthers:

Objective_01: Identification of the Attributes of Sustainable Packaging Design

Design attributes form the core of sustainable packaging identification, including the overall performance of the packaging, for example, durability, availability, etc. Design attributes will help in developing any packaging system that doesn't hurt people's health while also achieving environmental aims. Another important group of attributes is economic viability, which includes cost-effectiveness, market accessibility, and scalability potential that make it possible for sustainable solutions to be used by the masses.

Functional performance attributes make sure that sustainable packaging keeps protecting products, extending their shelf life, and making them easier for consumers to use without losing any of the environmental benefits. To keep food safe and to cut down on food waste, barrier characteristics against moisture, oxygen, and toxins must be maintained. The Sustainable design of packaging should have high durability, survive logistical stress, and user-centric.

The process of identifying attributes of sustainable packing includes a holistic literature study and analysis, discussion with experts, analysis industrial involvement, and a thorough customer survey to generate a comprehensive understanding the attributes of SPD to – influence positive performance and market compatibility. The framework made up of these attributes will thus enable assessment of contemporary packaging solutions and lead to eco-friendly interventions that are both good at performance and ensure environmental sustainability.

Objective_02: Development of a Framework to Develop Sustainable Packaging

The purpose of the framework is to bring out a balance between environmental and performance and its competing demands that exist across the lifespan of SPD. Stakeholder integration processes guarantee that the framework incorporates the perspectives of suppliers, manufacturers, retailers, consumers, and waste management systems. The collaborative approach identified has the potential to address implementation challenges early in the design phase and creates solutions that are effective across the production chain using design thinking. This framework enables stakeholders to assess the advantages of SPD and EOL practices. This resultant framework has been created certainly to be iterative and industry-friendly.

The conception of the framework starts with a comprehensive evaluation phase that takes product characteristics, sustainability and market contexts – into consideration. The beginning phase is to understand the type of protection needed, how long the attribute has to last, what types of layers are needed, and mechanical constraints. This is an important attribute of the framework because it enables decisions based on functionality and conventionality – how they may work together and their impact on environment. The designed framework has an assessment matrix, which rates materials based on various attributes of sustainability, like the Protection, reusability, affordability, energy efficiency etc.

An important feature of the designed framework needs optimisation of SPDs which provides guidelines to use sufficient materials while retaining high level of functionality. This takes into account the design structure that defines the strength-to-weight ratio by eliminating non-essential elements and hence making manufacturing easier. The decision making for designers and manufacturers is enhanced by employing the SPD framework which emerges out of the attributes selected in the first phase of this research.

Objective_03: Study of the Effectiveness of Sustainable Packaging Design Framework

The study process involved detailed process where respondents assessed a set of pre-verified SPD examples to include established sustainability terms/attributes. These examples were chosen to include versatile product categories, kinds of materials and their SPD approaches, which laid a solid foundation to check suitability of the newly designed SPD framework across contextual applications. Each example incorporated product information in detail, specifications of different materials, and reported sustainability claims to ensure respondents had enough knowledge for precise evaluation.

The basic validation method correlated attributes of the previously generated framework with respect to noticeable parameters in the SPD examples given. The respondents were given reference of entire framework, also descriptions of attributes in detail, criteria for sustainability and parameters of evaluation. This method allowed participants to categorically decide which elements of the framework were present or absent in the SPD examples thus bridging the gap between academic research and commercial applications.

The validation procedure also involved a qualitative data collection mechanism wherein respondents suggested additional attributes, which were present in the examples given but not reflecting in the original SPD framework. This open-ended element of the validation procedure made the exercise more comprehensive rather than a narrow approach of mere confirmation.

Quantitative analysis of the study responses gave a validation matrix to measure frequency of identified attribute, consistency of framework application and the correlation among the elements of the SPD framework. This further enhanced the comprehensive approach to validate the SPD framework through this research.

2.4 Summary

The present methods and procedures in sustainable packaging systems (SPS) and sustainable packaging design (SPD) show major performance limitations, in short of basic functionality attributes essential for holistic sustainability execution. Recent studies focus on isolated factors of sustainability rather than designing holistic solutions. Research that is inter-disciplinary and multi-disciplinary, with most of them evaluating several packaging issues in isolation, creates fundamental knowledge lacunas that majorly reduce practical applications and industry adoption. This division results in interventions that address isolated sustainability dimensions while neglecting the interrelated nature of environmental, economic, and social factor domains.

Researchers, academicians and industries need to study and design fundamental creative and functional attributes that may essentially enhance the performance of SPD interventions. Present methods are deficient in holistic procedures necessary to address the lacuna between theoretical sustainability guidelines and practical packaging contexts. With a significant increase in consumer demand, with 90% of consumers choosing brands with sustainable packaging, present experimentation and implementation have not evidently evolved to support holistic frameworks capable of simultaneously addressing environmental impact reduction, cost-effectiveness, and user accessibility. The absence of unified design principles that consider the full spectrum of sustainability requirements continues to limit the effectiveness and scalability of sustainable packaging innovations, highlighting an urgent industry requirement for practical solutions that can achieve widespread adoption and seamless implementation.

CHAPTER 3

Identification of the Attributes of Sustainable Packaging Design

The current packaging industry is under pressure to meet functional and environmental requirements like never before. With increasing global environmental awareness, the role of packaging has developed beyond mere protection and appearance to become key to marketing, corporate identity and business strategies reflecting environmental concerns. Although previous literature investigated holistic approaches for SPD(Svanes et al., 2010), what exactly it is about the design, among the others, that affects consumer preferences and satisfaction with sustainable packaging solutions has largely yet to be explored. The change in paradigm towards SPD requires systematic insight in consumer preferences and in quality aspects that deliver satisfaction, while offering a connection with the environment yet current literature lacks empirical frameworks for identifying and prioritising these attributes based on consumer-perceived importance.

Overall, identifying key design attributes is a minimum requirement for building efficient and performance-based SPD. Despite considerable work in this direction, very little has been done to develop a system of criteria for SPD: "Most work has focused on functional and environmental concerns but has not been systematically premised on consumers' perceptions of attribute salience" (Svanes et al., 2010). Current decision-making in the design of packaging is often made without knowledge of which attributes are most important for consumer satisfaction and perceived sustainability value. The development of packaging solutions that may effectively strike a balance between consumer acceptance, commercial profitability, and environmental responsibility is severely hampered by this information gap.

Traditional packaging design methods frequently place more emphasis on practical usage, like distribution, ease of use, and as a marketing tool, than they do on sustainability considerations (Löfgren & Witell, 2005). Nevertheless, today's consumers seek packaging solutions that are good for the environment and match quality criteria that have already been set. It is hard to make packaging that is good for the environment and works well, therefore we need to use systematic ways to find, rate, and rank design attributes based on how important they are for better performance, less harm to the environment, and happier customers.

This chapter addresses how crucial it is to have a realistic understanding of the package attributes that have the most significant impact on the degree to which consumers adopt sustainable packaging alternatives. This study gives a complete guide on how to use the Kano model to find and group sustainable package design attributes. Understanding the consumer's point of view, as opposed to past holistic approaches that mostly focused on technical design issues (Svanes et al., 2010). This study gives basic information for generating SPD solutions that make customers the happiest by carefully figuring out and ranking design attributes to help designers make better choices.

3.1 Theoretical Foundation

3.1.1 Sustainable Packaging Design Paradigm

The conceptual framework includes sustainability principles at every stage of the design process, from choosing materials to managing the end of life. This goes beyond traditional end-of-pipe solutions. With this change in thinking, we need to use systematic methods to uncover and rank design attributes that meet both environmental aims and customer needs. A review of the literature found that there is a lack of holistic strategy that considers social, environmental, and economic concerns at every stage of the packaging lifecycle. This is what is meant by "sustainable packaging design" (Singhal & Malik, 2018).

To make packaging systems work better, we need to make a big move toward circular economy concepts. These principles stress the need of using resources wisely and reducing waste through tactics like reuse, recycling, and regeneration. Life cycle thinking, which looks at the environmental effects of raw material extraction all the way to end-of-life management; circular economy principles, which design out waste and keep materials in productive use; and stakeholder theory, which takes into account the opinions of manufacturers, consumers, waste managers, and regulatory agencies, are all part of the SPD framework. Designers can use this all-encompassing approach to find ways to make the packaging better by enhancing its performance. Packaging Industry/Designers can use these attributes for better decision-making based on data that have less of an effect on the environment and make sure that the packaging solutions are socially, economically, and environmentally acceptable all the way through the value chain.

When developing eco-friendly packaging, stakeholder theory states it is important to think about what different groups of stakeholders, such as manufacturers, merchants, waste management systems, consumers, and environmental regulators, need and want. When we put these two contradictory theoretical frameworks together, the design optimisation problem gets even harder. An intensive process to identify & understand design attributes shall be most important to each stakeholder group and how they relate to each other.

3.1.2 Attribute Identification in Packaging Design Context

It is necessary to conduct a thorough investigation into a number of different domains in order to determine design attributes. These groupings are inclusive of aesthetic characteristics, economic prowess, environmental effects, and sociological outcomes. When it comes to packaging, the functional performance criteria comprise all of the conventional requirements, such as communication, usability, containment, and safety. Metrics such as the amount of carbon dioxide that is emitted, the amount of garbage that is produced, and the degree to which recycling is feasible are utilized in the process of evaluating the influence on the environment.

While pursuing economics, it is essential to study various financial aspects, such as total price of production, the enhancement of supply chains, and the total costs of disposability involved. Involving community members, making design culturally significant, and following inclusive design methods that warrant accessibility for all types of users may include few characteristics of various social structures. Aesthetic components include – graphics, visuals, brand message, emotional associations in the mind of users with respect to the brand, and so on. These components contribute to the adoption of a brand in the market and the purchasing behaviour of consumers. When it comes to improving packaging in a methodical manner, the first step that is essential is the identification of design elements. The intuitive judgment of a designer, market research, and competitive analysis are ways occasionally employed to identify critical characteristics. These may not encompass all the aspects that affect customer satisfaction and the operational efficacy of the environment.

3.1.3 Kano Model Application in Quality Attribute Classification

The Kano model, developed by Noriaki Kano, provides a theoretical framework for understanding the relationship between product attributes and customer satisfaction (Kano et al., 1984). The model categorises quality attributes into five distinct classifications: Must-be Quality (M), One-dimensional Quality (O), Attractive Quality (A), Indifferent Quality (I), and Reverse Quality (R). Above mentioned classification system enables systematic prioritization of design attributes based on their impact on consumer satisfaction and perceived value.

Must-be Quality attributes are quality attributes as essential requirements that reflect their basic expectations. Significant discontent arises when these qualities are lacking, but their existence only serves to avoid dissatisfaction rather than fostering positive satisfaction. Customer satisfaction and attribute performance have a linear correlation, as demonstrated by one-dimensional quality characteristics, where higher satisfaction levels are directly correlated with improved performance.

Attractive Quality attributes represent to create customer joy through attributes that go beyond fundamental expectations are represented by quality attributes. Even when customers do not specifically expect them, these qualities have the capacity to produce good satisfaction. The presence or performance level of indifferent quality qualities has no effect on customer satisfaction. When present, reverse quality attributes actually lower happiness, indicating that they should be avoided when making design choices.

The application of the Kano model in packaging design. Background. The application of Kano modelling for packaging design was found to be very effective in determining consumer needs and balancing between design decision alternatives (Dash, 2021). The model's value is to distinguish between fundamental expectations, performance drivers and delight factors, giving actionable direction for design optimisation. Nevertheless, to apply the Kano model successfully, the relevant attributes that need to be classified cannot be correctly assessed in a superficial manner.

3.2 Methodology

3.2.1 Research Design and Framework

Through expert validation and consumer preference analysis, this study uses a thorough multi-phase technique to systematically discover, improve, and categorize SPD attributes. Seven successive phases make up the study framework, each of which builds on the one before it to guarantee methodological rigor and thorough attribute identification. Brainstorming sessions, literature validation, language refinement, Pareto analysis, Delphi expert consensus, and Kano model classification are just a few of the analytical techniques that are integrated into the methodology. The period was 2-6 weeks. The week-wise timeline was carefully planned for carrying out a detailed study while keeping up with the research pace.

The methodical sequence of the stages led to creating attributes and their definitions improved with time and making validation successful for making reliable final classification framework.

3.2.2 Phase 1: Comprehensive Attribute Brainstorming

The foremost step of the research was to conduct a rigorous brainstorming to generate a huge set of attributes of packaging design attributes, which have high environmental impact. 341 comprehensive attributes were chosen in the initial phase. Then a systematic literature review SLR was carried out from a vast source of literature available online and in print to verify these attributes. SLR sources were journals, market reviews, business reviews, brand catalogues and other contemporary publications. A broad validation method led to systematic updating of attribute inventory and finally 120 unique characteristics were supported and chosen.

3.2.3 Phase 2: Literature Review Mapping and Validation

A holistic mapping of SLR was done in the following phase, which took 6 weeks by ensuring that attributes were important and relevant. For validation, 402 dynamic sources of reliable publications were referred to ensure that a large database was covered. Out of 341 characteristic traits, the researchers arrowed down to 160 characteristic traits after validation and comprehensive evaluation via 402 SLR sources.

3.2.4 Phase 3: Attribute Refinement for Survey Implementation

In the third phase, 340 characteristic traits chosen were related to real life implementation for SPD. A refinement was undertaken to reduce these attributes so that they may be taken up for experiments with consumers. A categorical clarity evaluation was one of the six specific basis that were employed in the refining process. The preliminary assessment was done with specific review panels comprising experts only. Hence, it was possible to retain 160 characteristics that were important and specific. The process of refining is centred on the creation of attributes through the utilisation of common language descriptors such as action-oriented verbs, descriptive adjectives, and phrase structures that are simple to comprehend. Without sacrificing the technical precision and comprehensive range of dimensions that are essential for the development of ideas for SPD, this technique ensured that respondents understood the concepts as well as they possibly could.

Taxonomy of Word Study and Semantic Clustering

Following the completion of the initial round of refinement, a taxonomy classification framework was established specifically for the purpose of organizing and categorizing the retained attributes according to the conceptual domains and semantic linkages that they possessed. The framework allowed to keep cluster groups coherent and varied from other semantic categories. For example, the taxonomic cluster group "aesthetics" included a wide variety of visually oriented adjectives, including statements like "visual appeal," "aesthetically pleasing," "chromatic properties," "morphological characteristics," "tactile qualities," and associated perceptual aspects.

Final Attribute Selection and Survey Optimisation

After application of the above mentioned refinement methods to a large number of attributes, 18 attributes were shortlisted. This selection was significant because the customer's response also became clearer and led to more statistical significant data upon analysis. These attributes were holistic, semantically and environmentally conscious.

3.2.5 Phase 4: Attribute Definition and Clarification

For each SPD attribute, a definition was defined to reduce variance and improve consistency in data collection from participants. Easy, clear and understandable language was used for participants'' ease. For example, the workable definition of the term "biodegradable" was "materials capable of natural decomposition through biological processes without environmental detriment, including composting and microbial degradation pathways," similarly the definition of "recyclable" was "materials possessing the capacity for reprocessing and subsequent utilization in manufacturing cycles." In addition, terms/synonyms were provided fir additional clarity and understanding. For instance, the terms "resilient," "robust," "long-lasting," and "structurally sound" were added to associate with the term "durable" to establish comprehensive semantic frameworks that accentuate attribute identity and feedback accuracy.

This process led to a string foundation for valid data collection with specific and relevant attributes. The definitions have been depicted in Table 3.1.

Table 3.1: Definition of shortlisted attributes

S.No	Attribute	Definition	Other parameters
1	Accessibility	In the state of being always available	Accessible Availability Attainability Acquirable Within reach Easy to reach
2	Adaptable	Referring the ability of an identity to adapt it-self efficiently and fast to changed circumstances.	Adjustable Convertible Flexible Modifiable Scalability Compatible
3	Aesthetic	Being interested in how something looks, feels and seems pleasing to the senses and especially to the sight	Pleasing Beautiful Attractive Eye catchy High visibility Appreciable Desirable

			Use of Colors, form, textures or other elements of design
4	Affordable	The state of being cost-effective enough for mass to be able to buy.	Cost-effective Inexpensive Low-cost Cost accepted by mass
5	Contextual	A diversified solution that is convenient to use, generous and impactful in most situations in various demographic situations	Achievable Awareness Convenient Generous Impactful Adequate Feasible Dependable Loyal
6	Durable	Made up of good quality material that can last for long	Material Strong Sturdy Resilient Long-lasting, Robust

7	Emotional	Consumers experience a feeling or attachment with a product.	Affectionate Caring Cultural Nostalgic Attachment Belongingness
8	Sustainable	Created to develop eco-friendly solutions that address immediate needs while integrating a long-term outlook that "Returns to its roots". Not or less harmful to the environment.	Biodegradable Sustainable development Natural Eco-friendly Recyclable Minimal damage Eco-system Green Non-polluting Low carbon-footprint Energy-Efficient
9	Ergonomic	Product to improve people's working/operating conditions and help them work more effortlessly.	Easy to use User friendly Flexibility in use

			Low pain points Used by mass
10	Functional	Relating to the way in which product can serve for longer time than intended, or relating to how useful it is.	Useful Easy to use Re-usability After-use Shelf-life
11	Inclusive	Should be easily used by as many people as possible of all backgrounds and abilities	Comprehensive For all
12	Informative	A component of design that uses visuals, text or content that strategically convey a message or express information.	Branding Readability Promotional Communicative Information
13	Intuitive	With an intuitively designed product, customers will understand how to use it without much effort.	Understandable Perceived value Perceived information Status
14	Materials	A substance that can be used for making a sustainable solution	Easily available Robust Long lasting

			Procurable Eco-friendly Production – friendly transportable Durable Hygienic Re-growing
15	Portability	Should provide a ease factor in transportation / distribution of packaging or its material	Light weight Cost effective Manageable Convenient Compact
16	Protection	The state of being shielded from harm and being hygienic.	Shelf-life Hygienic Harm-less Low / Zero contamination
17	Reusable	Reusable for multiple applications. Whether starting fresh or repurposing the packaging after initial use.	Recyclable Repurposable Renewable Reutilizable Repeatable Recoverable Reclaimed

			Salvageable Refillable
18	Social		Behavioural Attachment Awareness Diverse Responsible Empowering Collaborative Social Values & Responsibilities

The 18 finalized sustainable package design attributes were shortlisted and presented to the target respondents for a comprehensive survey as part of a systematic taxonomic refinement process. In order to guarantee the validity and reliability of results pertaining to consumer preferences and perceptions of sustainable packaging qualities, the survey deployment process includes careful consideration of sample methods, questionnaire design, and data gathering protocols. Standardized descriptive language and operational definitions developed during the previous refinement processes were used to present each of the 18 traits to survey participants, allowing for uniform interpretation and assessment of each responder. In order to capture complex consumer sentiments on each SPD attribute, the survey instrument included suitable scaling mechanisms and response formats. This made it easier to do statistical analysis and preference ranking processes later on.

3.2.6 Phase 5: Pilot Test - Pareto Analysis for Attribute Prioritization

The 80-20 rule approach was applied in the pilot test's "Pareto text" phase to determine the essential few characteristics that have the biggest impact on the efficacy of sustainable package design. Initially, ten design attributes were proposed in order to comprehend the viewpoint of experts and users in survey at Appendix-I. The purpose of this pilot test was to determine whether the designers found these traits to be logical. In order to identify important traits that are either directly or indirectly related to SPD, thirty-five design professionals took part in a cumulative frequency distribution analysis. According to the Pareto Principle, sometimes referred to as the 80/20 rule, a basic pattern of unequal distribution seen in many different fields is that for many outcomes, about 80% of consequences result from 20% of causes (Pareto, 1906). "The Pareto analysis results revealed a clear hierarchical distribution of attribute importance. **Accessible** ranked highest with 35 occurrences (21.6%), followed by **Affordable** with 28 occurrences (17.3%), **Energy Efficient** with 20 occurrences (12.4%), **Protection** with 18 occurrences (11.1%), **Durable** with 15 occurrences (9.3%), and **Reusable** with 12 occurrences (7.4%). The cumulative impact of these top six attributes reached 79.0% of total responses, demonstrating the concentrated importance of these key SPD characteristics.

Table 3.2: Pilot – Test results from Pareto analysis

S.No.	Attributes	Frequency	Cumulative Frequency	Percentage
1.	Accessible	35	35	21.60%
2.	Affordable	28	63	17.28%
3.	Energy Efficient	20	83	12.35%
4.	Protection	18	101	11.11%
5.	Durable	15	116	9.26%
6.	Reusable	12	128	7.41%
7.	Functional	10	138	6.17%
8.	Adaptable	10	148	6.17%
9.	Aesthetic	8	156	4.94%
10.	Informative	6	162	3.70%

The analysis confirmed the Pareto principle application as the top six attributes representing sixty per cent of the total attributes accounted for approximately seventy-nine per cent of the total impact, providing empirical foundation for focusing subsequent detailed investigation on the most impactful design characteristics. Table 3.2 shows the results of the pilot test.

3.2.7 Phase 6: Delphi Method Expert Selection and Validation

To guarantee an adequate foundation for the final Kano model study, the Delphi technique was used for four weeks to systematically choose experts and validate attributes. In order to get trustworthy expert consensus through iterative rounds of anonymous surveys, Norman Dalkey, Olaf Helmer, and Nicholas Researcher created the Delphi method, a methodical, organized communication methodology, at the RAND Corporation in the early 1950s. This method employs rigorous feedback collection from a panel of experts where data or knowledge on any subject is limited. Several rounds of feedback collection, anonymous data collection from experts and statistical tests are few of its attributes (Hsu & Sandford, 2007; Okoli & Pawlowski, 2004).

Anonymity of data collection and structured data collection ensured high-level consensus building removing hierarchical barriers. To qualify as experts, the subject had to have 7 years of working experience and exhibit strong design and packaging skills. An expert panel of 27 members was selected for the task as per academic credentials, superiority, knowledge, design portfolio and experience.

The 3 top groups of the Kano model were —must-have, uni-dimensional, and attractive attributes—were made by systematically summarising expert responses after evaluation. By adding empirical analysis and subject, expertise the method found a good framework for designing SPDs and received good support from experts in various fields.

3.2.8 Phase 7: Final Kano Model Survey Implementation

After generating attributes from Delhi method, Standard Kano model was applied for the last phase. Japanese professor Noriaki Kano and his fellows made the Kano Model, which is a theory for product design and development and its association with customer contentment, in the year 1984. It was first presented, as "Attractive Quality and Must-be Quality" (Kano et al., 1984). The model, which is based on Herzberg's Two-Factor Theory, shows that there is an asymmetric and non-linear relationship between consumer contentment and quality of product (Kano et al., 1984). Must-be requirements (basic expectations), One-dimensional requirements (performance characteristics that associate with contentment), Attractive essentials (attributes that are beyond expectations), Indifferent attributes (are neutral attributes), and Reverse attributes (attributes that cause dissatisfaction) are the 5 groups into which the framework ranges consumer choices (Kano et al., 1984). The questionnaire (Appendix - II) administered to respondents comprises a functional and dysfunctional set of questions to elicit emotional feedback from consumers (Berger et al., 1993). For the purpose of present research, the Kano model questionnaire had functional and dysfunctional questions for the 18 attributes, which led to systematic emotional evaluation of respondents. 5 options for each question was provided (Kano et al., 1984). The first question is also known as the functionality aspect question, enquires the consumer about how they might feel/respond if the product does meet their needs or worked as expected. In case, the product does not fulfil those requirements or performs poorly, the second question—also referred to as the dysfunctional question—indicates the answer. Depending on how customers react to both functional and dysfunctional questions, the criterion might alter.

The Functional arrangement of the question

Dysfunctional arrangement of the question

What if, the Sustainable Packaging is aesthetically pleasing?	1. I like it 2. Must be 3. I am neutral 4. I can live with it 5. I dislike it
What if the Sustainable Packaging is NOT aesthetically pleasing?	1. I like it 2. Must be 3. I am neutral 4. I can live with it 5. I dislike it

Figure 3.1: Kano model questionnaires

The Kano Model reveals that customer satisfaction operates on a non-linear relationship with product functionality, where different types of attributes impact satisfaction in fundamentally different ways (Kano et al., 1984). The model demonstrates three primary satisfaction dynamics:

Must-be Quality (Basic Requirements): These are attributes customers expect and take for granted. When implemented well, customers remain neutral, but when absent or poorly executed, customers experience significant dissatisfaction Kano Analysis: the Kano Model Explained - Qualtrics (Kano et al., 1984). For example, in a smartphone, basic calling functionality is expected—its presence does not delight customers, but its absence would cause major frustration.

One-dimensional Quality (Performance Attributes): These attributes demonstrate a directly proportional or positive correlation in-between investment and customer contentment — Customers are more satisfied as the product performs better. What is the Kano Model? Diagram, Analysis & Tutorial | ASQ (Berger et al., 1993). Battery life in smartphones exemplifies this category; longer battery life consistently increases satisfaction proportionally.

Attractive Quality (Delighters): These unexpected attributes exceed customer expectations and create excitement and delight. Their absence does not cause dissatisfaction, but their presence generates disproportionately positive responses and can differentiate products from competitors (Kano et al., 1984). Early smartphone attributes like fingerprint scanners or wireless charging were delighters that became performance attributes over time.

Reverse Attributes: Such attributes display different responses from different consumers; few may find them worth content, whereas others may not find them worth contentment. This ambivalence makes them divisive, as they may lead to contradictory reactions based on varying individual choices.

Indifferent Attributes: Such attributes create less impact on customer contentment, irrespective of their absence or presence. Consumers may not have vigorous preferences or responses to these attributes, and hence, they may not strongly influence the general perception of the service or product.

Kano Model states a relationship between a attribute's absence/presence and the customer's satisfaction level. Figure 3.2 shows the graphical representation of Kano model:

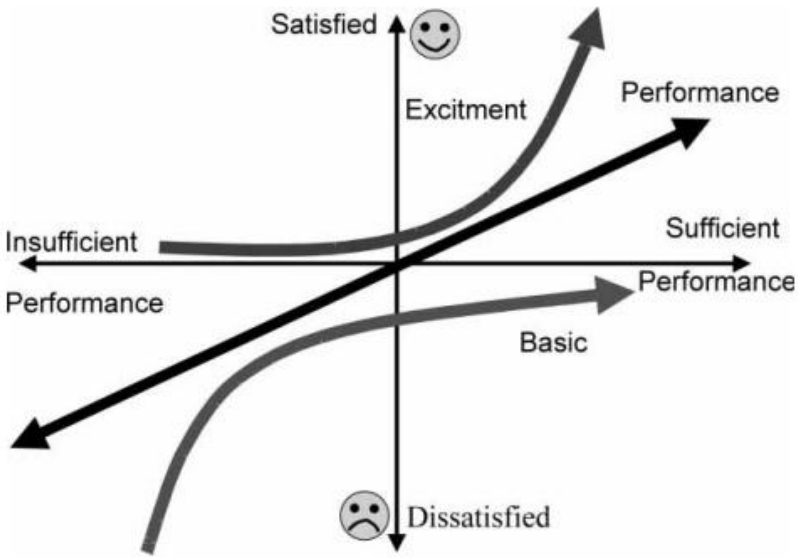

Figure 3.2: Kano model of excitement and basic quality (Matzler et al., 1996)

3.2.9 Statistical Analysis and Classification Methodology

The data was analysed utilising the Kano model through various methodologies to guarantee precision. Using standard methods, the authors calculated customer satisfaction and dissatisfaction coefficients. This led to a complete satisfaction index that ranges from -1 to +1. Answer consistency analysis was used to figure out the strength of each attribute, which allowed for prioritization within each area on a scale from 0 to 5.

The collected data was put through a full statistical analysis to classify attributes based on the well-known Kano model. Several analytical methods were used to make sure the data was reliable and valid. Standard formulas have been utilized to figure out the coefficients for customer happiness and dissatisfaction. Satisfaction index is found by adding sum all the answers that are uni-dimensional and attractive and then by dividing the sum by total number of responses that are attractive, uni-dimensional, has to be or must be or essential, and indifferent. Whereas, the dissatisfaction index is found by multiplying -1 by the sum of the one-dimensional and must-be answers divided by the same denominator. The total satisfaction index, which ranges from -1 to 1, is made up of the satisfaction and dissatisfaction indices added together. It gives a full picture of how each factor affects overall customer satisfaction. We measured the strength of attributes using statistical analysis of response consistency and coefficient magnitude. This let us put attributes in order of importance within each classification group, with confidence levels ranging from 0 to 5. Extensive statistical significance testing was performed by chi-square analysis to confirm the reliability of attribute classifications, with all nine final attributes exhibiting p-values below 0.01, signifying great statistical confidence in the classification outcomes.

A significant choice in the Kano model is which of the options to select for the study. The wording of the options, which were taken from (Berger et al. 1993), is comparable to the Japanese version proposed by (Kano et al. 1984). These selections may be "I like it that way," "It must be that way," "I am neutral," "I can live with it that way," and "I dislike it that way." The wording employed by (Berger et al. 1993) was determined to be the most appropriate by the authors for their analysis of Swedish customers. Although, the researchers mention that the statements or phrases must be according to the respondents being worked with. The respondent or the expert may choose one of the 5 choices given in Table 3.3 (Berger et al. 1993).

Table 3.3: Kano evaluation table

	Dysfunctional					
		I LIKE IT	**MUST BE**	**I AM NEUTRAL**	**I CAN LIVE WITH IT**	**I DISLIKE IT**
Functional	**I LIKE IT**	Questionable	Attractive	Attractive	Attractive	One-Dimensional
	MUST HAVE	Reverse	Indifferent	Indifferent	Indifferent	Must-have
	I AM NEUTRAL	Reverse	Indifferent	Indifferent	Indifferent	Must-have
	I CAN LIVE WITH IT	Reverse	Indifferent	Indifferent	Indifferent	Must-have
	I DISLIKE IT	Reverse	Reverse	Reverse	Reverse	Questionable

A = Attractive
O = One-Dimensional
M = Must have
I = Indifferent
R = Reverse
Q = Questionable

The categorisation of the attributes being studied have been done by using following three unique approaches:

a) **Frequency-based attribute classification method:** This method includes categorising individual term based on the feedback category with the maximum frequency (M, O, A, I, R, Q). The term is categorised as per the category that got the most number of feedback or selections.

b) **Comparison-based attribute classification method:** In this method, the qualities are classified by juxtaposing the overall frequencies of two response categories. If the aggregate frequency of categories M, O, and A exceeds that of I, R, and Q, the characteristic is categorised according to the maximum frequency within M, O, or A. If the cumulative frequency of I, R, and Q exceeds that of M, O, and A, the attribute is designated to the category with the highest frequency among I, R, or Q. If the sums are equal, the classification follows a priority order established by (Matzler et al. 1996), specifically M > O > A > I.

c) **Index-Based Attribute Classification Method:** This method introduces two indices: the Satisfaction Index (SI) and the Dissatisfaction Index (DI).

The Satisfaction Index is calculated as

$$SI = \frac{(A+O)}{(A+O+M+I)}$$

with a range from 0 to 1, while

The Dissatisfaction Index is determined as

$$DI = \frac{(M+O)}{(A+O+M+I)} * (-1)$$

, which ranges from -1 to 0.

A figure has been used to depict the Dissatisfaction and Satisfaction values for the twelve terms/attributes for an overall picture.

Several terms/attributes were classified using the Dissatisfaction and Satisfaction values, as shown in following Table 3.4.

Table 3.4: Value based term categorisation

Satisfaction Index (SI)	**Dissatisfaction Index (DI)**	**Classification**
<0.5	≥ 0.5	Must-be (M)
≥ 0.5	≥0.5	One-Dimensional (O)
≥ 0.5	< 0.5	Attractive (A)
< 0.5	< 0.5	Indifferent (I)

Total Strength (TS) and Category Strength (CS), initiated by Lee and Newcomb (1997), are two indices used to evaluate terms/attributes. Category Strength (CS) measures the variation in response values (%) between the maximum selection group and the second-most chosen group. For instance, if a terms' maximum response group is "O" with 40% of selections, and the second maximum is "A" with 30%, then CS would be measured as (40%-30%) which is equal to 10%. Whereas, Total Strength (TS), depicts the total % of selections in all the three groups: Must-be (M), One-dimensional (O), and Attractive (A). For instance, if terms' selections are 20% → M, 40% → O, and 10% → A, then Total Strength will be the addition of these %, which is 70 per cent.

3.3 Findings and Analysis

This quantitative experiment response, which have been outlined in Table 4, was carried out for categorisation 12 chosen terms (attributes) employing the Kano model. It depicts total responses which were from each group i.e. A= Attractive, O=One Dimension, M=Must have, I-Indifferent, R-Reverse and Q=Questionable. This categorisation was obtained by analysing CS (category strength), TS (total strength), and frequency of questionable feedback, in addition to statistical evaluation as depicted in Table 3.5.

Table 3.5: Characteristics and term groups (attributes) of packaging

S.No	**Attribute**	**A**	**O**	**M**	**I**	**R**	**Q**	**TOTAL**
1	**Accessible**	4	5	10	8	0	0	27
2	**Adaptable**	3	5	10	9	0	0	27
3	**Aesthetics**	11	7	6	3	0	0	27
4	**Affordable**	3	10	12	1	1	0	27
5	**Contextual**	2	3	4	17	1	0	27
6	**Durable**	4	6	9	8	0	0	27
8	**Functional**	3	9	8	7	0	0	27
9	**Informative**	11	7	6	3	0	0	27
10	**Portable**	4	7	6	10	0	0	27
11	**Protection**	2	10	12	2	1	0	27
12	**Reusable**	3	10	12	1	1	0	27

The findings of the experiment depict positive statistical significance, as 12 attributes obtained a p-value of less than 0.01, depicting promising correlations in the associations. The horizontal coordinate depicts the completion of these 12 attributes, whereas the vertical coordinate shows customer contentment; it also depicts the product to be retained in uni-dimensional group of terms, 'attractive' and 'must be' as depicted in Table 3.5. design attributes like Protection, Reusable, affordable, accessible and energy efficient turned to be the essential design characteristic terms for SPD. Functional and Durable were uni-dimensional. Table 3.6: Shows the consumer contentment and consumer discontentment coefficient for the terms along with their respective strength.

Table 3.6: Consumer satisfaction and consumer dissatisfaction coefficient

S.NO	**ATTRIBUTES**	**SI= (A+O) / (A+O+M+I)**	**DI= (O+M) / (A+O+M+I) x (-1)**	**Total Satisfaction Index**	**Attribute Strength**	
1	**Protection**	0.44	-0.81	-0.37	**4.81**	**MUST HAVE**
2	**Reusable**	0.48	-0.81	-0.33	**4.59**	
3	**Affordable**	0.48	-0.81	-0.33	**4.66**	
4	**Adaptable**	0.29	-0.55	-0.26	**4.33**	
5	**Accessible**	0.33	-0.55	-0.22	**4.23**	
6	**Durable**	0.36	-0.55	-0.19	**4.26**	**ONE-DIMENSIONAL**
7	**Functional**	0.36	-0.55	-0.19	**3.74**	
8	**Aesthetics**	0.66	-0.48	0.18	**3.59**	**Attractive**
9	**Informative**	0.66	-0.48	0.18	**3.41**	

In addition, the horizontal coordinate in the figure 3.3 shows the degree to which the quality terms of the product are satisfied, giving a calculation of how well each term is addressed in the characteristics of the product. Whereas, the vertical coordinate depicts consumer contentment, showing the level of satisfaction of the customers with respect to the product attributes. The 2- D: two-dimensional framework enables researchers to comprehend both the product's adherence to certain quality standards and the correlation of those standards with consumer perceptions and satisfaction. Figure 3.3: Showing the Analysis of the Kano model of SPD attributes.

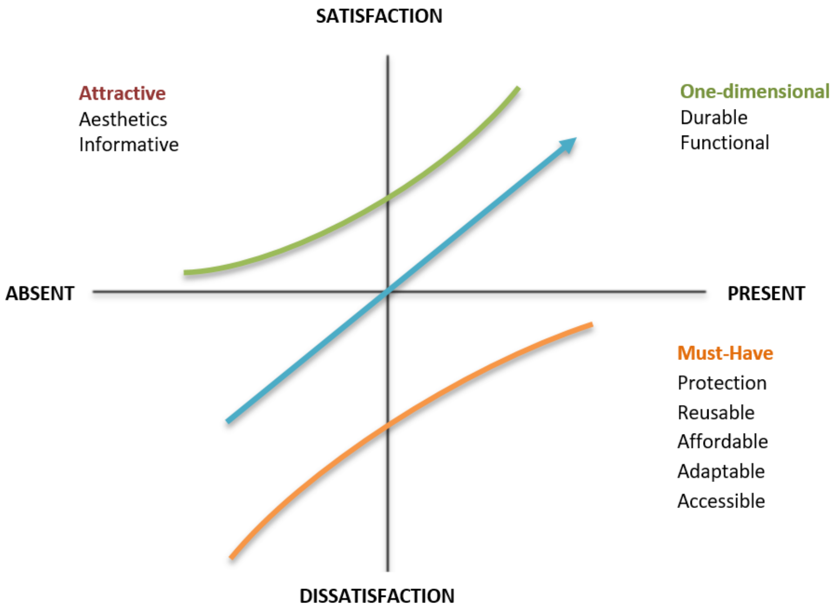

Figure 3.3: Analysis of the Kano model for SPD attributes

3.3.1 Comprehensive Attribute Classification Results

The empirical methodology effectively categorized all 09 identified sustainable package design attributes into specific Kano categories, demonstrating statistically significant connections for each attribute with p-values consistently under 0.01. The elevated statistical significance demonstrates strong confidence in the observed associations and confirms the trustworthiness of the categorization system. The allocation of characteristics within Kano categories reveals distinct variations in consumer perceptions of sustainable packaging aspects. The classification results furnish empirical information regarding the relative significance of various design elements and provide practical assistance for prioritising design decisions in sustainable packaging creation.

3.3.2 Must-be Quality Attributes: Foundation Requirements

Five attributes emerged as Must-be Quality characteristics, representing fundamental consumer expectations for sustainable packaging solutions. These attributes include Protection, Reusable, Affordable, Accessible, and Energy Efficient. The classification of these attributes as must-be requirements indicates that their absence would result in significant Experts' dissatisfaction, while their presence establishes the minimum acceptable foundation for packaging design.

Protection functionality demonstrated the highest attribute strength (4.81) among must-be attributes, reflecting its fundamental importance in packaging design. Consumer/Experts' expectations for protection encompass multiple dimensions, including physical protection from damage, contamination prevention, and preservation of product quality throughout the supply chain. The classification of protection as a must-be attribute confirms that sustainability considerations cannot compromise the fundamental protective function of packaging.

The reusable attribute received a strength rating of 4.59, indicating a strong customer preference for packaging that is reusable. This result shows that people are becoming more aware of the cycle economy. They think that sustainable packaging will help reduce waste because it is made to be reused. The basic classification shows that designs for single-use packaging may face more resistance from customers as their standards for sustainability change.

With an attribute strength of 4.66, affordability indicates that sustainability components must be affordable by the masses and feasible to gain customer acceptance. The essential classification indicates that consumers/Experts' desire eco-friendly packaging solutions to be priced comparably to conventional alternatives. This study shows how important it is to find sustainable design methods that do not cost a lot of money but still performs better.

Consumer expectations for packaging that accommodates different user abilities and requirements are an aspect of accessibility standards. To ensure that environmental benefits do not impair usability for any customer group, sustainable package design must embrace universal design principles, according to the essential categories.

3.3.3 One-dimensional Quality Attributes: Performance Drivers

Durable and Functional are two traits that are considered One-dimensional Quality qualities. These traits show that there is a straight relationship between how well a characteristic works and how satisfied a client is. This means that making these areas better will directly lead to happier customers.

Durability factors include both physical strength and long-term viability, which shows that consumers choose packing solutions that stay intact for a long time. The one-dimensional classification shows that better durability performance leads to higher levels of customer satisfaction, which makes it a crucial area for businesses to stand out from the competition.

The durability attribute answers a lot of customer questions, such as how much money they will save by not having to replace things as often, how good it is for the environment by not having to replace things as often, and how reliable it is by keeping its performance over time. Improving durability can help with sustainability goals by lowering the number of packages needed for a certain use and making reusable packaging solutions last longer.

Functional qualities deal with factors that determine how easy and convenient something is to use, which in turn affects how satisfied users are. The one-dimensional classification shows that functional improvements lead to higher levels of satisfaction, which means that spending money on functional upgrades gives consumers the same amount of value.

Functional performance includes many factors, such as how easy it is to use, how convenient it is, how comfortable it is to use, and how efficient it is to run. Improved functionality can help with sustainability goals by making sustainable packaging solutions more user-friendly and making it less likely that consumer will choose less sustainable options since they do not work as well.

3.3.4 Attractive Quality Attributes: Delight Generators

Aesthetics and informative elements become Attractive Quality traits that might make customers happy beyond what they expected. These traits show positive satisfaction coefficients (0.18 for both), which means they could give a business a competitive edge by making the customer experience better. On the other hand, absence of these attributes does not make customers unhappy.

Aesthetic considerations include visual design attributes that can set a brand apart and make it more appealing to customers. The attractive classification means that better aesthetic performance can lead to higher satisfaction and a competitive edge, while basic aesthetic performance does not lead to unhappiness. This conclusion shows that aesthetic investment should focus on making design experiences that are unique and memorable, not just achieving basic visual requirements. The aesthetic attribute looks at a number of things that affect how people react, such as how they feel about the brand, how appealing it is on the shelf, and how much they identify with the design values. Improving aesthetics can help with sustainability goals by making consumers more likely to choose eco-friendly packaging and promoting premium positioning that allows for investment in eco-friendly materials and procedures.

Informative attributes include instructive parts that help consumers learn about the benefits of sustainability, how to use the product properly, and how to handle it at the end of its life. The appealing classification shows that good informational content can make customers happy and give a business a competitive edge, whereas basic informational content does not make customers unsatisfied/unhappy. The informative attribute encompasses multiple communication functions, including sustainability benefit communication, usage optimization guidance, proper disposal instructions, and brand value expression. Better informative material can help with sustainability goals by helping consumers understand the environmental benefits and encouraging them to use and dispose of products in ways that are best for the environment.

The examination of the satisfaction index shows that there are clear trends in each category of attributes. Must-be attributes demonstrate negative total satisfaction indices (-0.37 to -0.22), confirming their foundational role in consumer expectations. One-dimensional traits have mild negative values (-0.19), while appealing attributes have positive values (0.18), which supports their importance as variables that make people delighted.

3.4 Discussion and Implications

3.4.1 Discussion: Theoretical Contributions

This study shows how the Kano model have been utilized to prioritize design attributes in eco-friendly product development by applying it to the design of sustainable packaging. The results add to what we know about what consumers want in terms of eco-friendly packaging and support the theoretical frameworks that already exist in this area. The classification scheme gives packaging designers and manufacturers useful advice on how to improve sustainability while keeping customers happy. The selection of must-be characteristics sets minimum criteria for market acceptance, whereas uni-dimensional and attractive characteristics provide prospects for competitive variance. The findings depict that to design successful sustainable packaging; designers need to lay stress on the basic needs of protection and reusability before adding aesthetic or informational attributes. This systematic method helps to make strategic decisions and allows optimal use of resources.

3.4.2 Implementation: Strategic Framework for Implementation

Based on the empirical findings, a three-tiered implementation strategy emerges:

Tier 1 - Essential Requirements: Immediate attention to must-be attributes (Protection, Reusable, Affordable, Accessible, Energy Efficient) to ensure consumer acceptance and sustaining commercial challenges.

Tier 2 - Performance Enhancement: Strategic enhancement of one-dimensional attributes (Durable, Functional) to achieve competitive differentiation and customer satisfaction growth.

Tier 3 - Delight Generation: Selective implementation of attractive attributes (Aesthetics, Informative) to create exceptional consumer experiences and brand loyalty.

3.5 Summery

The present chapter provides a priority list of design attributes for designing sustainable packaging using the Kano model to find and rank the attributes that are most wanted by the consumers. The empirical analysis successfully classified 09 design attributes into distinct Kano categories, providing clear guidance for design prioritisation and resource allocation decisions.

Finding protection, reusability, and affordability as must-have attributes sets basic standards for accepting sustainable packaging. By putting durability and functionality in the same category, it becomes clear that there are ways to stand out from the competition by improving performance. Finally, the recognition of aesthetics and informative attributes as attractive attributes suggests potential for consumer delight generation through strategic design enhancements.

The identified design attributes can be utilized by Packaging Industry/packaging designers, manufacturers, and sustainability experts who want to make packaging that meets both environmental and consumer needs. The systematic approach makes it possible to make decisions based on data and allocate resources strategically in projects that design sustainable packaging.

CHAPTER 4

Development of a Framework to Design Sustainable Packaging

The packaging design operations are part of a complicated ecosystem with many interdependent stakeholders, each of whom has a different level of influence over design choices, market results, and sustainability efforts. As the Packaging Design Industry is facing more and more pressure from environmental issues, changes in regulations, and working for customer expectations, it is becoming more and more important to understand how stakeholders interact with one another. In the past, packaging design was a simple linear process in which producers made containers that worked for their products. Now, it is a complex field that requires careful consideration of the needs and interests of many different stakeholders. This chapter gives a full look at the principal individuals involved in the packaging design industry, looking at their occupations, their motives, roles, responsibilities and the complicated connections that affect how packaging is made today. In this chapter, we will discuss the process of developing a better sustainable packaging solution by utilizing the "Sustainable Packaging Initiate - Innovate Design (SPIID)" Framework. This framework includes three primary stakeholder groups: (i) the packaging industry and designers, (ii) consumers, and (iii) government regulatory bodies. In spite of the fact that they assist primary groups throughout decision-making processes, secondary stakeholders have a great amount of roles and responsibilities in the development of SPD. The strategy that has been designed is capable of effectively addressing the fragmentation that prevails in package creation. This fragmentation occurs when stakeholders operate separately, which results in solutions that may fulfil particular criteria but do not accomplish the larger sustainability goals.

The packaging sector has faced immense sustainability problems in the last few years, mostly because of its impact on the environment and the need to follow rules. The way packaging is designed now has a big problem: stakeholders work alone instead of together. Depending on the main stakeholder group, this broken approach shows itself in different ways. For example, a design that focuses on the industry emphasises manufacturing efficiency, while a design that focuses on the customer emphasises usability and aesthetics. Finally, a design that focuses on compliance requirements emphasises meeting those criteria.

Two main sections were discovered in designing SPD framework SPIID. The first part is making packaging that fulfils environmental requirements by choosing the right materials and making it in the right way. Second, the design has to be something that people will want to buy and that manufacturers can profit. This approach focuses on bringing together all of the major stakeholders to generate sustainable outcomes, because focusing on the needs of each individual stakeholder leads to packaging that is only useful for a small number of purposes. In other circumstances, packaging solutions that were only made with one stakeholder in mind would slowly show their flaws when they were used in the real world. A technically good design might not pass consumer acceptance testing, and solutions that consumers like might not follow environmental rules. In fact, the design process must take into account the needs and abilities of all stakeholder groups at the same time for sustainable packaging to operate.

Designers need to think about the needs of all stakeholders in order to make packaging that is sustainable. If these essential needs are found and included, the packaging that is made will meet environmental, business, and legal goals all at the same time. But figuring out what these needs are and putting them in order of importance for all the different groups of stakeholders is a hard task because there isn't enough information and the priorities are different. Stakeholder requirements are often stated in words and include uncertainties, which makes it hard to turn them directly into design specifications. In practice, rigorous analysis of input from all-important parties leads to effective packaging solutions. Based on what is known, designers usually give one group of stakeholders more weight than others do, which leads to packaging that does not meet all of its sustainability goals. The Packaging Design Industry needs to create a methodical framework that, when used in the packaging design process, will lead to better, more sustainable solutions. The suggested work creates a paradigm for making long-lasting packaging solutions that is based on integrating major stakeholders, setting priorities for requirements, and working together to design the packaging. This model is named the SPIID framework in this work.

4.1 Description of the Problem

When looking at how packaging is designed nowadays, it has been seen that the understanding of how to make packaging that is good for the environment with good performance is lacking. To be truly sustainable, one need to think about the effect on the environment, how easy it is to make, how well it will be accepted by consumers, and how well it will follow the rules, all at the same time. The Packaging Industry needs to understand that sustaining packaging is important, rather than focusing on just material, which lacks performance. In today's packaging design, we only deal with the concerns of each stakeholder one at a time, not all at once.

Designers need to think about the basic needs of all stakeholder groups at the same time in order to make packaging that is practical & sustainable. It is hard to get these requirements out and put them together since information from stakeholders is often in the form of language and has uncertainties and ambiguities. This makes it harder to turn stakeholder requirements into design specifications that can be acted on. Most of the time, current design methods follow a hierarchical pattern in which one group of stakeholders makes the decisions and other groups give input within set limits. This leads to packaging solutions that work best for the most important stakeholders but make things worse for others. For instance, designs that follow regulations could not be appealing to consumers, whereas designs that focus on cost might be able to make things more efficiently but not meet environmental standards.

To design sustainable packaging, you need to know a lot about a lot of different things, such as how materials work, how they are made, how consumers behave, and the rules that govern the industry. No one stakeholder has a complete understanding of all of these areas, so we need to work together to use everyone's knowledge and skills. What are the most important attributes of designs that should be considered while designing? All these factors can lead to a better SPD and better decisions to develop SPD.

4.2 The Stakeholders

These section sorts' stakeholders into groups depending on how much they can directly affect the results of packaging design and how much useful knowledge they can bring to the table. The SPIID framework is used in the general packaging design process to deal with problems that come up when stakeholders are split up and requirements are conflicting. There are three main processes that the SPIID framework goes through to change:

Step 1: Put stakeholders into primary and secondary categories depending on how much they directly affect design outcomes and how much important knowledge they can bring to the table.

Step 2: (i) Use organized collaborative methods to bring together the needs of the main stakeholder groups; (ii) Use systematic evaluation criteria to rank the needs in order to settle disagreements and set design priorities.

Step 3: Create design deliverables based on the needs of all stakeholders and the way decisions are made together.

The framework suggests the SPIID paradigm as a way to create truly sustainable packaging. The strategy is based on integrating main stakeholders, setting priorities for requirements, and working together to design. When you classify primary stakeholders, you find three important groups: those who work in the packaging sector or design it, customers, and government regulatory authorities. This rating is based on how much they can directly affect the results of packaging design and how much useful knowledge they can bring to the table. Secondary stakeholders are crucial because they give context and help key stakeholders make decisions, but they do not make the main design decisions. These are people who supply raw materials, marketers, merchants, distributors, and companies that handle garbage.

Through structured collaboration processes, the needs of main stakeholders are brought together. These processes make it easier for groups with different backgrounds and goals to communicate and make decisions. Using a set of systematic evaluation criteria, competing needs are ranked in order of importance to set a clear design direction. The proposed method can effectively get around the problems with current package development procedures and come up with solutions that really last.

The framework developed encourages a collaborative and iterative process for the Industry to follow. It allows one to consider various design and production constraints and how to overcome them as well. As shown in Figure 4.1 & 4.2.

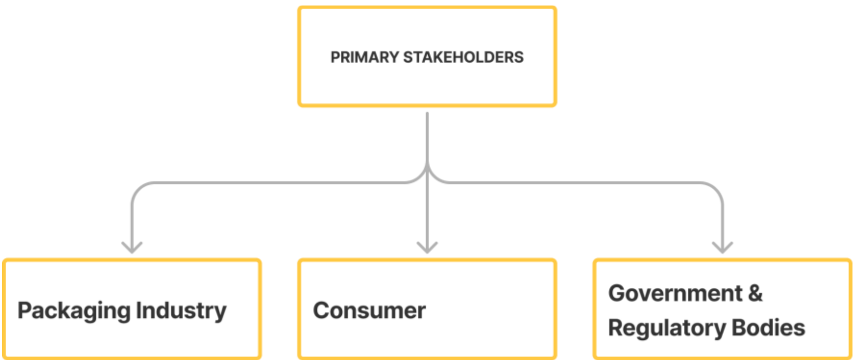

Figure 4.1: Flow Chart of Primary Stakeholders

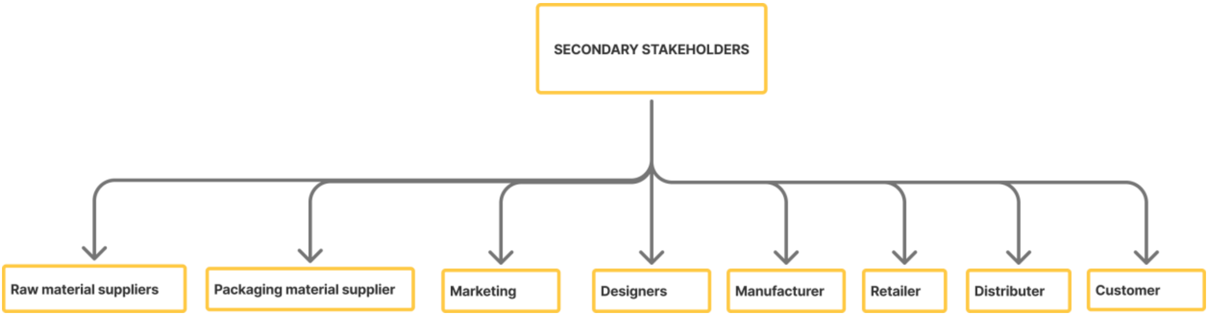

Figure 4.2: Flow Chart of Secondary Stakeholders

When designing packaging in a traditional way, designers usually focus on one set of stakeholders and add design attributes to meet the needs of other groups as a secondary concern. For example, manufacturing-focused techniques put production efficiency first and add attributes to fulfil the needs of customers and the law. In the same way, designs that focus on consumers put a lot of emphasis on usability and try to get around problems with manufacturing and regulations. However, this systematic method is not enough to attain full sustainability or to make packaging solutions that are truly sustainable. While designers focus on just one stakeholder while making packaging, they only add attributes that only partially meet the needs of other stakeholders, which does not lead to the best integration. The result of current design practice is packaging that meets the needs of certain stakeholders while letting down others. Sometimes, design only focuses on two stakeholder groups, but it cannot be truly sustainable unless all of the main stakeholders are fully included in the design process. The SPIID framework brings together requirements through organised collaboration methods that make it possible to evaluate the needs of all main stakeholders at the same time. This method understands that designing packaging that lasts requires balancing optimisation across several factors instead of putting them in order of importance. The SPIID framework consists of various stakeholders who will play important roles and responsibilities in developing SPD. The list is discussed further:

4.2.1. Primary Stakeholders:

Packaging Design Industry/ Designer

The packaging design Industry will be the most important core of the framework, where all the major stakeholders will be collaborating and taking combined decisions while utilising the SPD attributes. With the Packaging Industry, various secondary stakeholders will also work, such as suppliers, marketing teams, retailers, designers, distributors, etc, to understand the content and map the SPD attributes for the development of SPD. The Industry will consider manufacturing constraints, including foldability, machining precision, and assembly methods. Ensure compatibility with large-scale production requirements. During this stage, major SPIID model will be utilized by the industry.

Core Responsibilities Packaging Industry:

a. Innovation leadership in sustainable materials and processes
b. Production capacity and quality management
c. Technology advancement and implementation
d. Cost optimisation while maintaining sustainability goals
e. Industry standard setting and best practice sharing
f. Mass production in less time

Key Capabilities:

a. Technical expertise in material science and manufacturing
b. Production scale and efficiency optimisation
c. Quality assurance and control systems
d. Research and development capabilities
e. Industry network and influence

Engagement Strategies:

a. Investment in sustainable technology development
b. Collaboration with material suppliers and researchers
c. Commitment to long-term sustainability goals
d. Transparency in environmental impact reporting

Design Professionals Core Responsibilities:

a. Creative innovation balancing design attributes like aesthetics, function, and sustainability
b. Technical expertise in materials and manufacturing processes
c. User experience optimisation for sustainable packaging

d. Collaboration with cross-functional teams
e. Continuous learning and skill development in sustainability

Design Considerations:

a. Material selection for environmental performance
b. Minimisation of material usage while maintaining function
c. Integration of user experience and sustainability
d. Aesthetic appeal that communicates sustainability values

Product Development:

a. Enhanced capability in sustainable design approaches
b. Access to comprehensive resources and tools
c. Improved collaboration with cross-functional teams
d. Greater impact through systematic approach

Customers and End Users

Consumers are the final judges of how well packaging works, even if they do not have much say in the design process. Their buying choices, comments, and shifting tastes shape industry trends and affect the goals of stakeholders. All other stakeholders need to know how consumers act and what they like.

Customers today are becoming more knowledgeable about packaging issues. When they buy something, they think about how it will affect the environment, how easy it will be to use, and how it will look. Because of this change, other parties have had to come up with more complex ways to design packaging that take all of these different issues into account. Consumer stakeholders have the most power over design processes when they are involved in the market instead of directly participating in them. However, social media and digital platforms have made consumer voices louder, giving them more direct power to shape business decisions and industry trends than ever before. As is can be seen in the figure 4.3.

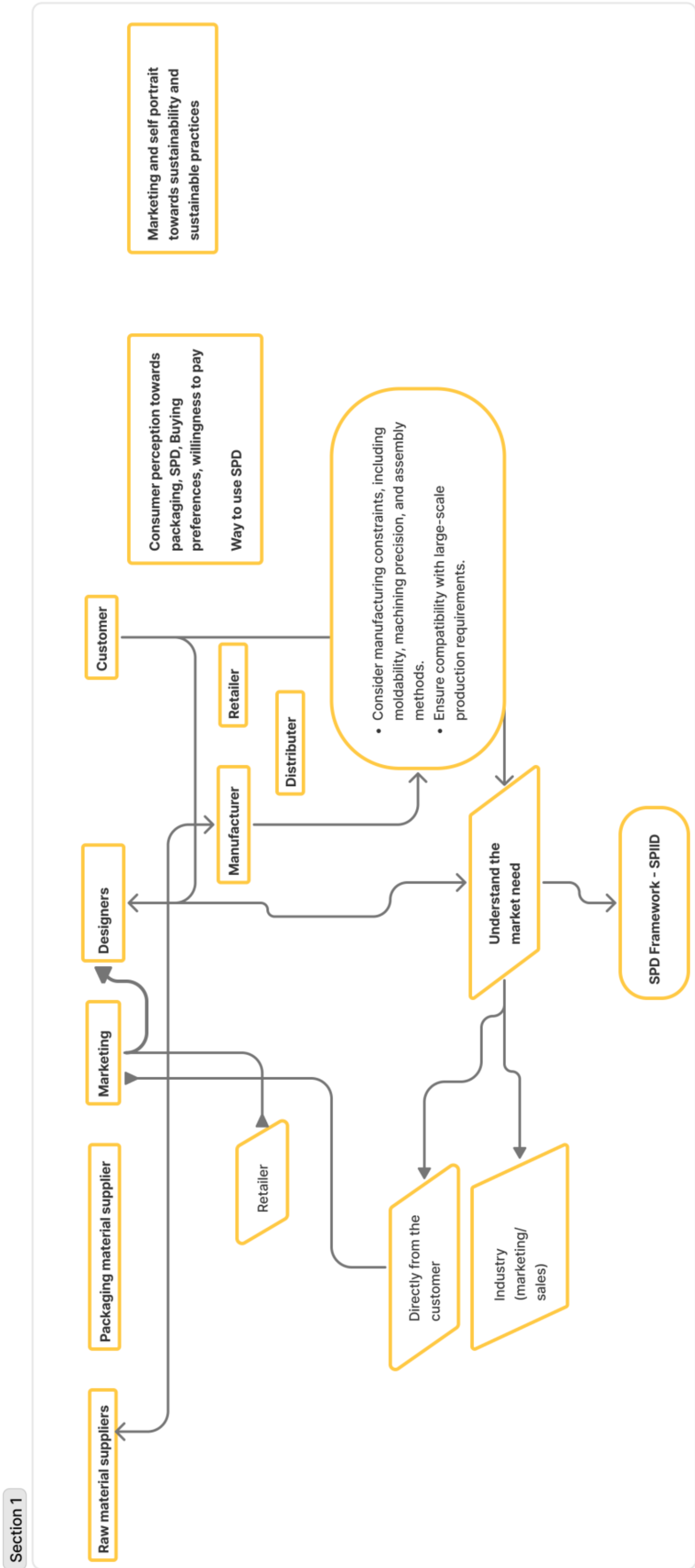

Figure 4.3: Flow Chart of Information flow

Core Responsibilities:

a. Informed purchasing decisions considering environmental impact
b. Proper disposal and recycling behaviour
c. Feedback provision to brands and retailers
d. Advocacy for sustainable packaging options
e. Education and awareness building within communities

Key Influences:

a. Purchase decision power and brand selection
b. Social media influence and word-of-mouth communication
c. Market demand signals through buying behaviour
d. Feedback on packaging performance and usability
e. Community leadership in sustainability practices

Engagement Strategies:

a. Education about sustainable packaging benefits
b. Clear labelling and communication of environmental features
c. Community-based sustainability initiatives
d. Transparent communication about trade-offs and benefits
e.

Government Agencies and Regulatory Bodies

Regulatory stakeholders set the rules that all other stakeholders must follow. Their power shows itself in safety standards, environmental rules, labelling requirements, and material limits that have a direct effect on what can be designed. The rules and regulations for designing packaging are getting more complicated and changing all the time. New rules on plastic waste, chemical safety, and recycling are always being made, which means that people in the sector have to keep changing how they do things. This change in regulations requires stakeholders to be involved and plan for compliance ahead of time.

When it comes to managing regulatory stakeholders, international trade issues make things even more complicated. Packaging designs often have to follow a number of distinct sets of rules, which means that people who work in different areas need to work together carefully.

The government will have more influence on how packages are designed because of public awareness campaigns, pressure from businesses, and lobbying for new rules. Their focus on sustainability concerns has changed the priorities of the sector and the way stakeholders interact with each other. These groups frequently lead the way in making changes in their fields by bringing attention to environmental issues and suggesting solutions that other stakeholders must think about. They have an impact on several levels, such as public opinion, regulatory pressure, and direct contact with businesses.

The relationship between people who care about the environment and people who work in the sector has changed from being enemies to working together more and more. Many environmental groups now engage directly with businesses to come up with eco-friendly packaging solutions since they know that working together typically leads to better results than fighting.

Government & Regulatory Bodies

Core Responsibilities:

a. Policy framework development and implementation
b. Regulatory standard setting and enforcement
c. Infrastructure development for waste management and recycling
d. Public education and awareness programs
e. International cooperation and standard harmonization

Key Tools:

a. Legislation and regulatory frameworks
b. Economic incentives and penalties
c. Public funding for infrastructure development
d. Research and development support
e. International cooperation mechanisms

Policy Areas:

a. Packaging waste reduction targets
b. Material restriction and substitution requirements
c. Recycling and circular economy promotion

4.2.2 Secondary stakeholders:

Manufacturers of packaging and suppliers of materials

The industrial backbone of the packaging design ecosystem is made up of material suppliers and packaging manufacturers. These stakeholders have a lot of technical knowledge about material qualities, manufacturing processes, and production capabilities that have a direct impact on design options and limitations.

As concerns about sustainability grow, the interaction between material suppliers and other stakeholders has gotten more complicated. To make materials that fulfil environmental standards while still working well, suppliers are putting a lot of money into research and development. Brand owners, designers, and regulatory organisations all need to work closely together during this innovation process. Stakeholders in manufacturing also have important responsibilities in figuring out costs and if production is possible. Their feedback during the design phase can have a big effect on how well the project goes; therefore, it's important to get stakeholders involved early on in the packaging creation process.

Retailers and partners in distribution

Retailers have a lot of power over packaging design decisions since they control shelf space, how products are displayed, and what customers need to buy. Their main concerns are operational efficiency, protecting the goods during shipping, and making it appealing to customers at the time of sale. The retail stakeholder group has gotten better at asking for certain types of packaging. Major retailers now require certain sustainability criteria, full lifecycle evaluations, and packaging optimisation requirements that are meant to cut down on waste and shipping expenses. These restrictions have a big impact on how things are designed and what materials are used. The expansion of e-commerce has had a big effect on the power of retailer stakeholders. Online stores need different kinds of packaging than traditional stores; thus, designers need to come up with solutions that work well in both types of stores. This demand for two channels makes it harder to handle stakeholders.

Secondary Stakeholders (Influencers & Enablers) Roles & responsibilities:

Raw Material Suppliers: Providers of base materials for packaging production

Packaging Material Suppliers: Specialised suppliers of packaging components

Marketing Teams: Internal teams responsible for brand communication and positioning

Design Professionals: Creative and technical experts who develop packaging concepts

Manufacturers: Companies that integrate packaging into their production processes

Retailers: Distribution channels that present products to consumers

Logistics Partners: Companies handling distribution and supply chain management

4.3 SPIID Framework

This study uses a systems thinking method to find and group the different stakeholders who are involved in the package design ecosystem. The framework "Sustainable Packaging Initiate - Innovate Design (SPIID)" collaboratively works with both primary and secondary stakeholders to show how their interactions affect design choices, market trends, and the general direction of the industry. Their expertise will make sure that proposed solutions can be put into action by doing feasibility studies, looking at manufacturing limitations, analysing costs, and assessing innovative capabilities. Customers give important information on how they use things, what they look for when they buy something, and how they get rid of things. Their feedback makes sure that eco-friendly packaging solutions are useful and accepted by the market. Government agencies set and enforce rules for the environment, safety, and compliance. They set rules and criteria for how packaging should be designed to have the least impact on the environment. The aim is to create a conceptual framework to allow any researcher or designer involved in an SPD process to follow logical, consistent procedural steps. The framework is further divided into 5-Major steps and into 3 major phases: Initiate, Integrate and Innovate. Each phase consists various steps of SPIID framework as shown in Figure 4.4:

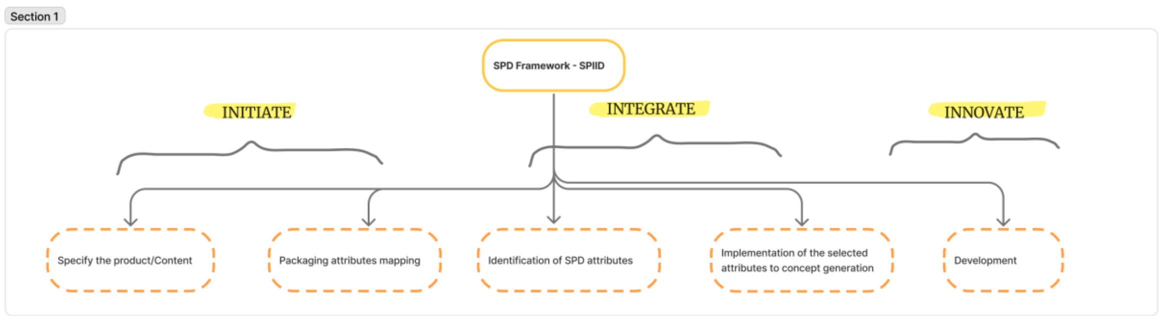

Figure 4.4: Flow Chart of 3 Phases

INITIATE Phase:

Systematic foundation building with all stakeholders

Understanding the requirements and mapping the attributes

INTEGRATE Phase:

Structured collaboration and multi-criteria optimisation

Holistic solutions that balance all stakeholders needs

Finalizing the priority list of the SPD attributes

INNOVATE Phase:

Systematic innovation and breakthrough solution ideation

Product trials and development

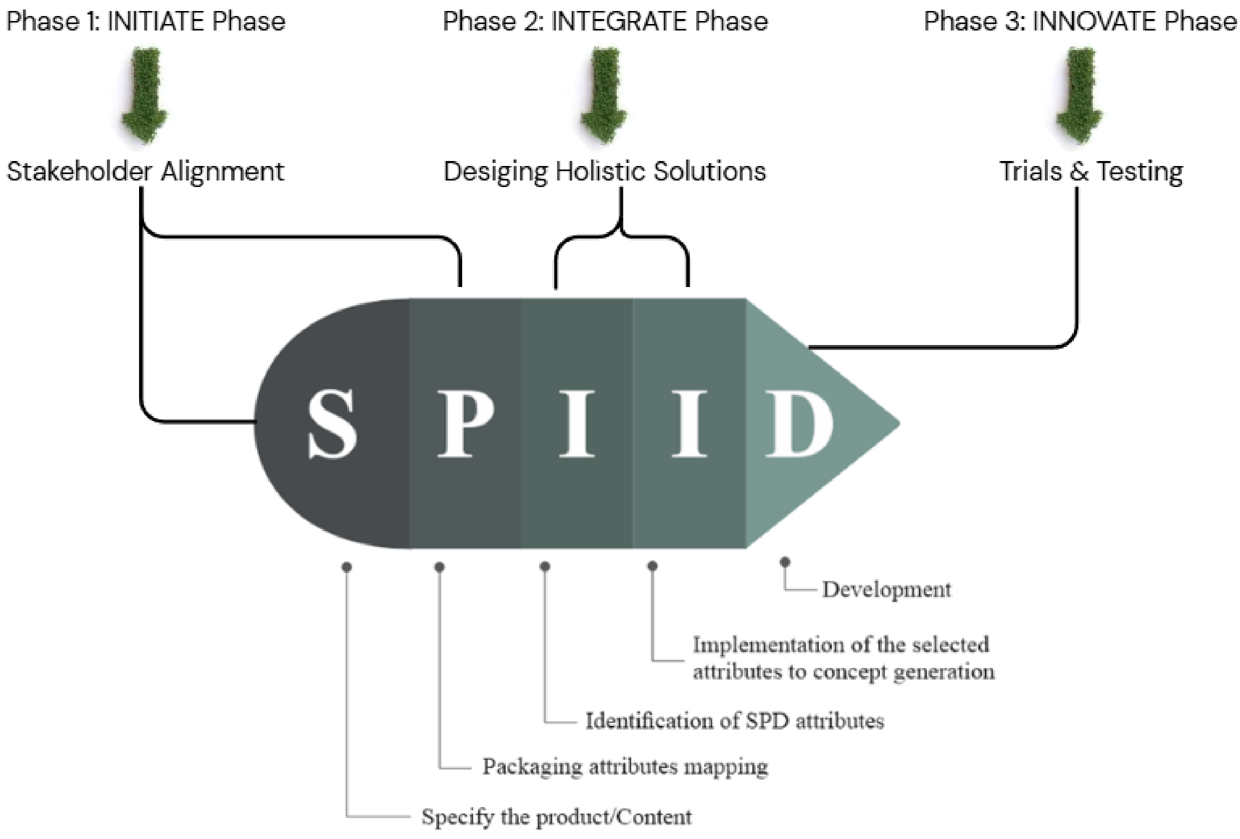

Figure 4.5: SPIID Framework

INITIATE Phase:

During the Initiate phase, Two major steps will be taken care of during this phase of the SPIID framework. Here, the Industry stakeholders will try to understand the content and basic properties of the framework to minimise over-packaging by matching protection to actual needs. Selecting appropriate sustainable materials based on specific requirements to reduce material waste through optimised sizing. This will enable the industry to Design for end-of-life scenarios appropriate to the product and create packaging that extends product shelf life, reducing food/product waste. It will also take consider the following aspects:

Distribution Requirements

a. Expected transportation methods and distances
b. Stacking requirements
c. Vibration tolerance
d. Drop resistance needs

Shelf Life Considerations

a. Required barrier properties
b. Expected storage conditions
c. Product degradation factors

Consumer Interaction

a. How consumers will use the product
b. Dispensing/removal requirements
c. Reseal ability needs
d. Portion control considerations

Physical Properties

a. Dimensions, weight, and shape
b. Fragility assessment
c. Temperature sensitivity
d. Moisture sensitivity
e. Light sensitivity

The next step is packaging attribute mapping, which provides a methodical way to fully analyse and understand the complicated connections between product attributes, target consumer demographics, brand strategic goals, and regulatory compliance requirements. During this stage, a systematic mapping technique is utilized to find links between the necessary packaging properties and design attributes identified. This strategy is in line with known packaging research methods that stress the relevance of attribute analysis in improving design. This methodical methodology makes sure that the compression strength needs are exactly in line with the material qualities, structural configurations, and size criteria.

More detailed criteria for selecting attributes make it possible to optimise designs better. This strategy includes adjusting the packaging attributes to enhance its efficiency, protection, and cost-effectiveness. The improved attribute selection method sets clearer performance standards and design specifications, giving designers and stakeholders a common set of rules to follow in order to get the best results. Additionally, the attribute mapping method makes it easier for targeted innovation projects to happen by concentrating development efforts on the most important interactions between the product and the package.

By systematically finding and mapping these SPD attributes, innovation efforts may be strategically focused on regions that will have the biggest effect on total packaging performance. The end of this step is when all of the detected attributes are mapped to the established packaging criteria. This creates a systematic foundation for making design decisions. This methodical approach makes sure that all packaging solutions are created with full consideration of performance needs, regulatory restrictions, and market positioning goals. In the end, this leads to the best packaging systems that strike the right balance between functional performance and cost-effectiveness.

INTEGRATE Phase:

During this phase, the next 2 major steps are being followed, which are (i) finalising the most Important attributes based on the requirement. This step will enable the team to define critical physical attributes relevant to the product's intended application. It will ensure the creation of measurable benchmarks for sustainability performance for the product/content type by enable systematic evaluation of design attributes and alternatives. It will also offer to communicate concrete sustainability attributes to stakeholders by facilitate continuous improvement through attribute refinement. The second step (ii) is the Implementation of the selected attributes to concept generation. In this step, precise content measurement needs to be understood. Like eliminate over-packaging through exact volume analysis and headspace requirements. Production scale thresholds - Match sustainable materials to appropriate production volumes for economic viability. Usage-based unit optimisation - Design for typical consumption patterns to minimise product and packaging waste. Material efficiency scaling - Leverage production volume to improve material efficiency per unit. Recovery system compatibility - Ensure designs align with real-world recycling infrastructure capacity and collection thresholds.

Develop physical and virtual prototypes for performance validation. It will help in conducting empirical testing under real-world conditions to evaluate material resilience, structural integrity, and compliance with industry standards. Iterate and refine concepts based on testing feedback, ensuring alignment with technical and functional criteria. Complete these steps for further development of the final packaging. This step also becomes a major follow-up step in the framework as one can return to this phase in case the developed SPD solutions do not work.

INNOVATE Process:

The Innovate phase's last step is the Development step in the packaging design process. It turns theoretical specifications into real packaging solutions through systematic production and iterative performance evaluation. At this important stage, all of the aesthetic and functional details are finalised. This includes choosing the surface finishes, colour palettes, typographic specifications, photographic images, and labelling configurations that will make up the product's visual and informational interface with the consumer. The assembly process uses formal methods to check how well manual tasks like folding, inserting, labelling, sealing, and scanning are done. This makes sure that the manufacturing steps follow the design criteria and production limits that have already been set. After the physical construction and delivery of packaging prototypes, a full performance evaluation framework is put in place to see if the new packaging solution works better than prior versions or benchmark standards. This evaluation uses systematic methods like packaging scorecards to look at how well packaging works with products and processes in the supply chain. It includes both qualitative assessments of how good it looks and how well it works, as well as quantitative measurements of how strong it is, how well it protects things, and how efficiently it moves things around. Because this step is iterative, it requires constant improvement, where design changes are made as performance issues arise and then the package is reassembled until it works perfectly. Package testing looks at how the packaging, its contents, outside forces, and the end user all work together and affect each other. It uses both qualitative and quantitative methods to make sure that the final packaging solution meets all the requirements for market deployment and customer satisfaction.

4.4 Encouraging Collaborative Relationships

Stakeholders working together will become increasingly important for effective, SPD projects. These partnerships could be formal, similar to a corporate collaboration, or informal, like sharing information with one another. The best partnerships bring together the needs of all parties involved around common goals while yet taking into account each person's worries. Now, it is important for sustainability projects to encourage people from different stakeholder groups to work together. In order to make genuine progress on environmental challenges, many different groups of stakeholders usually need to work together in new ways and share the work.

Technology platforms and industry groups help stakeholders work together by giving them places to share information and work together to solve problems. These approaches of working together help everyone see things from each other's point of view and come up with solutions that work for everyone. This framework will encourage the industry and designers to work together in an iterative way so that they may fix and process the designs at any point in the design stage. The SPIID framework is a reflection of the contemporary packaging design process, which is developed keeping in mind what has not been explored yet in the domain of SPD. Some of the new areas explored are discussed in table 4.1:

Table 4.1: Differentiation between Existing and SPIID Framework

Dimension	**Existing Frameworks**	**SPIID Framework**
Primary Approach	Technical/Policy-driven	Human-centred design thinking
Starting Point	Materials, Processes, Systems	User needs & empathy mapping
Decision Logic	Quantitative metrics	Qualitative + Quantitative insights
Design Process	Linear assessment	Iterative design thinking
Sustainability Scope	Environmental + Economic	Environmental + Economic + Practical
Target Users	Engineers, Policy makers, Supply chain	Designers, Design teams, Creative professionals
Output Type	Assessment scores, Compliance checklists	Design attributes, Design guidelines

4.5 Conflict Resolution and Interest Alignment

When diverse groups have distinct needs or priorities, conflicts among stakeholders are bound to happen. To manage stakeholders well, you need ways to find, deal with, and settle these issues before they affect the project's results. Some common areas of conflict are trade-offs between cost and sustainability, between aesthetic preferences and functional needs, and between short-term and long-term goals. To reach a successful conclusion, people usually have to make compromises and come up with creative solutions that accommodate the interests of all stakeholders. Interest alignment techniques help keep people from fighting by finding things they all agree on and goals they all want to reach. When stakeholders see how their own success depends on how well the whole system works, they are more willing to work together and support ideas that help everyone.

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4.6 SUMMARY

The SPIID framework offers an organised way to design sustainable packaging that addresses the crucial need for everyone involved to have a say in the design process. The framework will assist stakeholders in the packaging industry, consumers, and government regulators to work together in a structured approach to find packaging solutions that fulfil all the possible environmental goals while still being able to generate money and respect the rules. The framework sets up a methodical manner for stakeholders to collaborate, determine priorities for requirements, and work together to come up with ideas. This is the basis for a SPD practice. By integrating this SPIID framework into conventional packaging design processes, It effectively address challenges related to sustainability requirement prioritisation and design uncertainty. This entailed the development of a stage-gate process model customised to incorporate sustainability issues in each step and the development of decision-making tools calibrated to stakeholders' particular needs and responsibilities. The integration of checkpoints and validation processes into the design process, definition of precise sustainability criteria and measurement protocols for objective assessment, and development of feedback mechanisms to enable ongoing improvement of packaging and the system itself. The resultant framework gave an overall but adaptable approach to packaging design that balanced different stakeholder views while staying focused on central sustainability goals. The SPIID framework might quickly and efficiently fix the flaws with how packaging is made and lead to the introduction of truly sustainable packaging alternatives. The suggested method aids both theory and practice in the field of SPD by giving us a disciplined way to deal with the complex difficulties that crop up in modern packaging creation.

CHAPTER 5

Systematic study of effectiveness of the framework

The validation of theoretical frameworks constitutes a critical phase in this research, particularly when establishing the practical applicability and robustness of newly developed conceptual models. This chapter gives a full evaluation of how well the suggested Sustainable Product Design SPIID framework works through case studies of great packaging solutions that show how to use proven sustainable design methods. The main idea behind this validation method is that if the identified framework attributes accurately capture the essential characteristics of sustainable product design, then products that are recognised as examples of sustainable packaging should show these attributes. On the other hand, if certain design attributes are missing or only show up in small amounts in recognised sustainable products, it reveals limitations within the proposed framework structure.

The later sections of this chapter are divided into sub-sections, each corresponding to a distinct case study. Simultaneously, a comprehensive case-study analysis and framework validation evaluation have been conducted. Each case study thoroughly assesses the inclusion of identified framework attributes, while the concluding section combines all findings to establish clear conclusions about the framework's effectiveness and accuracy. The analysis format remains consistent across all case studies to facilitate comparison and provide comprehensive coverage of all framework design attributes. This systematic approach enables a comprehensive assessment of the framework's efficacy and generates valuable insights for both theoretical advancement and practical application in the creation of SPD solutions.

This extensive validation method gives the research the real-world evidence it needs to back up the suggested SPIID paradigm. It also lists ways to improve the framework and make it more useful in real life. The results show that the framework may be used to describe sustainable design practice and to guide the development of future designs.

5.1 Framework Objective and Validation Methodology

The primary purpose of this chapter is to use five carefully chosen case studies—Aashirvad organic atta paper packaging, Puma's The Clever Little Bag, Nykaa Paper Lipstick packaging, TATA Tea 1868 tin containers, and NUA sanitary product packaging systems—to systematically identify and map the nine core design attributes of the Sustainable Product

Design (SPD) framework. The case study was selected on purpose based on established criteria for choosing case studies (Yin, 2018; Stake, 1995) because they are well-known examples of great SPD in industry publications and peer-reviewed academic literature (Bhamra & Lofthouse, 2007; Charter & Tischner, 2001). The market studies also suggested that this packaging introduction led to high sales, and consumers felt that the packaging was a sustainable design solution.

The chosen scenarios include a wide range of product categories, material uses, and customer groups. This makes sure that all aspects of SPD are covered, as Eisenhardt (1989) suggests for strong theory validation. This variety makes it possible to look at how universal the framework is while also taking into consideration differences that can affect how attributes show up in different situations (Flyvbjerg, 2006). The selection criteria are in line with recognized rules for case study research in design science, where exemplar instances are the best way to test and confirm theories (Cross et al., 2004).

5.1.1 Systematic Attribute-Mapping Methodology

The validation process takes a simple but comprehensive approach. Real packaging examples are analysed against the framework using proven research methods that have worked well for other design studies (Cross, 2011; Dorst, 2008). Each case study focuses on the essential design aspects: the reasoning behind design decisions, material selection, manufacturing processes, how consumers interact with the packaging, and disposal considerations. This methodical analysis follows established guidelines from design research experts Blessing and Chakrabarti (2009).

The analysis then records what actually appears in each case - noting whether framework elements are clearly present, partially visible, or completely absent in these real-world examples. This documentation reveals how effectively the theoretical framework translates to actual practice. The approach draws from pattern-matching methods that researchers like Campbell (1975) and Trochim (1989) developed for validating theories in complex design environments. Ultimately, this method tests whether the framework truly captures what happens in real packaging design scenarios.

5.1.2 Dual-Axis Research Design and Expert Panel Constitution

The validation used a two-part research approach that gathered feedback from different stakeholders and tested the framework across various products. This follows proven methods that design researchers use when they need multiple perspectives to validate their work (Blessing & Chakrabarti, 2009; Cash et al., 2016). The study brought together 30 experts from three different backgrounds: 10 industry professionals who actually implement packaging solutions, 10 entrepreneurs focused on bringing products to market, and 10 academic researchers with deep theoretical knowledge.

This three-way approach ensures the framework is tested from practical, business, and academic angles - a method that validation experts strongly recommend (Denzin, 1978; Patton, 2002). All experts needed at least 10 years of professional experience to participate. This requirement comes from research showing that a decade of hands-on experience gives people a solid understanding of how markets work, how technology changes, and how the field evolves over time (Ericsson & Lehmann, 1996; Chi, 2006).

The ten-year experience requirement makes sense because expertise research shows this timeframe allows professionals to see patterns others might miss. They understand market ups and downs, technology shifts, and how consumer behaviour changes (Dreyfus & Dreyfus, 1986). This experience level allows experts to contribute a meaningful understanding of sustainable packaging challenges and successful implementation approaches.

5.1.3 Data Collection Framework and Statistical Analysis

The process of collecting data employed a categorical method for 9 attributes that were theoretically extracted for 5 product purposes, which generated 450 specific expert assessments (9 terms x 5 products x 10 participant experts per group) via a structured questionnaire evaluation at Appendix III. Every participant expert gave assessment by Relative Importance Index (RII) process which well-known and popularly used method for evaluation of relevance in engineering and design research (Tam & Fung, 1998; Enshassi et al., 2009; Doloi et al., 2012).

This comprehensive collection of data stretches beyond a general validation experiment as depicted in systematic literature review (Creswell & Creswell, 2017; Robson & McCartan, 2016) and it provides a strategic base for empirical research. The RII method was employed for its effectiveness in validating expert cohesion in relation to the attributes and their importance and its proven validity in design research set-ups (Johnson & LeBreton, 2004; Akintoye, 2000).The validation was done using Relative Importance Index (RII) method. Where RII was calculated using RII formula:

$$RII = \frac{\sum_{i=1}^{2} (W_i \times n_i)}{(A \times N)}$$

Where:

RII = Relative Importance Index

W_i = Weight assigned to the i-th response (0=Not at all present, 1 = partially present, 2 = Fully present)

n_i = Number of respondents who selected the i-th rating

A = Highest weight (2 in a 2-point Likert scale)

N = Total number of respondents

The evaluation employed a structured importance classification system derived from established RII interpretation frameworks (Johnson & LeBreton, 2004; Doloi et al., 2012):

Table 5.1: Evaluation Criteria

Attributes/Packaging	**Mean RII Range**
Very High importance	($0.8 < RII \leq 1.0$)
High importance	($0.6 < RII \leq 0.8$)
Desirable	($0.4 < RII \leq 0.6$)
Neutral	($RII \leq 0.4$)

This classification system enables systematic interpretation of expert consensus regarding attribute importance while maintaining consistency with established validation methodologies in design research (Akintoye, 2000; Sambasivan & Soon, 2007).

5.2 Theoretical Foundation for Framework Validation

In design research, framework authentication usually adheres to a collection of rules that inspect at how well theoretical ideas complement to the real-world observations. In the area of design research, there is plenty of records about this method. For example, Hevner et al. (2004) and Peffers et al. (2007) have set up stern regulations for how to examine theoretical frameworks countering real-world data. This study uses acknowledged methods from design research, where theoretical frameworks are examined in opposition to their real-world applications to see how robustly they clarify things and how beneficial they are in practice (Singh et al., 2020).

The validation method used for this study looks at whether the 9 SPD design attributes were intentionally or unintentionally included in the pre-design stages of the selected packaging outcomes. This analysis looks back at design attributes picks based on performance, material choices, and other attribute preferences to check if the framework can completely elaborate on the sustainable results attained in these cases. The authors have made an effort to search if these attributes were used as leading principles in the initial stages of design to devise these packaging solutions, either by being expressly conceptual during the design process or by exhibiting naturally thriving, sustainable design outcomes.

The basic validation hypothesis says that if the proposed framework effectively captures the key attributes of SPD, then the nine attributes should be clearly apparent in all five case studies. The fact that these nine attributes are seen across a wide range of packaging applications, product categories, and design settings will prove that the framework is complete and can be used in any situation. On the other hand, the systematic lack of any attribute could mean that there are holes in the theoretical framework that need to be filled or rethought. The study uses a pattern-matching approach, which means that it compares theoretical predictions about the existence of certain attributes with actual examples of good SPD. This strategy makes sure that the framework validation is based on real-world facts while yet being theoretically sound.

The process of validation identifies the product design which last long needs operating within complex, multi-faceted systems where 9 design terms, considerations and performance goals meet. The evaluation method is simple application of design framework. It is interesting to notice how they fit well together in the entire ecosystem. The comprehensive assessment is required for sustainable design systems as it is complex. The process assesses at both the attributes and the correlations among them. It also sheds light on how these attributes work in cohesion and contrast among each other and how they suit design contexts and their combination impacts the holistic sustainability performance. The purpose of the validation method is not only to see the performance of individual attributes but how well they work in cohesion with each other.

The validation method also takes care of perspectives of strategic design decision making process where the attributes may behave in different ways in various steps of the design process – ideation, development, implementation, evaluation and post launch steps. This gradual aspect ensures that the validation of the framework changes with time across stages of design process influencing sustainability concerns associated at every stage.

5.3 Case Study Selection Rationale

The five selected case studies represent diverse approaches to SPD, each addressing distinct challenges and opportunities within the sustainability paradigm:

Aashirvaad Organic Atta Packaging (P1) is an example of a SPD that meets current environmental criteria and what customers want.

PUMA Clever Little Bag (P2) is an example of a SPD that serves the needs of both the environment and customers.

Nykaa Paper Lipstick Packaging (P3) shows how high-end design can be combined with environmental awareness, showing that luxury market positioning can work with eco-friendly materials and circular economy ideas.

TATA Tea 1868 Tin Containers (P4) highlight how vintage materials can be used in modern sustainable design frameworks. This shows how existing technologies can be improved for better environmental performance while still being functional.

NUA Sanitary Product Packaging (P5) shows how sustainable design can meet social, environmental, and functional needs at the same time by coming up with new ways to meet the needs of users in difficult product categories.

Expected Outcomes and Framework Validation Criteria

The effectiveness of the SPD framework will be assessed through several validation criteria to assess the efficacy of the SPD framework. The comprehensiveness criterion evaluates whether the nine identified qualities encompass all significant facets of sustainable package design demonstrated in the case studies. This entails examining whether the characteristics of the framework can comprehensively elucidate all significant sustainable design decisions and methodologies observed in the cases.

The discriminatory power criterion assesses the framework's capacity to differentiate various approaches to sustainable design and identify the specific characteristics that contribute to successful sustainability outcomes. This entails examining the manifestation of various attributess throughout the five scenarios and their impact on overall sustainability performance.

Third, the criterion for practical application assesses whether the framework provides designers with actionable guidance for decision-making. It will be assessed based on the accessibility, quantifiability, and applicability of framework qualities in practical design contexts. Whether these characteristics were utilised in the initial stages of packaging design.

5.4 Implications for Framework Development

The validation method does more than just check if the framework is correct. It shows how important different attributes are in different design situations, points out areas where the framework could be improved, and gives real-world evidence for the theoretical ideas behind the SPD model. Also, the study helps us understand better how the concepts of sustainable design may be used in real-world design choices and results. The study looks at effective examples of sustainable package design to give evidence-based ideas that can help with both the theory and practice of using sustainability principles in product design.

The rest of this chapter is divided into sections for each case study. After that, there is a full cross-case analysis and a framework validation assessment. Each case study section goes into great detail about how framework attributes show up in real life. The last section puts all the findings together to come to clear conclusions about how effective and valid the framework is. The analysis keeps the same structure for all case studies so that they can be compared, and all parts of the framework may be fully covered. This methodical methodology makes it possible to thoroughly evaluate the framework's performance and come up with useful ideas for both theoretical development and real-world use in designing sustainable products.

This thorough validation method gives the study the real-world evidence it needs to back up the proposed SPD framework and find ways to make it better and more useful in real life. The results show that the framework works as both a descriptive model of sustainable design practice and a prescriptive tool for guiding future design development.

5.5 CASE STUDIES

5.5.1 Aashirvaad Organic Atta: A Case Study in Sustainable Packaging Design (P1)

Aashirvaad Organic Atta's paper-based packaging represents an exemplary model of SPD that aligns with contemporary environmental standards and consumer expectations. This report analyses why the packaging design demonstrates best practices in sustainable packaging through scientific literature and industry research findings. ITC's Aashirvaad Organic Atta was launched on Earth Day 2023, introducing innovative paper-based packaging as part of their Sustainability 2.0 initiative. The preference for purchasing brands with sustainable packaging has grown to 90% and growing regulatory pressure for eco-friendly solutions. This packaging redesign addresses critical market demands while maintaining product integrity and functionality.

Sustainable Design Features Analysis

1. Paper-Based Material Selection

The use of paper as the primary packaging material aligns with established sustainability principles. Research demonstrates that paper packaging provides significant environmental advantages over plastic alternatives (Hopewell et al., 2009). The material used is wood fibre, which is a renewable resource that originates from sustainably managed forests, and is the mostly recycled of all packaging materials.

Key Features:

ECF (Elementary Chlorine-Free) Kraft Paper: Crafted from ECF unbleached, food-grade craft, which can be repulpable for recycled paper

Biodegradable Material: The packaging uses paper, which is renewable as well as a biodegradable material

Recyclability: The paper substrate can be easily recycled through existing waste management systems

2. Minimal Plastic Integration

Environmental Benefits: The design concept of using as less plastic as possible resolves worries about plastic contamination. To keep things fresh, only a little plastic is needed, and it can be readily separated for recycling. This method fits with the idea of a circular economy, where materials may be easily separated and processed through different recycling streams.

Scientific Support: Research shows that people think packaging that clearly shows trash is better for the environment than traditional packaging that does not show any waste. The visible paper part meets consumer expectations for sustainability while still working.

3. Enhanced Traceability through QR Technology

Transparency in Innovation: The new packaging has a "unique QR code" that makes it easier to trace the food's origins. This lets buyers easily trace information about the farms and groups of farmers that grow the product. This transparency tool meets consumers' needs for supply chain accountability and proof that products are organic.

Consumer Engagement: The QR code system lets customers check the organic credentials and agricultural methods, which builds trust and helps them, make smart buying decisions that are in line with their ideals of sustainability.

Alignment with Sustainable Packaging Principles

1. Renewable Resource Utilisation

Plant-based packaging materials are generated from renewable resources, offering a continuous and replenish able source. The paper-based design uses ITC's own Paperboards and Specialty Paper Division, which keeps the supply chain in check and the quality consistent.

2. Biodegradability and Circularity

Biodegradable food packaging can be a part of an important circular system that gets rid of trash and increases food production. The paper packaging breaks down organically, which is good for the soil instead of bad for the environment.

3. Consumer Preference Alignment

According to research, people know that food packages have an effect on the environment, are worried about how bad for the environment containers that aren't sustainable are, and want a change in the materials used to package food. The Aashirvaad design directly responds to these consumer preferences.

Performance and Functionality

Shelf Life Maintenance

Even though it changed from plastic to paper, the pack keeps the product's shelf life as long as any other pack on the market. This shows that eco-friendly packaging can keep working well without hurting the quality or safety of the product.

Consumer Usability

The packaging design uses eco-friendly materials while still being useful, which is important for market acceptance, according to studies that shows the need for a balance between environmental responsibility and customer convenience.

Industry Impact and Recognition: Sustainability 2.0 Integration

The new packaging is part of ITC's larger Sustainability 2.0 agenda, which aims to boost efforts on all fronts to fight climate change, make the switch to a net-zero economy, and make a circular economy work for post-consumer packaging waste. Aashirvaad is a leading brand that shows how to make packaging that is both environmentally friendly and commercially viable. This meets the industry's demand for realistic solutions that can be widely adopted.

Aashirvaad Organic Atta's paper-based packaging is a good example of how to design packaging that is beneficial for the environment. It uses renewable resources, uses very little plastic, makes it easier to track, and maintains its function. The design solves the problem of sustainability research being done in pieces by using a whole approach that takes into account environmental, social, and economic factors. This case shows that eco-friendly packaging may suit modern consumer needs and government rules while still being good for people, the earth, and making money.

5.5.2 PUMA Clever Little Bag: A Case Study in Sustainable Packaging Design Innovation (P2)

PUMA's "Clever Little Bag," which was made in collaboration with fuse project, is a ground breaking example of SPD that shows how creative thinking can lead to big environmental gains while still being useful. This report looks at the design's environmental impact and long-term viability using scientific research and data that can be measured. PUMA's Clever Little Bag, which came out in 2010, changed the way shoes are packaged by replacing the traditional shoebox with a new hybrid system that combines a simple cardboard frame with a reusable non-woven bag. The design came out of a thorough 21-month research and development process that looked at the full product lifespan to find ways to make it more environmentally friendly.

Design Innovation and Structure

Material Composition and Design Philosophy

The Clever Little Bag is made of "a die-cut sheet of thin-gauge recycled paperboard that doesn't have any ink on it and tapers to make four walls. A 20 percent, non-woven polypropylene bag holds the walls in place." This new way of thinking about packaging asks why shoes, which are usually not square or stiff, should be wrapped in traditional box shapes.

Key Design Elements:

a. **Minimal Cardboard Frame**: Uses 65% less cardboard than the standard shoebox
b. **Reusable Bag Component**: Made from recyclable non-woven polypropylene
c. **Integrated Handle**: Eliminates need for additional plastic shopping bags
d. **Stackable Structure**: Maintains retail infrastructure compatibility

Environmental Impact Assessment

Life Cycle Assessment (LCA) Validation

PUMA used life cycle assessment to guide the re-design of PUMA's Red Shoe Box, concluding that the material-efficient design of the "Clever Little Bag" concept would offer reductions for all considered environmental impacts compared to the current Red Shoe Box. This comprehensive LCA approach aligns with established sustainable packaging methodologies that evaluate environmental performance from cradle to grave.

Quantified Environmental Benefits

The environmental impact reduction achieved by the Clever Little Bag demonstrates substantial sustainability improvements across multiple categories:

Annual Environmental Savings:

a. **Paper Reduction**: 8,500 tons less paper consumed
b. **Water Conservation**: 1 million liters of water saved
c. **Energy Efficiency**: 20 million megajoules of electricity saved
d. **Fuel Reduction**: 1 million liters less fuel oil used and 500,000 liters of diesel saved during transport
e. **Plastic Elimination**: 275 tons of plastic saved through replacement of traditional shopping bags

Manufacturing Impact Reduction: The design reduces water, energy and diesel consumption on the manufacturing level by more than 60% per year

Material Science and Environmental Performance

The substantial reduction in cardboard usage aligns with research demonstrating that corrugated packaging has achieved a 50% per-unit reduction in greenhouse gas emissions between 2006 and 2020. The Clever Little Bag's 65% reduction in cardboard usage directly contributes to lower environmental impact across multiple categories including water usage, energy consumption, and greenhouse gas emissions.

Life Cycle Assessment Methodology

The design development process exemplifies best practices in SPD by performing a full audit of the packaging's life cycle, from manufacturing to distribution to retail, in order to fully understand the environment they were designing for. This comprehensive approach addresses the critical need for systematic environmental assessment that evaluates packaging impact from raw material extraction through end-of-life disposal.

Infrastructure Compatibility and Scalability

The design's success demonstrates that "any design can reduce material use, but the brilliance of this design was that it required no changes in Puma's existing global infrastructure". This compatibility factor is crucial for large-scale sustainability implementation, as research indicates that infrastructure adaptability significantly influences the adoption success of sustainable packaging solutions.

Circular Economy Integration

Reusability and Multi-functional Design

The Clever Little Bag embodies circular economy principles through its designed reusability. The "clever little bag" is an iconic brand element upon leaving the store as it replaces the plastic shopping bag, and can also be repurposed for creative reuse. This multi-functional approach extends the packaging lifecycle beyond single-use applications, supporting waste reduction and resource efficiency.

End-of-Life Considerations

The bag is made of non-woven polyester consisting of polypropylene, and eventually is also recyclable. This recyclability attribute ensures that even at end-of-life, the packaging components can be reintegrated into material cycles rather than contributing to waste streams.

Industry Impact and Recognition

Design Awards and Recognition

The Clever Little Bag received significant industry recognition, including the Core77 Design Award 2011 Winner for Packaging, validating its innovation and sustainability credentials within the design community.

Market Response and Brand Impact

This design resulted in a frenzy of positive PR, and almost a decade later it remains the go to example of a well executed sustainable packaging redesign. The design's lasting influence on sustainable packaging discourse demonstrates its significance as a benchmark for industry innovation.

PUMA's Clever Little Bag represents a paradigmatic example of SPD that successfully integrates environmental responsibility with functional excellence and commercial viability. Through comprehensive life cycle assessment methodology, innovative material utilization, and infrastructure-compatible design, the project achieved quantifiable environmental benefits including 65% cardboard reduction, 60% manufacturing impact reduction, and substantial savings in water, energy, and plastic consumption.

The design's scientific approach to sustainability assessment, combined with its demonstration of circular economy principles and multi-functional reusability, establishes it as a benchmark for sustainable packaging innovation. Despite its eventual discontinuation, the Clever Little Bag continues to influence sustainable packaging research and development, providing a framework for integrating environmental performance with commercial requirements in packaging design.

5.5.3 Nykaa Paper Lipstick as an Example of Sustainable Product Design: A Research Report (P3)

Nykaa's 'Masaba by NYKAA' collection features HCP's stock full-size Paper Lipstick in 12 variations, utilizing HCP's super smooth full-size lipstick mechanism with a highly effective chamfered collar that helps prevent fraying of the cap during repeated use. The Paper Lipstick uses HCP's super smooth lipstick mechanism plus a highly effective chamber at the base of the metal A-shell that prevents fraying of the sleeve during repeated use, and is FSC certified.

This report examines Nykaa's paper lipstick packaging as an exemplary case of Sustainable Product Design (SPD), demonstrating how the beauty industry can integrate environmental responsibility into product development while maintaining commercial viability. The analysis reveals that Nykaa's paper lipstick embodies key SPD principles through material choice, circular economy integration, and consumer perception management, positioning it as a model for sustainable cosmetics packaging.

Sustainable product design (SPD) has emerged as a critical business consideration, with organizations focusing on sustainable product design standing to gain from improved compliance, reduced emissions, and reduced resource scarcity concerns, while also reaping benefits such as increased revenue growth and improved relationships with customers and employees. The cosmetics industry, which generates over 120 billion units of packaging annually with most ending up in landfills, faces particular pressure to adopt sustainable practices (Goldn, 2022).

The European Union Joint Research Commission shares that over 80 percent of all product-related climate impacts are determined throughout the design stage of a product, making sustainable product design a critical factor in a business sustainability strategy. This makes Nykaa's paper lipstick packaging a compelling case study for examining how SPD principles can be effectively implemented in the cosmetics sector.

Key SPD Principles

Research identifies several core principles of sustainable product design:

1. **Material Selection**: Use non-toxic, sustainably produced, or recycled materials which have a lower environmental impact than traditional materials

2. **Manufacturing Efficiency**: Use manufacturing processes and produce products which are more energy efficient than traditional processes and end products
3. **Product Longevity**: Build longer-lasting and better-functioning products which will have to be replaced less frequently, which reduces the impact of producing replacements
4. **End-of-Life Considerations**: Design products for reuse and recycling. Make them easy to disassemble so that the parts can be reused to make new products

SPD Principles in Nykaa's Paper Lipstick

Sustainable Material Selection

Paper is considered one of the most environmentally friendly materials available, with consumers highlighting the negative environmental impact of plastic packaging, while paper is reported to be more environmentally friendly. Paper packaging is a renewable resource and can be recycled, while plastic packaging is not biodegradable and takes centuries to decompose.

FSC Certification Benefits

The use of FSC-certified paper ensures that materials come from responsibly managed forests, helping to reduce deforestation and promote biodiversity. FSC certification allows businesses to demonstrate environmental responsibility and supports sustainable practices that help protect forests, wildlife habitats, and local communities.

Paper and packaging are some of the most widely used forest-based products, so ensuring they are sustainably sourced is crucial to protecting healthy, resilient forests. FSC certification allows companies to provide the responsible choices consumers want and demonstrate commitment to forests worldwide.

Perceived Environmental Friendliness

Research documents the perceived environmental friendliness (PEF) bias whereby consumers judge plastic packaging with additional paper to be more environmentally friendly than identical plastic packaging without the paper. The PEF bias is driven by consumers' "paper = good, plastic = bad" beliefs.

57 to 60 percent of US consumers rank glass, paperboard, and paper as extremely or very sustainable, ranking these materials higher than plastic alternatives.

Market Demand for Sustainability

Nykaa aims to bring sustainable brands to consumers while promoting overall awareness around environment-friendly products. The brand itself uses 100% recyclable paper for its outer cardboard packaging and has made several attempts to reduce the use of plastic.

A survey found that 57% of US consumers are more likely to buy products with eco-friendly or recyclable packaging, underscoring the urgent need for improved recycling systems and sustainable packaging solutions.

Packaging in Circular Economy

Packaging design has been recognised as the fundamental stepping-stone towards a circular economy. Resources should be kept in closed loops, thereby generating zero waste.

The cosmetic industry is investigating Circular Economy (CE) as a paradigm which could support companies in the transition towards a sustainable future, with packaging solutions being one of the key areas for circular practices.

Recyclability and End-of-Life

Paper tube packaging is made of 90% recycled paper certified by FSC, creating zero waste packaging that is fully FSC certified and creates a good appearance while being affordable and natural.

Functional Design Features

The Paper Lipstick features HCP's super smooth full-size lipstick mechanism with a highly effective chamfered collar that helps prevent fraying of the cap during repeated use, ensuring durability while maintaining sustainability.

The design enables full colour printing with special touches such as foils and spot UV to make logos pop, giving brands the opportunity to create highly detailed graphics and vivid designs.

Strategic Positioning

Nykaa's paper lipstick demonstrates how SPD can serve multiple strategic objectives:

a. **Environmental Responsibility**: Through FSC-certified materials and renewable resource utilization
b. **Market Differentiation**: Leveraging consumer preference for sustainable packaging
c. **Brand Positioning**: Establishing credibility in the sustainability space
d. **Innovation Leadership**: Pioneering sustainable solutions in cosmetics packaging

Best Practices Identified

a. **Third-Party Certification**: Use of FSC certification provides credible sustainability claims
b. **Functional Integration**: Maintaining product performance while improving environmental impact
c. **Aesthetic Appeal**: Demonstrating that sustainability doesn't compromise visual design
d. **Supply Chain Integration**: Working with specialized suppliers like HCP for sustainable solutions

Nykaa's paper lipstick exemplifies effective implementation of sustainable product design principles within the cosmetics industry. By combining FSC-certified materials, functional design innovation, and strategic market positioning, the product demonstrates that sustainability can be successfully integrated into cosmetics packaging without compromising performance or aesthetic appeal.

Sustainable product design is instrumental in improving the sustainability of a product throughout its entire life cycle, requiring consideration of a spectrum of influential factors. Nykaa's approach addresses multiple SPD factors including material selection, environmental impact reduction, and consumer perception management.

The case study reveals that successful SPD implementation requires a holistic approach that considers environmental impact, consumer preferences, functional requirements, and business objectives. As the cosmetics industry faces increasing pressure to adopt sustainable practices, Nykaa's paper lipstick serves as a valuable model for balancing commercial success with environmental responsibility.

5.5.4 TATA Tea 1868 Tin Packaging: A Sustainable Product Design Case Study (P4)

This report examines TATA Tea 1868's premium copper-colored tin packaging as an exemplary case of Sustainable Product Design (SPD), demonstrating how luxury brand positioning can be successfully integrated with environmental responsibility. The analysis reveals that TATA Tea 1868 embodies key SPD principles through material choice, circular economy integration, aesthetic appeal, and comprehensive corporate sustainability strategy, positioning it as a model for sustainable luxury packaging in the beverage industry. Sustainable product design (SPD) has emerged as a critical business imperative, with organizations focusing on sustainable practices standing to gain improved compliance, reduced emissions, and enhanced customer relationships while achieving revenue growth. The packaging industry, particularly in the luxury segment, faces unique challenges in balancing aesthetic appeal, functionality, and environmental responsibility. TATA Tea 1868's tin packaging strategy provides a compelling case study for examining how premium brands can successfully implement SPD principles without compromising their luxury positioning.

Product Overview: TATA Tea 1868

TATA Tea 1868 represents a specially curated range of 13 luxury teas launched to celebrate the 150th anniversary of the Tata Group. First unveiled at the World Economic Forum (WEF) in Davos, Switzerland in January 2018, this collection marked the celebrations of the Tata Group's 150-year-old legacy. The packaging utilizes premium copper colored tin packs which, in addition to cueing premiumness, makes for perfect gifting collectables and allows 1868 to play a role in the luxury gifting and restaurants and catering markets.

Sustainable Product Design Framework Analysis

Tin as a Sustainable Material

Tin is both luxurious and sustainable, completely recyclable without loss of quality, with many countries achieving tin recycling rates of over 90%. Tin packaging offers infinite recyclability, with 80% of metal produced still available for use today, demonstrating the material's exceptional durability and circular potential.

Environmental Performance

Tin packaging offers a significantly reduced environmental footprint compared to alternative packaging materials, with lightweight nature translating to lower transportation costs and energy consumption. Tin cans require less energy to produce than glass and aluminum, reducing their overall carbon footprint compared to other packaging options.

Recyclability and Resource Conservation

Metal based packaging materials provide excellent barrier properties and are infinitely recyclable without compromising quality or properties. Metal packaging is 100% recyclable an infinite number of times, renewable, and permanent, keeping materials in the infinite loop of metal recycling.

Reusability and Extended Product Life

Tin containers can be easily repurposed or upcycled by consumers for storage, organization, or creative DIY projects, encouraging a culture of reusability and reducing overall environmental footprint. This secondary functionality extends the product lifecycle beyond its primary purpose, embodying circular economy principles.

Corporate Sustainability Strategy

Tata Consumer Products promises to deliver products that are fit-for-purpose, resource-efficient, made from low-impact materials, and reusable or recyclable at the end of its life. The company is 100 percent EPR (Extended Producer Responsibility) compliant and has achieved 500 tonnes of plastic packaging reduction through packaging optimization.

Industry Leadership in Sustainability

Tata Consumer Products signed up as a founding member of the India Plastics Pact in September 2021 and is a member of the UK Plastics Pact (since 2018) and the Europe Plastics Pact (since 2021), demonstrating comprehensive commitment to sustainable packaging across global markets.

Premium Market Integration

Tin is a highly customisable choice for high-end products with enormous print options available on tin plate, adorned with emboss, deboss and various other finishes. The packaging depicts Indian stories of tea with graphics and post-finish processes such as foiling and spot UV enhancing each element of the pack.

Consumer Perception and Market Response

Many consumers associate tins with quality and luxury, which can be a significant selling point for brands looking to differentiate themselves in the market. According to Bain & Company, 50% of consumers now consider sustainability one of their top four purchase criteria, indicating strong market alignment.

Life Cycle Assessment Perspective

Life cycle assessment research demonstrates that sustainable packaging must be effective, efficient, and safe for human health and the environment, with direct environmental effects, packaging-related waste reduction, and circularity as key sustainability aspects.

Metal packaging provides excellent barrier properties for food applications while offering recyclability, ability to withstand high heating temperatures, rigid structure, and unique decorating possibilities.

Sustainable Packaging Research

Research indicates that packaging materials contribute significantly to product costs and environmental influence, with metal packaging offering superior recyclability compared to other materials. Life cycle assessment studies show that metal packaging formats, including cans, demonstrate favourable environmental performance when evaluated against comprehensive sustainability criteria.

Strategic Implications for Sustainable Product Design

Integration of Luxury and Sustainability

TATA Tea 1868 demonstrates that luxury positioning and environmental responsibility are not mutually exclusive. The premium tin packaging enhances perceived value while delivering superior environmental performance compared to alternative materials.

Circular Economy Implementation

The packaging strategy exemplifies practical circular economy implementation through:

a. Material selection prioritizing infinite recyclability
b. Design for reusability and secondary applications
c. Integration with established recycling infrastructure

Corporate Sustainability Leadership

TATA Consumer Products' comprehensive approach to sustainability, including EPR compliance and international pact memberships, provides the necessary organizational framework for effective SPD implementation.

TATA Tea 1868's tin packaging exemplifies successful integration of sustainable product design principles within luxury market positioning. The environmental benefits of tin packaging underscore its pivotal role in fostering sustainability and driving positive change in the packaging industry. By combining premium aesthetic appeal with superior environmental performance, the product demonstrates that sustainability can enhance rather than compromise luxury brand values.

The case study reveals that effective SPD implementation requires holistic consideration of material properties, corporate sustainability strategy, consumer preferences, and circular economy principles. Sustainable packaging must be effective, efficient, and safe for human health and the environment while addressing direct environmental effects, waste reduction, and circularity.

As the packaging industry continues to evolve toward greater environmental responsibility, TATA Tea 1868's approach provides a valuable model for luxury brands seeking to integrate sustainability into their core value proposition without sacrificing aesthetic appeal or market positioning.

5.5.5 NUA Sanitary Packaging: A Sustainable Product Design Case Study (P5)

This report examines NUA sanitary pads packaging as an exemplary case of Sustainable Product Design (SPD), demonstrating how feminine hygiene products can integrate environmental responsibility, user convenience, and social consciousness. The analysis reveals that NUA's packaging strategy embodies key SPD principles through innovative paper-based disposal systems, minimalist design aesthetics, biodegradable materials, and holistic consideration of the product lifecycle, positioning it as a model for sustainable packaging in the feminine hygiene industry. The feminine hygiene products market faces significant environmental challenges, with over 12 billion disposable menstrual hygiene products utilized annually, producing around 245,000 tonnes of CO_2 annually and containing plastics that can take up to 500 years to decompose in landfills. Sustainable product design (SPD) in this sector requires careful consideration of environmental impact, user needs, and social acceptability. NUA's packaging approach provides a compelling case study for examining how feminine hygiene brands can successfully implement SPD principles while addressing the unique challenges of discretion, hygiene, and disposal in this product category.

Product Overview: NUA Sanitary Packaging System

NUA is a feminine care brand offering 100% safe, toxin-free, and rash-free sanitary pads with an innovative packaging system. Each NUA pad comes in an individual paper-based disposal cover with a reseal-able flap, designed for secure, worry-free disposal. The sleek, customizable packs utilise neutral tones and minimalistic design, catering to modern women seeking discretion and personalisation. The product is Made Safe Certified by Safe Cosmetics Australia, ensuring the exclusion of potentially toxic chemicals and clinical testing for skin safety.

Sustainable Product Design Framework Analysis

Paper-Based Disposal System

NUA's paper-based hygienic disposal covers represent a significant innovation in sustainable feminine hygiene packaging. Paper is considered one of the most environmentally friendly materials available, with superior biodegradability compared to conventional plastic packaging. The paper-based disposal system addresses the critical environmental challenge that most disposable menstrual products face inadequate disposal methods, with 15% burned, 18% thrown in rivers or streets, and 9% flushed down toilets.

Biodegradable Materials Integration

The individual biodegradable Secure Shield Covers are described as eco-friendly materials contributing to a healthier planet. Research indicates that biodegradable polymers emerged as an alternative approach for many industrial applications to control the risk caused by non-biodegradable plastic, offering advantages for waste management systems to realize overall environmental benefits.

Individual Packaging for Hygiene and Discretion

Each pad comes with its own disposal cover, addressing the fundamental hygiene requirements that are non-negotiable in the sanitary napkin segment. The design ensures products are untouched and clean while providing discrete disposal solutions. Modern women need solutions that fit their busy lives, and packaging that is discreet, compact, and easy to carry adds tremendous value.

Re-sealable Functionality

The disposal covers feature re-sealable flaps, allowing users to place used pads into the cover, seal the flap, and discard safely. This design addresses consumer needs for convenient disposal methods while maintaining privacy and hygiene standards.

Minimalist Design Philosophy and Environmental Integration

NUA's neutral colors and simple design are examples of sustainable packaging concepts that put function before excess. Research on consumers shows that eco-friendly packaging should use as little packing as possible. For example, people say things like "don't over-package products; use just enough packaging to keep them safe and of good quality." The design philosophy fits with what customers want: packaging that is clearly labelled for sustainability and stands out from less sustainable options.

Consumer Perception Benefits

The aesthetic appeal of paper-based packaging materials is generally described as "looks natural," "biodegradable," and "recyclable," which are positive features expected from sustainable packaging materials. The minimalist approach reduces material usage while maintaining product integrity and brand appeal.

Lifecycle Considerations and Disposal Innovation (End-of-Life Management)

The paper-based disposal solution solves the most important problem with managing period hygiene: how to safely throw away old menstrual management products. Menstrual health depends on having the right infrastructure for disposal, and NUA's design makes it easier to dispose of things in a responsible way. Research shows that good menstrual hygiene practices require access to safe and convenient facilities to dispose of used materials.

Waste Reduction Strategy

By providing individual disposal covers, NUA reduces the need for additional packaging materials at point of disposal, streamlining the waste management process. This approach aligns with sustainable packaging principles that focus on waste reduction and responsible consumption throughout the product lifecycle.

Environmental Impact of Feminine Hygiene Products

Life cycle assessment research demonstrates that the environmental impacts of feminine hygiene products remain largely unquantified, with most materials utilized in production being plastic-based and produced from non-renewable resources. The prevalence of non-recyclable and non-biodegradable disposable menstrual products harms the environment through water pollution, landfill contribution, and microplastic generation.

Sustainable Packaging Material Research

Academic studies confirm that paper-based packaging materials offer significant environmental advantages. Research indicates that biodegradable packaging materials can successfully replace petroleum-based materials and solve environmental problems caused by their use or deposition. Consumer studies show that participants perceive paper-based packages as natural, biodegradable, and recyclable.

Consumer Behaviour and Disposal Practices

Studies show that how people use single-use menstrual products and packaging systems has a big effect on the environment. Research shows that a lot of people don't know about the health and environmental issues with feminine hygiene products. This shows how important it is to design packaging that makes it easy to throw away these goods in a responsible way.

Strategic Implications for Sustainable Product Design

Holistic System Design

NUA's method shows that good SPD in feminine hygiene means looking at the whole product system, from the main package to the ways it may be thrown away and how it feels to use. Putting disposal covers on each pad makes a closed-loop system that meets both environmental and human needs at the same time.

Material Selection Strategy

Using paper-based materials for disposal covers is an example of strategic material selection that strikes a compromise between environmental performance and functional needs. The fact that the disposal mechanism is biodegradable meets customer expectations for eco-friendly packaging while also fulfilling hygiene and privacy needs.

Design for Behaviour Change

The packaging design makes it easy and discreet to throw away things in a responsible way, which encourages good disposal habits. This technique takes into account studies that shows that a lot of women throw things away in the wrong way since there aren't enough good disposal options and infrastructure.

NUA's sanitary packaging is a great example of how to use sustainable product design concepts in a tough area like feminine hygiene products. The new paper-based disposal system meets several SPD goals: it is environmentally friendly since it uses biodegradable materials, it is easy for users to use because each item is packaged separately, and it is socially responsible because it has discreet disposal methods. The case study shows that to successfully use SPD in feminine hygiene, you need to carefully balance environmental performance, functional needs, and social acceptability. NUA shows that sustainability may improve product functioning and user experience rather than hurt them by combining minimalist design with new ways to get rid of things.

There isn't much scientific research on the environmental effects of menstrual products, and it's hard to measure them. NUA's plan to incorporate paper-based disposal devices is a big step toward solving the environmental problems that come with feminine hygiene products while also keeping the privacy and cleanliness standards that customers expect. NUA's packaging strategy is a great example for businesses that want to make sustainability a major part of their value proposition while also dealing with the unique problems that come with this type of product. This is especially important now that the feminine hygiene industry is under more pressure to deal with its environmental effect.

5.6 RESULTS

The "Results" section constitutes the empirical basis of this research. It accomplishes this by systematically summarising facts acquired within the specified methodological framework, devoid of any interpretation or analytical data. This part commences with basic descriptive statistics and progresses to intricate analytical findings, featuring a systematic organisational framework that navigates readers through the data in a coherent and logical manner. This framework is employed in this part.

To guarantee that the survey results are conveyed clearly and comprehensively, they are systematically categorised into three principal analytical groups prior to presentation. The first category assesses outcomes from the standpoint of packaging, concentrating on the analysis of expert opinions and behavioural patterns across five distinct types and qualities of packaging. In the second category, we give judgments gathered from specialists. These conclusions encompass the perspectives and assessments of industry experts and academic specialists engaged in the field. The third category emphasizes attribute-wise analysis, carefully examining how certain product attributes and features affect consumer perceptions and decision-making processes. This tripartite organizational structure facilitates a thorough examination of the research data while maintaining analytical rigor and ensuring that readers can easily navigate through the empirical evidence that forms the basis for subsequent discussion and interpretation. Mentioned below in Table 5.2 shows the RII for P1: Aashirvaad Organic atta from, Industry’s, entrepreneur's and Academia’s perspective respectively:

Table 5.2: RII index of P1 from the Industry's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	3	7	10	0.85	85.00%	Very High
REUSABLE	2	5	3	10	0.55	55.00%	Medium
AFFORDABLE	1	4	5	10	0.7	70.00%	High
ADAPTABLE	0	6	4	10	0.7	70.00%	High
ACCESSIBLE	1	3	6	10	0.75	75.00%	High
DURABLE	0	7	3	10	0.65	65.00%	Medium-High
FUNCTIONAL	0	2	8	10	0.9	90.00%	Very High
AESTHETICS	1	3	6	10	0.75	75.00%	High
INFORMATIVE	0	3	7	10	0.85	85.00%	Very High

Table 5.3: RII index of P1 from the Entrepreneur's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	2	8	10	0.9	85.00%	Very High
REUSABLE	3	3	4	10	0.55	55.00%	Medium
AFFORDABLE	0	3	7	10	0.85	70.00%	High
ADAPTABLE	0	3	7	10	0.85	70.00%	High
ACCESSIBLE	0	2	8	10	0.9	75.00%	High
DURABLE	0	5	5	10	0.75	65.00%	Medium-High
FUNCTIONAL	1	2	7	10	0.8	90.00%	Very High
AESTHETICS	0	4	6	10	0.8	75.00%	High
INFORMATIVE	0	2	8	10	0.9	85.00%	Very High

Table 5.4: RII index of P1 from the Academia's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	5	5	10	0.75	85.00%	Very High
REUSABLE	2	3	5	10	0.65	55.00%	Medium
AFFORDABLE	0	3	7	10	0.85	70.00%	High
ADAPTABLE	1	3	6	10	0.75	70.00%	High
ACCESSIBLE	0	4	6	10	0.8	75.00%	High
DURABLE	0	5	5	10	0.75	65.00%	Medium-High
FUNCTIONAL	0	5	5	10	0.75	90.00%	Very High
AESTHETICS	0	7	3	10	0.65	75.00%	High
INFORMATIVE	0	1	9	10	0.95	85.00%	Very High

Table 5.5: RII index of P2 (PUMA – The clever Bag) from the Industry's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	1	9	10	0.95	85.00%	Very High
REUSABLE	0	2	8	10	0.9	55.00%	Medium
AFFORDABLE	1	3	6	10	0.75	70.00%	High
ADAPTABLE	1	0	9	10	0.9	70.00%	High
ACCESSIBLE	0	2	8	10	0.9	75.00%	High
DURABLE	0	2	8	10	0.9	65.00%	Medium-High
FUNCTIONAL	0	0	10	10	1	90.00%	Very High
AESTHETICS	0	1	9	10	0.95	75.00%	High
INFORMATIVE	0	2	8	10	0.9	85.00%	Very High

Table 5.6: RII index of P2 from the Entrepreneur's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	1	9	10	0.95	85.00%	Very High
REUSABLE	1	1	8	10	0.85	55.00%	Medium
AFFORDABLE	0	4	6	10	0.8	70.00%	High
ADAPTABLE	0	1	9	10	0.95	70.00%	High
ACCESSIBLE	0	2	8	10	0.9	75.00%	High
DURABLE	0	2	8	10	0.9	65.00%	Medium-High
FUNCTIONAL	0	0	10	10	1	90.00%	Very High
AESTHETICS	0	1	9	10	0.95	75.00%	High
INFORMATIVE	0	1	9	10	0.95	85.00%	Very High

Table 5.7: RII index of P2 from the Academia's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	0	10	10	1	85.00%	Very High
REUSABLE	0	4	6	10	0.8	55.00%	Medium
AFFORDABLE	1	3	6	10	0.75	70.00%	High
ADAPTABLE	0	4	6	10	0.8	70.00%	High
ACCESSIBLE	0	4	6	10	0.8	75.00%	High
DURABLE	0	3	7	10	0.85	65.00%	Medium-High
FUNCTIONAL	0	3	7	10	0.85	90.00%	Very High
AESTHETICS	0	1	9	10	0.95	75.00%	High
INFORMATIVE	1	3	6	10	0.75	85.00%	Very High

Table 5.8: RII index of P3 (Nykaa – Paper Lipstick) from the Industry's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	1	2	7	10	0.8	85.00%	Very High
REUSABLE	2	2	6	10	0.7	55.00%	Medium
AFFORDABLE	1	3	6	10	0.75	70.00%	High
ADAPTABLE	1	1	8	10	0.85	70.00%	High
ACCESSIBLE	2	3	5	10	0.65	75.00%	High
DURABLE	1	2	7	10	0.8	65.00%	Medium-High
FUNCTIONAL	1	3	6	10	0.75	90.00%	Very High
AESTHETICS	1	2	7	10	0.8	75.00%	High
INFORMATIVE	1	2	7	10	0.8	85.00%	Very High

Table 5.9: RII index of P3 from the Entrepreneur's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	1	1	8	10	0.85	85.00%	Very High
REUSABLE	1	4	5	10	0.7	55.00%	Medium
AFFORDABLE	0	4	6	10	0.8	70.00%	High
ADAPTABLE	1	0	9	10	0.9	70.00%	High
ACCESSIBLE	0	2	8	10	0.9	75.00%	High
DURABLE	0	3	7	10	0.85	65.00%	Medium-High
FUNCTIONAL	1	2	7	10	0.8	90.00%	Very High
AESTHETICS	0	2	8	10	0.9	75.00%	High
INFORMATIVE	0	1	9	10	0.95	85.00%	Very High

Table 5.10: RII index of P3 from the Academia's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	**0**	**1**	**2**				
PROTECTION	0	4	6	10	**0.8**	**85.00%**	**Very High**
REUSABLE	2	5	3	10	**0.55**	**55.00%**	**Medium**
AFFORDABLE	0	3	7	10	**0.85**	**70.00%**	**High**
ADAPTABLE	1	4	5	10	**0.7**	**70.00%**	**High**
ACCESSIBLE	0	4	6	10	**0.8**	**75.00%**	**High**
DURABLE	0	6	4	10	**0.7**	**65.00%**	**Medium-High**
FUNCTIONAL	0	3	7	10	**0.85**	**90.00%**	**Very High**
AESTHETICS	0	1	9	10	**0.95**	**75.00%**	**High**
INFORMATIVE	0	2	8	10	**0.9**	**85.00%**	**Very High**

Table 5.11: RII index of P4 (TATA Tea - 1868) from the Industry's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	**0**	**1**	**2**				
PROTECTION	0	1	9	10	**0.95**	**85.00%**	**Very High**
REUSABLE	0	2	8	10	**0.9**	**55.00%**	**Medium**
AFFORDABLE	0	2	8	10	**0.9**	**70.00%**	**High**
ADAPTABLE	0	0	10	10	**1**	**70.00%**	**High**
ACCESSIBLE	0	3	7	10	**0.85**	**75.00%**	**High**
DURABLE	0	2	8	10	**0.9**	**65.00%**	**Medium-High**
FUNCTIONAL	0	0	10	10	**1**	**90.00%**	**Very High**
AESTHETICS	0	2	8	10	**0.9**	**75.00%**	**High**
INFORMATIVE	0	1	7	9	**0.75**	**85.00%**	**Very High**

Table 5.12: RII index of P4 from the Entrepreneur's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	0	10	10	1	85.00%	Very High
REUSABLE	0	0	10	10	1	55.00%	Medium
AFFORDABLE	0	6	4	10	0.7	70.00%	High
ADAPTABLE	0	2	8	10	0.9	70.00%	High
ACCESSIBLE	0	3	7	10	0.85	75.00%	High
DURABLE	0	0	10	10	1	65.00%	Medium-High
FUNCTIONAL	0	1	9	10	0.95	90.00%	Very High
AESTHETICS	0	1	9	10	0.95	75.00%	High
INFORMATIVE	0	1	9	10	0.95	85.00%	Very High

Table 5.13: RII index of P4 from the Academia's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	0	10	10	1	85.00%	Very High
REUSABLE	1	1	8	10	0.85	55.00%	Medium
AFFORDABLE	0	5	5	10	0.75	70.00%	High
ADAPTABLE	0	4	6	10	0.8	70.00%	High
ACCESSIBLE	0	6	4	10	0.7	75.00%	High
DURABLE	0	3	7	10	0.85	65.00%	Medium-High
FUNCTIONAL	0	0	10	10	1	90.00%	Very High
AESTHETICS	0	1	9	10	0.95	75.00%	High
INFORMATIVE	0	4	6	10	0.8	85.00%	Very High

Table 5.14: RII index of P5 (NUA – Women Hygiene Product) from the Industry's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	**0**	**1**	**2**				
PROTECTION	0	2	8	10	**0.9**	**85.00%**	**Very High**
REUSABLE	0	3	7	10	**0.85**	**55.00%**	**Medium**
AFFORDABLE	0	0	10	10	**1**	**70.00%**	**High**
ADAPTABLE	0	4	6	10	**0.8**	**70.00%**	**High**
ACCESSIBLE	0	3	7	10	**0.85**	**75.00%**	**High**
DURABLE	0	4	6	10	**0.8**	**65.00%**	**Medium-High**
FUNCTIONAL	0	0	10	10	**1**	**90.00%**	**Very High**
AESTHETICS	0	2	8	10	**0.9**	**75.00%**	**High**
INFORMATIVE	1	2	7	10	**0.8**	**85.00%**	**Very High**

Table 5.15: RII index of P5 from the Entrepreneur's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	**0**	**1**	**2**				
PROTECTION	0	1	9	10	**0.95**	**85.00%**	**Very High**
REUSABLE	3	3	4	10	**0.55**	**55.00%**	**Medium**
AFFORDABLE	0	5	5	10	**0.75**	**70.00%**	**High**
ADAPTABLE	1	1	8	10	**0.85**	**70.00%**	**High**
ACCESSIBLE	0	3	7	10	**0.85**	**75.00%**	**High**
DURABLE	0	4	6	10	**0.8**	**65.00%**	**Medium-High**
FUNCTIONAL	0	2	8	10	**0.9**	**90.00%**	**Very High**
AESTHETICS	0	2	8	10	**0.9**	**75.00%**	**High**
INFORMATIVE	0	1	9	10	**0.95**	**85.00%**	**Very High**

Table 5.16: RII index of P5 from the Academician's perspective

Parameter	Rating 0	Rating 1	Rating 2	Total N	RII Value	RII %	Importance
Weights →	0	1	2				
PROTECTION	0	3	7	10	**0.85**	**85.00%**	**Very High**
REUSABLE	0	5	5	10	**0.75**	**55.00%**	**Medium**
AFFORDABLE	0	3	7	10	**0.85**	**70.00%**	**High**
ADAPTABLE	1	2	7	10	**0.8**	**70.00%**	**High**
ACCESSIBLE	0	4	6	10	**0.8**	**75.00%**	**High**
DURABLE	0	3	7	10	**0.85**	**65.00%**	**Medium-High**
FUNCTIONAL	0	2	8	10	**0.9**	**90.00%**	**Very High**
AESTHETICS	0	2	8	10	**0.9**	**75.00%**	**High**
INFORMATIVE	0	3	7	10	**0.85**	**85.00%**	**Very High**

Mentioned below in Table 5.17 – 5.19 shows the Mean of RII for all five packaging from respective experts:

Table 5.17: Mean of each packaging and attributes from Industry Experts

Attributes	P1	P2	P3	P4	P5	Mean of Each attribute
Weights →						
PROTECTION	0.85	0.95	0.8	0.95	0.9	**0.89**
REUSABLE	0.55	0.9	0.7	0.9	0.85	**0.78**
AFFORDABLE	0.7	0.75	0.75	0.9	1	**0.82**
ADAPTABLE	0.7	0.9	0.85	1	0.8	**0.85**
ACCESSIBLE	0.75	0.9	0.65	0.85	0.85	**0.8**
DURABLE	0.65	0.9	0.8	0.9	0.8	**0.81**
FUNCTIONAL	0.9	1	0.75	1	1	**0.93**
AESTHETICS	0.75	0.95	0.8	0.9	0.9	**0.86**
INFORMATIVE	0.85	0.9	0.8	0.75	0.8	**0.82**
Mean of Each Packaging	**0.74**	**0.91**	**0.77**	**0.91**	**0.88**	

Table 5.18: Mean of each packaging and attributes from Entrepreneur Experts

Attributes	**P1**	**P2**	**P3**	**P4**	**P5**	**Mean of Each Attribute**
Weights →						
PROTECTION	0.9	0.95	0.85	1	0.95	**0.93**
REUSABLE	0.55	0.85	0.7	1	0.55	**0.73**
AFFORDABLE	0.85	0.8	0.8	0.7	0.75	**0.78**
ADAPTABLE	0.85	0.95	0.9	0.9	0.85	**0.89**
ACCESSIBLE	0.9	0.9	0.9	0.85	0.85	**0.88**
DURABLE	0.75	0.9	0.85	1	0.8	**0.86**
FUNCTIONAL	0.8	1	0.8	0.95	0.9	**0.89**
AESTHETICS	0.8	0.95	0.9	0.95	0.9	**0.9**
INFORMATIVE	0.9	0.95	0.95	0.95	0.95	**0.94**
Mean of Each Packaging	**0.81**	**0.92**	**0.85**	**0.92**	**0.83**	

Table 5.19: Mean of each packaging and attributes from Academia's Experts

Parameter	**P1**	**P2**	**P3**	**P4**	**P5**	**Mean of Each Attribute**
Weights →						
PROTECTION	0.75	1	0.8	1	0.85	**0.88**
REUSABLE	0.65	0.8	0.55	0.85	0.75	**0.72**
AFFORDABLE	0.85	0.75	0.85	0.75	0.85	**0.81**
ADAPTABLE	0.75	0.8	0.7	0.8	0.8	**0.77**
ACCESSIBLE	0.8	0.8	0.8	0.7	0.8	**0.78**
DURABLE	0.75	0.85	0.7	0.85	0.85	**0.8**
FUNCTIONAL	0.75	0.85	0.85	1	0.9	**0.87**

AESTHETICS	0.65	0.95	0.95	0.95	0.9	**0.88**
INFORMATIVE	0.95	0.75	0.9	0.8	0.85	**0.85**
Mean of Each Packaging	**0.77**	**0.84**	**0.79**	**0.86**	**0.84**	

Mentioned below in Table 5.20 shows the Mean of RII for all five packaging from all three expert panels (Industry experts, Entrepreneurs and academia) and for all Five Packaging:

Table 5.20: Mean of each packaging from all the experts

Experts	P1	P2	P3	P4	P5
Industry	0.74	0.91	0.77	0.91	0.88
Entrepreneurs	0.81	0.92	0.85	0.92	0.83
Academia	0.77	0.84	0.79	0.86	0.84
	0.77	**0.89**	**0.80**	**0.89**	**0.85**

Table 5.21: Mean of all the attributes from all the experts

ATTRIBUTES	INDUSTRY	ENTREPRENEURS	ACADEMIC	MEAN
PROTECTION	0.89	0.93	0.88	**0.9**
REUSABLE	0.78	0.73	0.72	**0.74**
AFFORDABLE	0.82	0.78	0.81	**0.80**
ADAPTABLE	0.85	0.89	0.77	**0.84**
ACCESSIBLE	0.8	0.88	0.78	**0.82**
DURABLE	0.81	0.86	0.8	**0.82**
FUNCTIONAL	0.93	0.89	0.87	**0.90**
AESTHETICS	0.86	0.9	0.88	**0.88**
INFORMATIVE	0.82	0.94	0.85	**0.87**

5.6.1 Comprehensive Framework Validation through Multi-Dimensional Analysis

The comprehensive validation analysis encompasses both cross-product and individual attribute assessments, demonstrating exceptional consensus across all framework components. The cross-product validation reveals robust agreement across all five packaging products, with Relative Importance Index (RII) mean scores ranging from 0.77 to 0.92, indicating consistently high to very high importance ratings. Product 1 achieved an RII score of 0.77, representing high importance, while Packaging 2, 3, 4, and 5 all exceeded the 0.80 threshold with scores of 0.89, 0.80, 0.89, and 0.85 respectively, establishing their classification as very high importance parameters.

The attribute-level validation provides even more compelling evidence of framework significance, with all nine attributes achieving ratings between most essential and essential importance levels. The attribute RII scores range from 0.74 to 0.90, with eight attributes (89%) classified as very high importance (RII > 0.80) and one attribute maintaining high importance status. Attribute Protection and functional emerged as the most critical components with identical mean RII scores of 0.90 followed closely by Aesthetics at 0.88 and Informative at 0.87. The remaining attributes, adaptable, accessible, durable, affordable and reusable, achieved mean scores of 0.84, 0.82, 0.82, 0.80, and 0.74, respectively, ensuring that 100% of framework attributes exceed the established validation threshold of 0.70, with remarkable consistency in the high to very high importance categories.

5.6.2 Individual Attribute Validation and Importance Classification

The individual attribute analysis reveals exceptional validation strength across all nine Framework components, with every attribute receiving ratings within the most-essential to essential importance range. The comprehensive attribute assessment demonstrates mean RII scores spanning from 0.74 to 0.90, establishing a robust foundation for the packaging framework's theoretical and practical validity. Design Attributes like Protection and functionality achieved the highest validation scores of 0.90 each, representing critical framework components that received unanimous recognition across all stakeholder groups as the most essential elements.

The attribute validation hierarchy demonstrates consistent stakeholder recognition of framework importance, with Attribute Aesthetics following closely at 0.88 and Attribute Informative at 0.87, both firmly established in the very high importance category. Attributes: affordable, adaptable and accessible. Each achieved identical or near-identical mean scores of 0.84, 0.82, and 0.82, respectively, confirming their essential status within the framework structure. Attribute affordable maintained very high importance with a mean score of 0.80, while Attribute reusable, though receiving the lowest mean score of 0.74, still achieved high importance classification and exceeded the validation threshold by a substantial margin.

The attribute-level stakeholder analysis reveals distinct but complementary perspectives across the three groups. Industry experts provided scores ranging from 0.78 to 0.93, with their highest rating assigned to Protection (0.93) and lowest to Attribute Reusable (0.78), reflecting practical implementation priorities. Entrepreneurs demonstrated the most optimistic validation approach with scores between 0.73 and 0.94, achieving their highest rating for Attribute Informative (0.94) while maintaining their lowest score of 0.73 for Reusable. Academic stakeholders contributed the most conservative yet consistently positive ratings, ranging from 0.72 to 0.88, with Attribute Protection and Aesthetics tied at their highest rating of 0.88.

The validation process incorporated three distinct stakeholder groups, each contributing unique perspectives that collectively strengthen the framework's credibility. Industry experts, representing the practical implementation perspective, provided mean scores ranging from 0.74 to 0.91 across the five products, with a group average of 0.842. Their assessment identified P2 and P4 as the highest priorities, each receiving scores of 0.91, while maintaining that all parameters demonstrate at minimum high importance with no scores below 0.74.

Entrepreneurs, offering the market-oriented perspective, demonstrated the most optimistic validation with mean scores between 0.81 and 0.92 and the highest group average of 0.866. This stakeholder group similarly prioritized P2 and P4 with identical scores of 0.92, while ensuring all parameters achieved very high importance status with minimum scores of 0.81. The entrepreneurial perspective validates the framework's market relevance and commercial viability across all packaging types.

Academic stakeholders provided the theoretical foundation with more conservative but consistently positive ratings, generating mean scores from 0.77 to 0.86 and a group average of 0.820. Academics identified P4 as the single highest priority with a score of 0.86, while maintaining that all parameters warrant high to very high importance classification. The academic validation confirms the framework's theoretical soundness and scholarly merit.

5.6.3 Cross-Group Consensus and Reliability

The inter-group consensus analysis reveals varying degrees of stakeholder agreement across the five products, with P2 and P4 demonstrating the strongest consensus. P2 achieved the highest consensus across all groups with scores ranging from 0.84 to 0.92, representing a narrow variation of 0.08 points. P4 similarly demonstrated strong consensus with scores between 0.86 and 0.92, while P5 maintained good consensus within a 0.83 to 0.88 range. P1 and P3 showed moderate consensus with ranges of 0.74 to 0.81 and 0.77 to 0.85 respectively, though still maintaining acceptable validation thresholds across all stakeholder groups.

The maximum inter-group difference of 0.18 points occurred for P2, spanning from the academic score of 0.84 to the entrepreneurial score of 0.92. This variation pattern, where entrepreneurs consistently provide higher scores than academics, with industry experts maintaining intermediate positions, reflects expected stakeholder bias while remaining within acceptable validation parameters. The systematic nature of these differences actually strengthens the validation by demonstrating predictable stakeholder perspectives rather than erratic variation.

5.6.4 Statistical Validation and Comprehensive Framework Robustness

The statistical validation provides compelling evidence of framework reliability across both product and attribute dimensions, with 100% of products and attributes exceeding the established 0.60 validation threshold while demonstrating substantial margins above minimum requirements. The attribute validation reveals particularly strong performance, with 89% of attributes achieving very high importance status (RII > 0.80) and the remaining 11% maintaining high importance classification. This exceptional performance indicates that all framework components warrant inclusion in comprehensive packaging strategies, with the attribute hierarchy providing clear guidance for implementation prioritization.

The cross-validation strength emerges from successful triangulation across practical, market, and theoretical perspectives, supported by a robust sample representation of 30 participants equally distributed across stakeholder groups. The dual validation approach, combining product-level and attribute-level analysis, creates a comprehensive validation matrix that confirms framework stability and reliability from multiple analytical perspectives. The mean RII across all products of 0.84 with a standard deviation of 0.048 and range of 0.12 indicates consistent validation with minimal variation, while the attribute mean RII of 0.82 with even tighter clustering demonstrates exceptional framework coherence.

The priority hierarchy validation establishes clear ranking systems for both packaging and attributes, enabling practical implementation guidance. At the product level, P2 and P4 tied at 0.89 average scores represent critical importance, while P5 follows at 0.85, and P3 and P1 maintain very high and high importance respectively. The attribute hierarchy places Protection and functional as most essential components at 0.90 each, followed by aesthetics, informative, adaptable, accessible, durable, affordable, and reusable in descending order of importance. This dual hierarchical structure provides comprehensive implementation guidance while confirming that all framework components, whether analysed at product or attribute levels, warrant inclusion in sustainable packaging strategies. The consistent validation across five different packaging types and nine distinct attributes with cross-stakeholder consensus confirms the framework's broad relevance and applicability across diverse packaging contexts and implementation scenarios.

5.7 SUMMARY

The framework's validity is further reinforced through empirical observation that all recognised examples of successful sustainable packaging implementations consistently incorporate the nine validated attributes identified in this study. Leading sustainable packaging solutions across various industries demonstrates comprehensive integration of these framework components, providing real-world evidence that supports the theoretical validation results. The alignment between exemplary sustainable packaging practices and the framework's attribute structure confirms that the developed framework accurately captures the essential elements required for effective sustainable packaging implementation. This convergence between theoretical validation through stakeholder assessment and practical validation through industry best practices establishes the framework's credibility and ensures its practical applicability for organisations seeking to implement comprehensive sustainable packaging strategies.

CHAPTER- 6

CONCLUSIONS

The thorough identification and prioritising of the list of SPD attributes outlined in this research creates a strong model that balances theoretical insight with practical industry implementation. Through systematic listing and ranking of 09 important attributes and grouping them by their influence on customer satisfaction based on the Kano model, this study offers stakeholders a strategic blueprint for sustainable packaging innovation. The strength of the framework is its evidence-based priority system, which separates must-have qualities (protection, reusability, affordability, adaptability, and accessibility) from those that offer competitive differentiation (Durability and functionality) and being attractive (aesthetics and informative qualities).

This attribute-based approach goes beyond conventional methods by harmonising functional, environmental, and consumer-oriented visions within a single decision-making model. The triangulated research design—concatenating exhaustive literature review, expert verification, and consumer evaluation—guarantees that the framework enjoys both theoretical robustness and practical applicability. Through the identification of the diverse effects of attributes on customer satisfaction, the framework allows packaging developers to make effective resource allocation decisions, optimising sustainability gains while ensuring market acceptability.

The hierarchical structure of the attributes in the framework gives a controlled yet flexible framework for SPD, SPIID that can be tailored to various product classes and market segments. SPD attributes like protection from which all other sustainability factors have to work, underlining those environmental gains cannot be made at the cost of the package's prime purpose. A novel three-phase framework (Initiate, Integrate, Innovate) is introduced, enabling the strategic integration of design attributes that elevate sustainable packaging performance. At the same time, the parallel emphasis placed on reusability and affordability recognises the vital synergy between environmental performance and economic feasibility that green solutions need to capture. The SPIID framework can be utilised in the packaging design industry as a very iterative process, which will allow all the stakeholders to come together and collaborate.

This framework contributes importantly to theory and practice of sustainable packaging by shifting away from silo approaches towards an integrated model that acknowledges inter-relatedness of design characteristics. It offers a shared language and evaluation methodology to various stakeholders along the packaging value chain, enabling collaboration for sustainability. When industry professionals apply this framework, they not only receive an immediate practical aid for design decisions but also a strategic filter with which to look at long-term investments in sustainability. By connecting packaging development to attributes that truly matter to consumers, this framework enables the evolution of sustainability as a compliance requirement to one of competitive differentiation, and thereby drives faster progress toward authentically sustainable packaging solutions.

6.1 Contribution of Thesis

The major contribution of this work is to provide a comprehensive model, framework, methodology, and principles that would help packaging designers develop sustainable packaging solutions that balance environmental performance, functional requirements, and consumer acceptance. The key contributions of this work are as follows:

1. **Holistic Integration of Design Thinking, Sustainability, and Empathy:** This research introduces a comprehensive, *human-centred* framework (SPIID) for SPD that integrates environmental, economic, functional, and emotional dimensions. Unlike existing policy- and technology-driven models, the proposed SPIID framework advantages *design thinking* and *stakeholder empathy* to create solutions that are both sustainable and user-friendly.
2. **Sustainable Packaging Design Attribute Identification and Prioritisation Model:** A systematic approach is developed to identify and prioritise SPD attributes through evidence-based research methodology. This work establishes a comprehensive list of 09 critical attributes that influence sustainable packaging performance, providing designers with a structured foundation for decision-making. These include critical components like *protection*, *accessibility*, *durability, aesthetics*, and *information transparency*, allowing for a quantifiable and replicable assessment of design decisions.
3. **Development of the SPIID Framework:** The SPIID framework is an actionable design tool structured in three iterative phases: *Initiate, Integrate, and Innovate*. It enables designers, manufacturers, and stakeholders to collaboratively map, refine, and implement sustainable packaging solutions. The framework is scalable and adaptable across industries and packaging types by utilising the 5-step method.

4. **Validated through Real-World Applications:** The framework is validated using five industry case studies (e.g., Puma, Nykaa, Nua, Tata Tea, and Aashirvaad) and evaluated by 30 experts from academia, industry, and entrepreneurship using the Relative Importance Index (RII). High to very high validation scores (0.77–0.89) confirmed the practical utility and cross-sector relevance of the framework.
5. **Bridging Theory and Practice:** The study bridges the gap between environmental urgency and practical implementation. It provides not only conceptual understanding but also real-world design guidance for sustainable packaging, serving as a decision-making compass for designers, policymakers, and businesses alike. The model integrates theoretical insights with practical industry implementation requirements, ensuring that identified attributes are both academically rigorous and industrially relevant. This attribute-based approach goes beyond conventional methods by harmonising functional, environmental, and consumer-oriented considerations within a single decision-making framework.
6. **Paradigm Shift in Packaging Design Philosophy:** The research transitions packaging design from a traditionally compliance-based function to a strategic tool for competitive differentiation and sustainable innovation. The user-centred, empathy-driven approach marks a shift from assessing sustainability to actively *creating* it through design.
7. **Theoretical Contribution and Academic Rigour:** The research fills a critical literature gap by integrating *design methodology*, *sustainability science*, *market intelligence*, and *cognitive user experience*. It contributes to the field with a validated theoretical model, enriching both academic discourse and industry application.
8. **A Blueprint for Future Research and Innovation:** The SPIID model offers a foundational platform for further research into packaging design, material innovation, and consumer behaviour in sustainability contexts. Its modular nature allows for continuous expansion with emerging technologies like biomaterials. The SPIID framework represents a paradigm shift toward integrated SPD that acknowledges the interconnected nature of design attributes while providing practical tools for implementation across diverse industry contexts.

6.2 Limitations of the work

The limitations of work may include the following points:

1. The research is conducted in certain geographic areas, which can make it hard to apply the results to other cultural and regulatory settings. Varying areas have very varying consumer preferences, sustainability concerns, and package acceptability requirements. This could make it hard for the 18 SPD attributes and the SPIID framework to work in all worldwide markets.
2. The fact that sustainability rules, consumer awareness, and new technologies in packaging materials change quickly is a time limit. The way the framework is set up right now may not be able to keep up with how quickly packaging materials, smart packaging technologies, or AI-enabled design optimisation are changing. As new sustainability standards come up and new biomaterials are made, the framework's usefulness and relevance may go down over time. This means that it needs to be updated and recalibrated from time to time.
3. While the framework demonstrates a strong theoretical foundation and expert validation, the research scope does not encompass comprehensive field testing or longitudinal implementation studies across diverse organisational contexts. The absence of extensive pilot deployments and real-world performance monitoring limits the understanding of practical challenges and long-term effectiveness that may emerge during actual framework implementation.
4. The framework that was created takes a general approach that isn't exclusive to certain sorts of content or products. This framework is very flexible because it can be used in a lot of different situations. However, it may not have the specific attributes needed for certain types of content, like drugs, food that needs special storage, or dangerous materials that need special packaging rules. The framework's general nature may not be able to fully meet the specific needs and regulatory requirements of different types of products.

6.3 Future scope of work

The suggested SPIID framework is useful for assessing the design of sustainable packaging before and after a product is made. It can be changed much further and utilised in other areas where decisions about sustainable design are needed. Automated assessment tools and AI-enabled optimisation systems could be used to improve the framework's efficiency and the designer's productivity.

With technology and new enhancements coming in the future, these 09 design attributes may not serve the entire purpose of SPD. Therefore, to tackle these issues, there might be a need for some more things along with diverse ways to deal with these problems in order to come up with real universal solutions.

Content-specific studies represent a rapidly evolving research domain that offers substantial opportunities for future investigation. Future research may be driven by the convergence of technological progress, changing ways of communicating, and new needs in society. This change shows a number of important variables that are changing how researchers do content analysis and study.

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APPENDICES

APPENDIX – I

Pilot Test - Pareto Analysis for Attribute Prioritization survey

Survey on "Sustainable Packaging Design"

Questionnaire Survey on Sustainable Packaging Design Attributes

About Me: I am Taruna Singh, an Assistant Professor pursuing PhD at the Department of Design, Delhi Technological University, Delhi. I am writing to you to request your participation as an expert for my PhD research work in the area of "Sustainable packaging design". Your valuable insight will help us to develop and validate a sustainable packaging framework.

Aim of the survey:

The
main aim of the survey is to understand the attributes of Sustainable packaging design.

Introduction:

To
identify the most relevant attributes of Sustainable packaging design. Here, In my research I am working in the direction to develop a holistic methodology for sustainable packaging design. In which the combined systems of packaging and the packaged products across the whole distribution chain from manufacturer to end consumer will be discussed. This study will lead to the development of a "blueprint to obtain a better and sustainable packaging solution that is user-friendly, cost-effective, and a sustainable solution. The result of this survey will bring a list of most relevant attributes in order to design sustainable packaging solution from 360 perspectives.

1. Name

____

2. Age

____

3. Gender

Mark only one oval.

- ◯ Male
- ◯ Female
- ◯ Other: ____________________

4. Institution/University/Organization

____

5. Qualification

Mark only one oval.

- ◯ Bachelor
- ◯ Masters
- ◯ MPhil
- ◯ PhD

6. Designation

____

7. Department

____

8. Work Experience

____

9. Are you aware of the concept sustainable packaging Design?

Mark only one oval.

- Yes
- No

Skip to question 10

Rating the attributes for sustainable packaging Design

Mentioned below is the list of attributes that has been extracted after an extensive literature review. You are being shared the with a list of 19 attributes that have finalized after discussions to be evaluated from experts (you) to understand & to identify the most relevant attributes; how important they are to develop the most sustainable packaging solution. You are requested to rate each attribute from **1-5; 1 being the "not important" and 5 being the "most important"** attribute to develop sustainable packaging design.
To understand, please rate the following attributes being most to least relevant to **Sustainable Packaging Design**.

10. **Accessibility** : In state of being always available

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

11. **Adaptable**: Referring the ability of an identity to adapt itself efficiently and fast to changing circumstances.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

12. **Aesthetic**: Being interested in how something looks, feels and seems pleasing to the senses and especially to the sight

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

13. **Affordable**: The state of being cost-effective enough for mass to buy.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

14. **Durable**: Made up of good quality material that can last for long

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

15. **Reusable**: Reusable for multiple applications. whether starting fresh or repurposing the packaging after use.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

16. **Energy Efficient:** using manufacturing processes, materials, and transportation methods that consume minimal energy resources,

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

17. **Functional**: Relating to the way in which product can serve for longer time than intended, or relating to how useful it is.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

18. **Informative**: A component of design that uses visuals that strategically convey a message or express information.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

19. **Protection**: The state of being shielded from harm and being hygienic.

Mark only one oval.

- Not Important
- Least Important
- Moderately Important
- Important
- Most Important

20. **How would you define Sustainable Packaging Design?**

APPENDIX – II

Final Kano Model Survey Implementation

KANO model questionnaire on Sustainable Packaging Design

The Kano Mode is an approach to prioritizing features on a product roadmap . With the help of Kano analysis, I will be able to find attributes which are most relevant in context of sustainable packaging design process.
In this questionnaire there are 12 attributes against which two questions are asked one is functional question (what if this attribute is present) and dysfunctional question (what if this attribute is not present) and has five Likert scale options "**I like it", "I expect it" ,"I am neutral", I can live with it" "I dislike it".**
This will take only 5-10 mins to fill this questionnaire , you have to mark an option against each attribute's question(functional and dysfunctional)

1. Name

____

2. Occupation

____

3. Year of Experience

____

Questionnaire

Each section has one attribute and it has 2 questions

ACCESSIBLE

As In state of being always available in terms of material, production/ manufacturing techniques etc.

FUNCTIONAL QUESTION

Sustainable packaging should be **Accessible** all the time.

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

DYSFUNCTIONAL QUESTION

Sustainable packaging should NOT be **Accessible** all the time.

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

ADAPTABLE

Adaptable: Referring the ability of an identity to adapt itself efficiently and fast to changing circumstances.

FUNCTIONAL QUESTION

Sustainable packaging should be **Adaptable.**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

DYSFUNCTIONAL QUESTION

Sustainable packaging should NOT be **Adaptable.**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

AESTHETICS

Being interested in how something looks, feels and seems pleasing to the senses and especially to the sight

Sustainable packaging should be **Aesthetically pleasing.**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **Aesthetically pleasing.**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

AFFORDABLE

The state of being cost-effective enough for mass to buy.

Sustainable packaging should be **AFFORDABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **AFFORDABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

CONTEXTUAL

An diversified solution that is convenient to use, generous and impactful in most of the situation in various demographic & Societal situation

Sustainable packaging should be **CONTEXTUAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **CONTEXTUAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

DURABLE

able to resist wear, decay, etc that can last for long

Sustainable packaging should be **DURABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **DURABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

ENERGY EFFICIENT

With respect to extracting raw material till its displayed in the retail market and decomposed. The entire process should be using less energy to get the same job done

Sustainable packaging should be **ENERGY EFFICIENT**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **ENERGY EFFICIENT**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

ERGONOMICAL

Product to improve people's working/operating conditions and help them work more effortlessly.

Sustainable packaging should be **ERGONOMICAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **ERGONOMICAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

FUNCTIONAL

Relating to the way in which product can serve for longer time than intended, or relating to how useful it is.

Sustainable packaging should be **FUNCTIONAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **FUNCTIONAL**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

INFORMATIVE

A component of design that uses visuals that strategically convey a message or express information.

Sustainable packaging should be **INFORMATIVE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **INFORMATIVE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

PORTABLE

Should provide a ease factor in transportation / distribution of packaging or its material

Sustainable packaging should be **PORTABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT be **PORTABLE**

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

PROTECTION

The state of being shielded from deformation, harm and being hygienic.

Sustainable packaging should **PROTECT** the content inside.

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

Sustainable packaging should NOT **PROTECT** the content inside.

- I LIKE IT
- I EXPECT IT
- I AM NEUTRAL
- I CAN LIVE WITH IT
- I DISLIKE IT

APPENDIX – III

Data Collection Framework and Statistical Analysis for validation of Framework

Section 1 of 2

Survey to understand the Sustainable packaging design attributes

Dear All,

I am Taruna Singh, Assistant professor, Department of Design, Delhi Technological University also pursuing my PHD as Part-Time Candidate.

First of all I would like to Thank you for participating in our survey on sustainable packaging design.

The sustainable packaging design attributes examples presented in this survey are understood to incorporate sustainability features. Our aim is to identify which specific design attributes from our previously studied framework (which will be referenced in the survey questions) are present in these sustainable packaging examples.

Your expertise will help us determine which established design elements from our research framework appear in these packaging solutions. Please carefully review each example and indicate which of the listed attributes are observable in the designs presented.

Your thoughtful participation is invaluable to our research, and we sincerely appreciate your time and insights.

Name

Short answer text

Qualification

- ○ Bachelor's
- ○ Master's
- ○ PhD
- ○ Other...

Occupation

- ○ Industry
- ○ Academic
- ○ Entrepreneurs
- ○ Other...

Year of Experience

Short answer text

Institute/Organization Name

Short answer text

Section 2 of 2

Survey

Please examine the product packaging image provided and rate each of the following design attributes on a scale of 1-5 (where 1 = Not at all present, and 5 = Strongly present).

For each attribute below, please indicate to what extent you believe it is represented in this sustainable packaging design:

1. Accessibility: In the state of being always available at majority of the times and places

2. Adaptable: Referring the ability of an identity to adapt it-self efficiently and fast to changed circumstances.

3. Aesthetic: Being interested in how something looks, feels and seems pleasing to the senses and especially to the sight

4. Affordable: The state of being cost-effective enough for masses to be able to buy.

5. Durable: Made up of good quality material that can last for long

6. Functional: Relating to the way in which product can serve for longer time than intended, or relating to how useful it is.

7. Informative: A component of design that uses visuals, text or content that strategically convey a message or express information.

8. Protection: The state of being shielded from harm and being hygienic and keeping the content safe.

9. Reusable: Reusable for multiple applications. Whether starting fresh or repurposing the packaging after initial use.

AASHIRVAAD ORGANIC ATTA *

The new paper packaging was launched "to mark Earth Day on 22 April 2023" and is "expected to help consumers to adopt a more 'sustainable lifestyle'". The packaging "uses paper, which is renewable as well as a biodegradable material" while still ensuring "product shelf life is as good as any other pack available in the market." The paper used in this packaging comes from "ITC's Paperboards and Specialty Paper Division." The paper used is "ECF (elementary chlorine-free), unbleached, food-grade kraft" that is "repulp-able to make recycled paper." While the packaging is primarily paper-based, some minimal plastic is still used to ensure food safety and freshness.

	Not at all present	Partially Present	Fully Present
Protection			
Reusable			
Affordable			
Adaptable			
Accessible			
Durable			
Functional			
Aesthetics			
Informative			

PUMA SHOE PACKAGING *

Puma has introduced "a new shoebox design which will save 2800 tonnes of cardboard every year" as part of their sustainability strategy. These redesigned boxes are "just as sturdy as their predecessors and are made of more than 95% recycled cardboard." The environmental impact of this change is significant - Puma estimates that "it takes about 12 trees to make a tonne of cardboard," meaning they are "saving 33,600 trees every year" through this initiative.

The "Clever Little Bag" - Puma previously made waves with an innovative packaging concept: The "Clever Little Bag" was designed as "a sustainable replacement for the traditional shoebox, using 65% less cardboard" with "no printing or tissue" that "weighs less in shipping, replaces the plastic retail bag and is completely recyclable."

	Not at all present	Partially Present	Fully Present
Protection	○	○	○
Reusable	○	○	○
Affordable	○	○	○
Adaptable	○	○	○
Accessible	○	○	○
Durable	○	○	○
Functional	○	○	○
Aesthetics	○	○	○
Informative	○	○	○

NYKAA PAPER LIPSTICK PACKAGING *

The Masaba by Nykaa lipstick line is a collaboration between India's largest beauty retailer Nykaa and Indian fashion designer Masaba Gupta, representing "Masaba Gupta's first ever beauty collection" which combines "her brilliant print sensibility with Nykaa's expertise in colour cosmetics." The packaging uses what's called a "Paper Lipstick (598)*" design supplied by HCP Packaging. This "flush fit Paper Lipstick uses HCP's super smooth full-size lipstick mechanism with a highly effective chamfered collar that helps to prevent fraying of the cap during repeated use." The packaging features a "cap made up of thick paper and not plastic," which is described as "travel friendly" without "any hesitation of spoilage."

	Not at all present	Partially Present	Fully Present
Protection	○	○	○
Reusable	○	○	○
Affordable	○	○	○
Adaptable	○	○	○
Accessible	○	○	○
Durable	○	○	○
Functional	○	○	○
Aesthetics	○	○	○
Informative	○	○	○

TATA TEA 1868 PACKAGING *

Tata Tea 1868 uses "premium copper coloured tin packs which, in addition to cueing premiumness, makes for perfect gifting collectables" according to Ruchira Bhattacharya, Director of Innovation at Tata Consumer Products. The tins are marketed as "high-quality reusable tin box[es]" that contain the premium tea products, emphasizing both the luxurious nature of the packaging and its sustainability through reusability. The pyramid shape of linen potli offers functional benefits as it "allows for a more even and consistent brew" since "the tea leaves are not as cramped as in traditional flat tea bags" allowing "more movement and flow of water around the tea leaves." This Received recognition for its design excellence, winning "the award in beverage category at the SIES SoP Star Awards 2022."

	Not at all present	Partially Present	Fully Present
Protection	○	○	○
Reusable	○	○	○
Affordable	○	○	○
Adaptable	○	○	○
Accessible	○	○	○
Durable	○	○	○
Functional	○	○	○
Aesthetics	○	○	○
Informative	○	○	○

NUA SANITARY PADS PACKAGING *

Nua's sanitary pads come with "paper disposal pouches" for each pad, providing a more eco-friendly disposal option compared to plastic disposal bags used by many other brands. Nua is recognized for its "sustainable practices" including the use of "biodegradable and eco-friendly materials" in its products, though specific details about the full composition and biodegradability of their pads aren't extensively documented in the search results. Nua has made efforts toward sustainability through paper disposal pouches and natural materials, detailed information about the full lifecycle impact of their packaging, complete material composition, or third-party verification of biodegradability claims.

	Not at all present	Partially Present	Fully Present
Protection	○	○	○
Reusable	○	○	○
Affordable	○	○	○
Adaptable	○	○	○
Accessible	○	○	○
Durable	○	○	○
Functional	○	○	○
Aesthetics	○	○	○
Informative	○	○	○

LIST OF PUBLICATIONS

Journal Publications:

1. Singh, T., Singari, R. M., & Singh, S. (2025). *Comprehensive study of design attributes for sustainable packaging design: Analytical techniques and expert validation*. *International Journal of Innovation Studies*, *9*(1), 1101–1115. https://doi.org/10.xxxxxx/ijis.2025.9.1.1101

2. Singh, T., Singari, R. M., & Singh, S. (2025). *Advancing sustainable packaging: A unified approach integrating industry, innovation, and consumer*. *International Development Planning Review*, *24*(1), 527–541. https://doi.org/10.xxxxxx/idpr.2025.24.1.527

Conference Presentations:

1. **Singh, T.** (2024, December 17-18). *Certificate of presentation: Fostering sustainable packaging design: A collaborative framework involving industry, local innovation, and customers*. 2nd International Conference on Sustainability, Entrepreneurship, Equity, & Digital Strategies (SEEDS 2024), Middlesex University Dubai.
2. **Singh, T.** (2024, March 14-15). *Certificate of presentation: Intertwining sustainability and packaging design: A review*. International Conference 2024 on Intertwining Sustainability with Mission Life: Fashion, Entrepreneurship, and Cultural Integration in Harmony, National Institute of Fashion Technology (NIFT), Gandhinagar.
3. **Singh, T.** (2023, December 14-16). *Certificate of presentation: Exploring opportunities in sustainable packaging design industry: A review study*. 4th Asian Conference on Ergonomics and Design, Humanizing Work and Work Environment & BRICSplus HFE Conference 2023, Indian Institute of Management (IIM) Mumbai.

Curriculum Vitae

Taruna Singh

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Assistant Professor and Part-time PhD scholar at Delhi Technological University, with a Master's in Design from NID Gandhinagar and an undergraduate degree from NIFT Bangalore. Skilled in packaging design, visual merchandising, product design, and research methods. Having experience in accessory design, product design, merchandising, and research. Having hands-on experience with various materials and exploring different techniques. I like to design with a passion for integrating design thinking into various domains to create positive societal impact.

EDUCATION

Bachelor of Design in Fashion & Lifestyle Accessories | 2013 | NIFT – Bangalore

Master of Design in Lifestyle Accessories | 2013 | NID – Gandhinagar

PhD | 2025 | Delhi Technological University – New Delhi

PROFESSIONAL EXPERIENCE

- **Assistant Professor** - Since 2018 at Delhi Technological University (till now) - Teaching design methodology, materials, packaging, service & system design.
- **Lecturer**, Unitedworld Institute of Design — Teaching research methodology, sustainable design, packaging.
- **Senior Product Designer**, Frazer and Haws — Customized product design & production supervision.
- **Design Trainee**, Ravissant Pvt. Ltd. — Designed Indian wedding gifting collections.
- **Industrial Training**, Titan Watches — Trend forecasting & CMF research.
- **Design Training**, NCDPD — Craft-based personal accessory design.
- **Design Internship**, Arvind Pvt. Ltd. — Visual merchandising

HONOURS & RECOGNITIONS

- Jury Member (Graphic Design), IndiaSkill 2024, at Yashobhoomi Dwarka, India.
- Invited Speaker for Design thinking workshop organized by Shri Mata Vaishno Devi University, Jammu, India
- Two book chapter in IIP Series, Futuristic Trends in IOT, 2024.
- Jury Member at Jamia Milia Islamia, Guru Gobind Singh University, JIMS, Chitkara University for various courses.
- Faculty coordinator for developing concepts for proposed circulation gold/silver coins for security printing and minting corporation of India Ltd. 2022
- Administrative Position: Hostel warden, Member of DPC, DLC,T/T, etc @ DoD, DTU

PUBLICATIONS

1. Agarwal, V., Sunakshi, Medhashree, R., Singh, T., & Singari, R. M. (2019, December). Study and Applications of Fuzzy Systems in Domestic Products. In *International Conference on Advanced Production and Industrial Engineering* (pp. 77-87). Singapore: Springer Nature Singapore.
2. Pradhan, E., Dadheech, A., Agarwal, H., Singh, T., & Singari, R. M. (2021). Design concept of a model can-sized sub-orbital satellite. *Journal of Engg. Research EMSME Special Issue pp*, *79*, 88.
3. Bansal, S., Tripathi, A., Kumar, N., Singh, T., & Ranganath, M. S. (2023). Modeling and analysis of finger splint for mild to high-grade mallet finger fracture.
4. Singh, T., & Singari, R.M., Singh, S., (2023, December 14-16). Exploring opportunities in Sustainable Packaging Design industry. ACED 2023, BRICSplus HFE 2023 and HWWE2023. Mumbai, Mharashtra, India.
5. Singh, T., & Singari, R.M., Singh, S., (2024, March 14-15). Intertwining Sustainability with Mission LiFE: Fashion, Entrepreneurship and Cultural Integration in Harmony. Gandhinagar, Gujrat, India.
6. Singh, T. (2024, December 17-18). Certificate of presentation: Fostering sustainable packaging design: A collaborative framework involving industry, local innovation, and customers. 2nd International Conference on Sustainability, Entrepreneurship, Equity, & Digital Strategies (SEEDS 2024), Middlesex University Dubai.
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8. Singh, T., Singari, R. M., & Singh, S. (2025). Advancing sustainable packaging: A unified approach integrating industry, innovation, and consumer. International Development Planning Review, 24(1), 527–541. https://doi.org/10.xxxxxx/idpr.2025.24.1.527