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SUSTAINABILITY IMPLICATIONS OF POST-CONSUMER RECYCLED POLYPROPYLENE IN PLASTIC PACKAGING: A STAKEHOLDER PERCEPTION STUDY IN BANGLADESH

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Abstract

This thesis examines how industry stakeholders in Bangladesh perceive the sustainability implications of post-consumer recycled polypropylene (RPP) in the plastic-packaging sector; the data analysed are stakeholder judgements collected through a structured questionnaire and are not life-cycle inventory measurements of environmental performance. Conceptually, the work draws on Life Cycle Thinking (LCT), the impact-category vocabulary of Life Cycle Assessment (LCA), and Circular Economy Theory (CET). Methodologically, it uses a quantitative, cross-sectional, perception-based survey of 142 manufacturing, recycling and dual-activity firms in the industrial corridors of Dhaka, Narayanganj, Gazipur and Chattogram, with data collected between January and March 2026.

Respondents reported a clearly positive perception of environmental benefits from RPP substitution (composite mean = 3.81, SD = 0.93), more moderate perceptions of economic benefits (mean = 3.18, SD = 0.98), and lower perceptions of usability and product performance (mean = 2.91, SD = 0.94). The single-item overall sustainability-benefit measure was positive (mean = 3.60, SD = 0.80). Kruskal-Wallis tests revealed statistically significant differences between organisation types on the environmental, economic, usability and overall indices, while Spearman correlations confirmed the theoretically expected ordering of associations between RPP usage, life-cycle indicators and perceived outcomes. The seven multi-item scales returned Cronbach's alpha values between 0.672 and 0.917, and one single-item overall-perception measure supplemented these multi-item scales.

The study contributes context-specific, stakeholder-informed evidence to a literature dominated by technical LCA studies conducted in higher-income economies. Its findings are not a substitute for measured environmental performance data; rather, they identify the perceived adoption conditions, barriers and decision factors that shape RPP uptake in Bangladesh's plastic-packaging value chain — most notably the asymmetry between strong perceived environmental benefit and weaker perceived usability, the manufacturer-recycler perception gap, and the limited integration of energy and transport considerations into stakeholder reasoning. The study also delivers a research-grade questionnaire instrument that can be adapted and re-tested in adjacent emerging-economy settings.

Keywords: post-consumer recycled polypropylene; RPP; plastic packaging; Bangladesh; stakeholder perception; Life Cycle Thinking; Circular Economy; sustainability.

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Table 4. Composite-index means by organisation type and Kruskal-Wallis tests (n = 142). *p < 0.05, **p < 0.01, ***p < 0.001.

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1. Introduction

This chapter sets out the context, motivation and aims of the completed thesis. The rapid growth of plastic packaging, the environmental burdens associated with virgin polypropylene, and the rising importance of recycling and Circular Economy thinking together define a problem that is both industrially significant and academically under-researched in the Bangladeshi setting. While Life Cycle Assessment has been used widely to compare virgin and recycled polymers in developed economies, comparable evidence informed by local stakeholders is scarce for Bangladesh. To address this, the present study used a quantitative, cross-sectional, perception-based survey of 142 manufacturing, recycling and dual-activity firms in Bangladesh, conceptually anchored in Life Cycle Thinking, the impact-category vocabulary and Circular Economy Theory.

The contribution is a context-specific, stakeholder-informed account of how the perceived sustainability implications, opportunities and challenges of post-consumer recycled polypropylene (RPP) are understood inside Bangladesh's plastic-packaging value chain. The chapter is organised in six sections. Section 1.1 presents the background and motivation. Section 1.2 states the purpose and objectives of the study. Section 1.3 defines the research problem, the research question and the development task. Section 1.4 introduces the key concepts and the theoretical framework in summary form, with fuller treatment reserved for Chapter 2. Section 1.5 discusses the academic, industrial, policy and societal significance of the work. Section 1.6 outlines the structure of the remainder of the thesis.

1.1 Background and Motivation

The plastic-packaging industry in Bangladesh is rapidly growing, and today's choices over virgin and recycled materials will have profound implications for the nation's environmental future. However, context-specific evidence to guide these decisions are not available; although the majority of previously published LCA work has been carried out in EU, USA or East-Asian contexts, some Bangladesh-relevant LCAs are available but

few of the times any of them have included sustainability framing and data from key local stakeholders. The following sub-sections qualitatively progress through the gap in stages: the role of PP in modern packaging, the environmental burden of virgin PP, responses to virgin PP in the form of recycling and CE, LCT as an interpretive lens, the precise context of Bangladesh, and the final research need to be addressed by the thesis.

1.1.1 Growth of Plastic Packaging in Modern Economies

Plastic packaging plays a pivotal role in the production system and has become the main part of a retailing strategy due to its cheapness, lightness, strength, versatility and design. Among all the commodity polymers, polypropylene (PP) plays a very special role: It is used for various food containers, lids, caps, woven and unwoven sacks, films and thermoformed parts, and due to its remarkable physical-mechanical ability, chemical resistance and low density, it becomes difficult to replace it at a cost equivalent level (Galve et al., 2022).

Firstly, woven PP sacks are the predominant package size for products such as rice, fertilisers, cement and other primary products that occupy a big proportion in domestic and export logistics. Second, the rank and type of material used in the national production of fast-moving goods packaging is dominated by rigid PP containers and closures. Third, PP is the polymer that most local converters identify with when they talk about recycled content, making it the one most policy relevant, at least for a near term circular economy intervention. These three points provide the study with the specific context of PP and not a general plastic category.

1.1.2 Environmental Challenges of Virgin Polypropylene

The process of virgin polypropylene manufacturing involves the use of fossil-derived feedstocks, mainly oil and natural gas, and consequently is associated with the resource extraction, polymerisation and transport impacts that are inherent to petrochemical production (Boyd et al., 2021; Hahladakis et al., 2020). However, comparative LCA evidence has consistently pointed to the production stage of virgin PP as a major contributor to GHG emissions and cumulative energy demand along the packaging value

chain with the contribution varying dependent upon the energy mix, system boundary and allocation decisions adopted in the LCA study (Galve et al., 2022; Perugini et al., 2005).

The end-of-life load of PP also is relevant. No degradation of polypropylene by biological processes has been found, and the presence of polypropylene in landfilled and uncollected waste streams adds to the general plastic waste situation reported in marine and terrestrial environments (Hahladakis et al., 2018). The literature has raised concerns regarding micro plastics and potential human health effects, however the present thesis does not rely on the contested causal claims regarding human health, and instead solely refers to the four environmental burdens, which can be directly translated into the survey categories presented for the purposes of Chapter 4: fossil-resource use, cumulative energy demand, greenhouse-gas emissions, and waste persistence.

1.1.3 Emergence of Recycling and Circular Economy Approaches

Recycling is a technical operation that converts post-use materials into secondary feedstock. The circular economy is a broader system model that treats recycling as one of several strategies alongside reduction, reuse, repair and redesign for retaining material value within the economy (Ferrara and De Feo, 2023; Hahladakis et al., 2020). The two are related but not identical, and conflating them has led some industrial accounts to overstate what recycling alone can deliver. Post-consumer recycled polypropylene (RPP), the focal material of this study, is one expression of the circular-economy logic at the material level: it diverts post-use PP from disposal, reprocesses it through mechanical recycling, and re-enters it into manufacturing in place of virgin resin.

RPP can reduce energy use, emissions and landfill demand relative to virgin PP, but these reductions are conditional rather than automatic. The published evidence is consistent on this point: realised benefits depend strongly on collection coverage, sorting efficiency, contamination levels, the energy mix used during reprocessing, and the quality and yield of the recovered material (Geyer et al., 2017; Hahladakis et al., 2018). The present thesis therefore treats RPP as a potentially beneficial substitution whose

realised performance is contingent on operational and contextual conditions, and asks how Bangladeshi stakeholders perceive those conditions.

1.1.4 Role of Life Cycle Thinking in Sustainability Evaluation

Life Cycle Assessment is a quantitative methodology for evaluating environmental impacts across a product's life cycle, formalised in the international standards ISO 14040 (2006) and ISO 14044 (2006), which specify the four phases of goal and scope definition, life-cycle inventory analysis, life-cycle impact assessment and interpretation. LCA produces measured impact scores in defined categories, such as global-warming potential and cumulative energy demand, that are comparable across products under explicit boundary and allocation assumptions.

Life Cycle Thinking (LCT), by contrast, is a conceptual perspective rather than a measurement procedure. LCT encourages decision-makers to consider environmental burdens across all life-cycle stages and to avoid burden-shifting between stages. The present thesis does not perform a quantitative LCA: it does not collect inventory data on energy use, emissions, transport distances or material flows from individual firms. Instead, it uses LCT as the interpretive lens that organises the questionnaire around life-cycle stages and impact categories, and it uses the LCA literature as a reference vocabulary against which stakeholder perceptions are discussed. This distinction is preserved consistently throughout the thesis to prevent any expectation of measured environmental performance results.

1.1.5 Context of Bangladesh and Emerging Economies

Bangladesh provides a particularly informative setting for studying the perceived sustainability of RPP. The country's manufacturing base has expanded rapidly over the past two decades, and the plastic-packaging segment has grown alongside the food-processing, retail and ready-made-garment sectors that depend on it. At the same time, formal municipal waste collection is uneven, post-consumer plastic recovery is dominated by an extensive informal sector, and the electricity grid is heavily dependent on natural-gas-fired generation supplemented by imported fuels. Each of these features

rapid industrial demand, partial collection, informal recovery, and a fossil-heavy energy mix is directly relevant to whether RPP substitution actually delivers environmental gains in practice (Boyd et al., 2021; Lazarevic et al., 2010).

Nevertheless, most of the existing evidence on the LCA of PP and RPP is from contexts where the energy mix, sorting infrastructure and policy environment differ considerably from that of Bangladesh (Geyer et al., 2017; Keller et al., 2022). So, such results cannot therefore be moved directly. To make evidence-driven, local decisions and policies rather than importing evidence from elsewhere a locally grounded study is needed that documents how people in Bangladesh exist and perceive the implications of RPP substitution in the actual context in which the practitioners work.

1.1.6 Research Gap and Study Motivation

There are three gaps in the literature that motivate this study. The first is specifically related to Bangladesh: to be honest, in the world of LCA, the number of studies focused on plastic packaging has grown considerably over the years, but less positive work has been conducted on the packaging sector in Bangladesh and even then, very little has been done with primary data of any sort. The second is a stakeholder-perception evidence gap: When LCA evidence is available, it often does not take into account the real life viewpoints of the firms, recyclers, and/or sustainability managers who have to make the decision whether RPP is adopted or not, and whose tacit knowledge of quality, cost, customer acceptance and policy bottlenecks influence outcomes.

The third is an adoption-conditions gap: published work has focused on RPP as a generic good or a generic risk, rather than focusing on what types of conditions would render Bangladeshi stakeholders more or less willing to support the sustainability claims. It is the aim of the present study to solve these three gaps directly. This does not gauge environmental performance and does not purport to assess whether or not RPP “genuinely” lowers emissions in Bangladesh; that depends on inventory information which was not gathered by the project. What they do offer, however, is evidence structured according to a questionnaire, informed by stakeholders, highlighting

perceived sustainability implications, perceived opportunities and perceived challenges based on the categories of the LCA literature, interpreted through LCT and CET.

1.2 Purpose and Objectives of the Study

It is the purpose of the study and identifies its objectives. Both are explicitly framed as perception based, that is, not whether RPP is indeed in inventory terms more sustainable, but how it is perceived as such by Bangladeshi stakeholders. Its function is given in Sub-section 1.2.1. The general objectives and specific objectives are given in sub-section 1.2.2.

1.2.1 Purpose of the Study

This study aims to explore the perceived nature- and range of sustainability implications of post-consumer recycled polypropylene in plastic packaging in Bangladesh and perceived conditions for the post-consumer recycled PP to be deemed successful in plastic packaging. In this context, the meaning of the term “sustainability implications” is defined in four parts: (i) perceived environmental benefits; (ii) perceived operational and technical barriers; (iii) perceived contextual factors such as energy mix, transport, recycling infrastructure and policy support; and (iv) perceived industry and policy relevance for circular-economy transition.

The study did not measure environmental performance. It cannot, on the basis of perception data alone, confirm or deny whether RPP substitution reduces measured emissions, energy use or resource depletion under Bangladeshi conditions. What it can do and what it set out to do is record how knowledgeable industry stakeholders perceive these implications, and identify the practical opportunities and barriers that they associate with the adoption of RPP. This perception-based focus is preserved throughout the purpose, the research question, the questionnaire and the discussion in Chapter 5.

1.2.2 Research Objectives

The general objective of the study was to characterise stakeholder perceptions of the sustainability implications of post-consumer recycled polypropylene in Bangladesh's plastic-packaging sector, framed by Life Cycle Thinking, the impact-category vocabulary of Life Cycle Assessment, and Circular Economy Theory. To support this general objective, the study pursued five specific objectives, all of them perception-based and all of them tied to concrete elements of the questionnaire and analysis. The first specific objective was to describe the perceived environmental opportunities of incorporating RPP into PP packaging, using questionnaire items aligned with greenhouse-gas reduction, environmental-impact reduction and contribution to sustainable production.

The second was to describe the perceived operational and technical challenges associated with RPP, including product quality, customer acceptance and ease of integration. The third was to describe the perceived role of contextual factors energy mix, transport, process efficiency and policy support in shaping RPP outcomes. The fourth was to compare perceptions across stakeholder groups (manufacturers, recyclers and dual-activity firms) and across years of experience using non-parametric group-comparison tests, as detailed in Chapter 3. The fifth was to develop context-informed suggestions for industry decision-makers and policy actors, framed cautiously as practitioner-grounded recommendations rather than as broad policy conclusions, given the purposive nature of the sample.

1.3 Research Problem and Research Question

The sub-sections below state the research problem in a form that is fully consistent with the perception-based design, present the central research question and its sub-questions, and define the development task that links the academic study to a reusable instrument for the sector.

1.3.1 Research Problem

The research problem addressed by this thesis is the lack of context-specific, stakeholder-informed evidence on the perceived sustainability implications of post-consumer recycled polypropylene in Bangladesh's plastic-packaging sector. Two distinct evidence gaps overlap in this problem. The first is a quantitative gap: very few published studies report Bangladesh-specific life-cycle inventory or impact data for PP and RPP, and primary operational data energy use per tonne of resin, transport distances, contamination yields, reject rates are difficult to obtain from individual firms because they are commercially sensitive and often unrecorded. The second is a perceptual gap: even if more inventory data were available, they would not capture the practical knowledge that local manufacturers, recyclers and sustainability managers.

There is a need for a different response to the two gaps. There is a need for inventory information to close out this quantitative gap which cannot be achieved in this master-level perception study. However, bridging the perceptual gap is not impossible: even when it is not possible to provide numbers of items in inventory, it is possible to identify barriers to operations, issues of quality, infrastructural weaknesses and adoption conditions; these perceptions are a defendable form of evidence on which one can base industry and policy decisions. It is thus the perceptual gap itself which is the target of the present study. It aims to start the discussion on the subject by mapping perceptions of stakeholders about its effects and conditions for adoption.

1.3.2 Research Question

The main research question of the thesis is:

What are the perceptions of industry stakeholders with respect to the sustainability aspects, potential and issues of post-consumer recycled polypropylene for plastic packaging in Bangladesh?

The research questions are broken down in four sub-questions which can be answered per question by the empirical chapter. SQ1: What environmental advantages do stakeholders see when thinking about the RPP virgin PP substitution, in the impact

categories identified by the LCA and included in the questionnaire? SQ2: What are the perceived operational and technical barriers that stakeholders deem as the most limiting to the adoption of RPPs? SQ3: What do stakeholders identify as being the most important enablers and/or limiters of RPP outcomes related to energy mix, transport, process efficiency and policy support? SQ4: Are there systematic perception differences between manufacturers, recyclers (dual activity firms), and between practitioners with varying levels of experience?

1.3.3 Development Task of the Study

Alongside the analytical research question, the thesis also performed a defined development task. The output of this development task is the LCA-informed perception questionnaire used in Chapter 3 and reproduced in full in Appendix A. The instrument operationalises Life Cycle Thinking, LCA impact categories and Circular Economy Theory into a 23-item structured questionnaire whose internal-consistency reliability is reported in Chapter 4 (Cronbach's $\alpha = 0.67–0.92$ across seven multi-item indices). The development task is therefore the design, piloting and reliability-testing of this instrument as a reusable artefact.

The instrument is not claimed to be a fully validated industry tool. It has been piloted and shows acceptable to excellent reliability on the present sample, but it has not been subjected to confirmatory factor analysis, multi-country replication or longitudinal re-testing. The development claim made in this thesis is therefore restricted: the questionnaire is offered as a research-grade, theoretically grounded perception instrument suitable for adaptation in subsequent studies of plastic-packaging sustainability in emerging economies. The wider validation work needed before the instrument could be recommended for routine use by industry stakeholders is identified in Section 5.5 as a direction for future research.

1.4 Key Concepts and Theoretical Framework Overview

This section introduces the four concepts on which the thesis depends Life Cycle Thinking, Life Cycle Assessment, Circular Economy and post-consumer recycled polypropylene at the level of working definitions only. Fuller theoretical treatment, including engagement with the conceptual debates within each tradition, is reserved for Chapter 2.

1.4.1 Introduction to Key Concepts

Four concepts structure the thesis. LCA is a quantitative methodology for measuring environmental impacts across a product's life cycle, formalised in ISO 14040 (2006) and ISO 14044 (2006). LCT is the conceptual perspective behind LCA: it does not produce numerical impact scores but it requires that environmental decisions be made with all life-cycle stages in mind. Post-consumer recycled polypropylene (RPP) is the material focus of the study and is defined here, throughout the thesis, as PP recovered from end-use waste streams and reprocessed mechanically into a secondary resin suitable for new packaging. Mechanical recycling is the dominant route in the Bangladeshi context surveyed, and chemical or solvent-based pathways although covered in some recent international literature (Caudle et al., 2025) are not part of the empirical scope.

1.4.2 Life Cycle Thinking as a Conceptual Foundation

Life Cycle Thinking provides the conceptual foundation for the study. Its core requirement is that decisions about a product's environmental impact be made with the entire life cycle in view raw-material extraction, polymerisation, conversion, distribution, use and end-of-life rather than by reasoning about a single stage in isolation. LCT therefore offers a structural defence against burden-shifting, the analytical mistake of "improving" one stage at the cost of greater impact in another.

Operationally, LCT enters this study in two specific ways. First, the questionnaire items in Section B (independent variables) are organised around production-stage processes (energy use, process efficiency, transport) so that respondents are asked to consider

stages explicitly, not just the substitution event itself. Second, the discussion in Chapter 4 reads stakeholder responses through an LCT lens and identifies cases where respondents focus on substitution but underweight upstream energy or downstream transport a classical burden-shifting risk that LCT exists to flag.

1.4.3 Life Cycle Assessment as a Reference Framework

The study did not perform a full LCA. It used LCA as a reference framework that is, as the source of the impact categories and vocabulary in which respondents were asked to express their perceptions. Three impact categories were used in the questionnaire: greenhouse-gas reduction, overall environmental-impact reduction, and contribution to sustainable production (items C1.1–C1.3). These categories correspond to the most policy-relevant and most widely reported indicators in the comparative LCA literature on plastic packaging broadly, global-warming potential, cumulative environmental impact and resource-related performance (Galve et al., 2022; Tunçok-Çeşme et al., 2024).

Stakeholder perceptions in these categories are not directly comparable to measured LCA results, and the thesis does not claim such direct comparability. They are, however, discussed in relation to the LCA literature in Chapter 4 in order to identify points of agreement and points of tension between perception and measurement.

1.4.4 Circular Economy Theory and Material Sustainability

Circular Economy Theory (CET) frames the strategic context of the study but is not equated with recycling. CET treats recycling as one of several strategies for retaining material value, alongside reduction of unnecessary packaging, reuse, repair, redesign for recyclability, and value-retention practices that delay end-of-life entry. RPP is therefore one expression of circular-economy logic, not the whole concept (Hahladakis et al., 2020; Matos et al., 2024).

CET is useful for a stakeholder-perception study, beyond its descriptive value for material flows, because it provides a vocabulary for the systemic enabling conditions collection systems, design-for-recyclability, demand for recycled content, policy signals

that determine whether material substitution at the firm level translates into systemically circular outcomes. Several questionnaire items draw directly on this CET vocabulary, in particular those addressing process efficiency, waste-reduction practices and customer acceptance of recycled content.

1.4.5 Integration of Theoretical Frameworks

The three frameworks are integrated in the study by mapping each onto a specific dimension of the questionnaire and the analysis. LCT structures the life-cycle stages reflected in Sec. B (energy use, process efficiency, transport) and disciplines the discussion against burden-shifting. LCA-derived impact categories structure Sec. C1 (environmental benefit), where respondents express perceptions in language drawn from comparative LCA work. CET structures the systemic, beyond-the-firm reading of the data particularly the role of dual-activity firms in Sec. 4.2, the discussion of enabling conditions in Sec. 4.4, and the limitations of recycling-only thinking flagged in Chapters 4 & 5. The frameworks are therefore complementary along three different axes interpretive, vocabulary, and systemic rather than redundant listed side by side.

1.4.6 Conceptual Direction of the Study

The conceptual direction of the thesis is descriptive and comparative rather than causal. The questionnaire is organised into two blocks Section B captures perceived material-use, energy, process-efficiency and transport conditions, while Section C captures perceived environmental, economic and usability outcomes, with Section D capturing an overall sustainability judgement and the analysis describes the patterns within and between these blocks. The terms "independent" and "dependent" are used in the study only as questionnaire-block labels for ordering purposes; no causal model is tested, and the cross-sectional design does not support causal inference.

Likewise, the questionnaire does not present respondents with discrete substitution scenarios (e.g. "no substitution", "50% substitution", "100% substitution") and the analysis therefore does not compare such scenarios. What the survey does record is the proportion and frequency of RPP that respondents currently use in their organisations

(items B1.1 and B1.2), which is then used as a perceived-usage variable in the cross-group comparisons of Chapter 4.

1.5 Significance and Relevance of the Study

The contribution of this thesis is real but modest in scope. It rests on a purposive sample of 142 respondents, on perception data rather than measurement data, and on a single point-in-time, cross-sectional design. The four sub-sections below state the academic, practical, policy and circular-economy relevance of the work in terms that are realistic about these features.

1.5.1 Academic Significance

Academically, the thesis contributes stakeholder-based evidence to LCA-informed sustainability scholarship in a setting that this scholarship has rarely covered with primary local data. It does not strengthen the empirical reach of LCA scholarship in the strict inventory sense it produces no new inventory data but it adds a structured perception layer that complements, and can be triangulated against, future quantitative work. The instrument developed for the study (Appendix A) is potentially transferable to other emerging-economy settings with similar packaging-industry structures, subject to language adaptation, contextual re-piloting and re-testing of internal-consistency reliability.

1.5.2 Practical and Industrial Relevance

The results identify four concrete actions for Bangladeshi manufacturers regarding RPP: impact categories in and out of which they perceive the greatest positive impacts from RPP (and therefore can stand up for to explain to customers); operational and quality concerns they flag the most (and therefore the technical issues will be most worth investing in); contextual factors that they currently underweight, but on which they can act (e.g., share renewable energy in other sources of power); and finally, the performance gap between the dual-activity firms and pure manufacturers, which provides a reference point for capability-building with regard to RPP. The study,

however, does not pretend to optimise individual production processes since such data were not collected on this level.

1.5.3 Policy and Societal Relevance

The findings may serve as indicative evidence from the stakeholders for policymakers, and do not provide fully fledged evidence-based policy to regulate EPR and CE framework in Bangladesh. They should be applied in conjunction with technical LCA data and waste-flow data and economic analysis. In particular, the results can contribute to designing an EPR levy and incentives, prioritizing investments in formal collection and developing national RPP quality standards but must be interpreted only as one of multiple inputs, with the inventory and economic studies not replaced by them.

1.5.4 Relevance to Sustainability and Circular Economy Transition

For Bangladesh's circular-economy transition specifically, the study provides structured stakeholder data on the perceived enabling conditions and binding constraints for RPP adoption in PP packaging. Two findings, anticipated in Chapter 4, are particularly relevant: first, that environmental perception is strongly positive but is decoupled from upstream energy and downstream transport reasoning, indicating a need for systemic-thinking outreach; and second, that dual-activity firms hold the most favourable perceptions across multiple constructs, indicating an organisational form that may serve as a transition exemplar. These observations support they do not prove the policy direction toward closed-loop integration.

1.6 Structure of the Thesis

The remainder of the thesis is organised in four further chapters and a set of appendices. Chapter 2 develops the theoretical framework and reviews the relevant literature on LCA in plastic packaging, the environmental burden of virgin PP, the environmental performance of RPP, technical and operational recycling challenges, the role of circular economy in plastic packaging, and the contextual factors that shape sustainability outcomes. Chapter 3 sets out the methodology of the completed study, including the

research design, the target population and sampling, the questionnaire, the data-collection process, the data-analysis methods, and the reliability, validity and ethical considerations applied.

Chapter 4 presents the empirical results from the survey of 142 respondents, including the sample profile, the reliability of the measurement indices, descriptive results for each construct, cross-group comparisons by organisation type and experience, inter-construct correlations, and an interpretation of the findings against the theoretical framework. Chapter 5 concludes the thesis: it summarises the findings, reflects on the research question, evaluates the integrity of the work, acknowledges its limitations, suggests directions for future research, and reflects on the researcher's personal learning. The references and appendices follow.

2. Theoretical Framework and Literature Review

There are two goals of this chapter. The first is to lay out the theoretical context in which Life Cycle Thinking, the reference vocabulary for the questionnaire and the analysis, is organised, and to indicate the mapping of each element of this context to a specific feature in the questionnaire and the analysis, which is called the Circular Economy Theory. We will review the literature critically, pinpoint differences in studies, clarify any disagreements based on the methodologies and develop a solid argument for using perception in the present thesis' design. The two purposes are two kept separately: Grossly, Section 2.2 develops the background framework; there is a review of the literature in Section 2.3, and the chapter concludes in Section 2.4 with implications for the methodology of Chapter 3.

2.1 Introduction to the Theoretical Framework

The theoretical framework of this thesis combines three traditions whose reach and methods are different but complementary: LCT, LCA and CET. LCT is the interpretive lens; LCA is the source of the impact-category vocabulary used in the questionnaire; CET is the systemic strategy that situates RPP within the wider circular-economy debate. Each tradition is mapped onto a specific empirical element of the study. LCT maps onto Section B of the questionnaire (life-cycle-stage variables: material use, energy, process efficiency, transport). LCA maps onto Section C1 of the questionnaire (impact-category-derived items: GHG reduction, overall environmental-impact reduction, contribution to sustainable production). CET maps onto the dual-activity contrast, the systemic conditions discussion and the policy reading developed in Chapters 4 and 5.

The conceptual diagram for this mapping is presented in Figure 1.

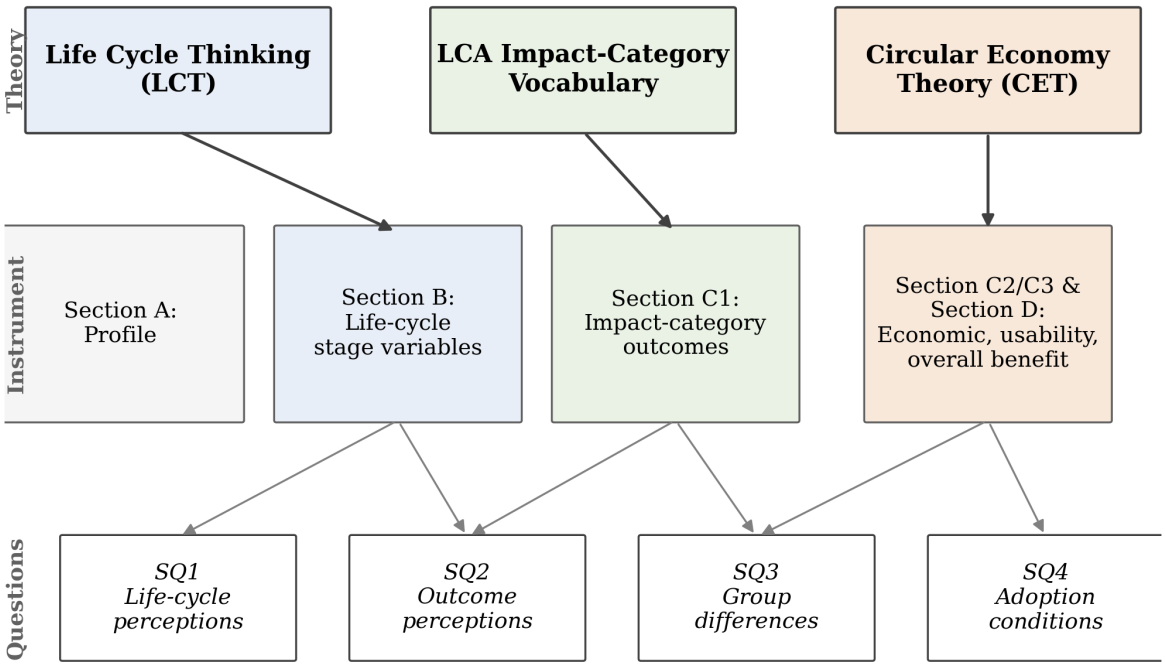

Figure 1. Conceptual framework of the study, showing the mapping between LCT, LCA-derived impact categories, Circular Economy Theory, the questionnaire blocks (Sections A–D) and the four sub-questions of the thesis.

2.2 Key Theories and Concepts

The theories and concepts are introduced below in an order that reflects the logic of the study, not the historical order in which they were developed. LCT is presented first because it provides the interpretive lens. LCA is presented second as the reference method whose vocabulary the study borrows. CET is presented third as the system-level strategy. PP and RPP are then introduced as the material focus, followed by the environmental impact indicators used in the questionnaire and the contextual factors that shape outcomes in Bangladesh. A short synthesis closes the section.

2.2.1 Life Cycle Thinking (LCT)

Life Cycle Thinking is the conceptual position that environmental decisions about a product should be informed by the whole life cycle, not by any single stage. Two consequences follow from this position and matter for the present study. The first is the concern with burden-shifting: improvements at one life-cycle stage can be cancelled, or worse, by unintended impacts at another, and an LCT-disciplined analysis is one that asks where burden has moved to as well as where it has been reduced (Tunçok-Çeşme et al., 2024). The second is the concern with system boundaries: the choice of where the analysed system starts and ends is itself a substantive decision, and conclusions about "sustainability" depend on it.

For the purposes of this thesis, the design of the questionnaire was informed on two fronts by Operation. Respondents were first asked to imagine 4 different conditions that occurred in the production stage: use of material, use of energy, process efficiency and transport, and then were asked about the outcome questions (Section C). This was an intentional cue to thinking in life-cycles. Second, it was analysed whether the outcome judgements (environmental benefit, economic, usability, overall) of the respondents were correlated with the perceptions of the life-cycle-stages of their Section B. A weak correlation in this regard is substantively and epistemologically interesting because it means there is burden-shifting reasoning that LCT is in place to unmask.

2.2.2 Life Cycle Assessment (LCA)

Life Cycle Assessment is a quantitative tool to assess the environmental impacts of products, processes and services. It is formalised in two international standards (ISO 14040 (2006) and ISO 14044 (2006)) which provide the structure of the method in four phases: goal and scope definition, LCI analysis, LCI assessment and interpretation, and define the principles of transparency, consistency and reproducibility that distinguish LCA from less structured environmental evaluations. The present study did not perform an LCA. Two distinct reasons explain this choice. The first is data availability: firm-level inventory data on energy consumption per ton of resin, transport distances,

contamination yields and reject rates were not obtainable from the sampled organisations because such data are commercially sensitive and frequently unrecorded.

The second, and more important, reason is that perception research answers a different research question. LCA answers the question "what is the measured environmental performance of this product system?". The present thesis answers the question "how do knowledgeable practitioners perceive the sustainability implications of this product system in their context?". The two questions are complementary, but they are not the same; perception findings cannot replace inventory findings, and inventory findings cannot replace perception findings. Recognising this distinction is essential to the methodological coherence of the thesis.

2.2.3 Circular Economy Theory (CET)

Circular Economy Theory is a strategic system-level framework that aims to retain material value within the economy by replacing linear take-make-dispose flows with closed-loop flows of reduction, reuse, repair, recycling, and redesign for recyclability (Ferrara and De Feo, 2023; Hahladakis et al., 2020). Two clarifications matter for the present study. The first is that recycling is not the whole of CET. CET prioritises higher-value strategies reduction and reuse above recycling, and design-for-recyclability above end-of-pipe recovery. The literature has converged on this hierarchy, and a study that reduced CET to recycling alone would understate what the framework requires (Matos et al., 2024).

The second clarification is that the realisation of circular-economy benefits is conditional on system design. Even in the recycling-focused part of CET, results depend on collection coverage, sorting fidelity, contamination, market demand for recycled content, and the energy mix used in reprocessing (Hahladakis et al., 2018; Niero et al., 2017). The present thesis adopts CET in this conditional, system-design-aware sense rather than as a blanket endorsement of recycling. CET is used to interpret the systemic enabling conditions that respondents perceive which is why the strongest CET reading in Chapter

4 attaches to the dual-activity firms, whose closed-loop operational form most closely resembles the integration that CET prescribes.

2.2.4 Polypropylene in Plastic Packaging

Polypropylene is a thermoplastic polymer whose mechanical strength, chemical resistance, light weight and low cost have made it one of the dominant packaging materials of the past four decades (Galve et al., 2022; Hahladakis et al., 2018). PP is produced in several grades homopolymer, random copolymer and block (impact) copolymer whose mechanical and processing characteristics differ. Different packaging applications use different grades: rigid containers and closures typically use homopolymer or random copolymer; films and thermoforms make extensive use of homopolymer; woven sacks use specific PP grades engineered for tensile performance.

Virgin PP material does not have the same limitations as recycled PP (RPP) material. Mechanical recycling generally leads to a drop in molecular weight, a change in variation of melt-flow and contamination from incompatible polymers, additives, and food residues (Caudle et al., 2025; Ignacio et al., 2023; Velásquez et al., 2023). With proper process control RPP is able to recover sufficient quantities of virgin PP to use in non-food rigid packaging and woven sacks in meaningful percentages. The regulatory and safety stance is more stringent when it comes to post-consumer RPP for direct food contact: few jurisdictions allow the use of post-consumer RPP materials for direct food contact without clear authorisation, and all require high levels of decontamination treatments if it is to be allowed.

2.2.5 Environmental Impact Indicators in Sustainability Assessment

Two LCA impact indicators dominate the published literature on plastic packaging: global-warming potential (GWP), which captures life-cycle greenhouse-gas emissions in CO2-equivalent terms, and cumulative energy demand (CED), which captures the total primary energy consumed across the life cycle (Galve et al., 2022; Ncube et al., 2021; Tunçok-Çeşme et al., 2024). These two indicators were chosen as the analytical anchors for the present questionnaire because they are the most consistently reported and the

most policy-relevant in the comparative literature on PP and RPP. Other indicators toxicity, water use, land use, marine litter are recognised in the LCA literature but are reported less consistently and were excluded to keep the questionnaire short and respondents able to answer reliably.

Because most respondents are unlikely to be familiar with the technical terms "global-warming potential" or "cumulative energy demand" themselves, these technical indicators were translated into plain-language items that map onto the same underlying constructs. GWP is operationalised as item C1.1 ("Use of recycled materials reduces greenhouse-gas emissions"). The wider environmental burden, including CED-related effects, is operationalised as item C1.2 ("Use of recycled materials reduces overall environmental impact"). Item C1.3 ("Use of recycled materials contributes to sustainable production") captures the systemic dimension. This translation step is reported here so that the validity of the perception responses can be assessed transparently in Chapter 4.

2.2.6 Contextual Factors Influencing Sustainability Outcomes

Particularly in the Bangladesh context, the substantive nature of the contextual factors that determine whether RPP substitution really achieves sustainability gains is a key aspect of the questionnaire and lies at the heart of section B of the questionnaire. The context of that section is contained within 4 contextual factors. Energy-mix factor (operationalised by items B2.1, B2.2 and B2.3) is capturing how energy-efficient is the production, how widely energy-saving technologies are used and how much renewables are used. The process-efficiency factor items B3.1–B3.3 captures production-line efficiency, waste-reduction practices and overall process optimisation. The transport factor items B4.1 and B4.2 captures perceived transport efficiency and the perceived environmental impact of transport distances.

A fifth set of factors informal recycling, sorting infrastructure, market demand for RPP, customer acceptance, and policy support is present in the analysis indirectly: it appears in the dual-activity-firm contrast, in the cost and customer-acceptance items in Section

C, and in the open-text comments analysed qualitatively in Chapter 4. The mapping from contextual factors to questionnaire variables is therefore explicit and traceable. This is important because the validity of any perception study depends on whether respondents are answering the same conceptual question that the analyst has in mind, and the explicit mapping allows readers to inspect that correspondence directly.

2.2.7 Synthesis of Theoretical Concepts

The three frameworks work together along three different axes in this study. LCT provides the discipline against burden-shifting and structures the life-cycle-stage perception items in Section B. LCA-derived impact categories provide the vocabulary in which environmental outcomes are expressed in Section C1. CET provides the systemic frame that situates the firm-level findings within the wider question of whether circular outcomes are realised at the system level. The three are not redundant: each one does work that the others do not. LCT alone would not produce the impact-category-specific items; LCA-derived vocabulary alone would not discipline the analysis against burden-shifting; CET alone would not anchor the perception items in concrete life-cycle and impact-category language.

The synthesis matters because it allows the empirical work to speak simultaneously to the descriptive sustainability literature, to the LCA literature on PP packaging, and to the policy literature on circular-economy transition in emerging economies.

2.3 Review of Relevant Literature

The literature reviewed in this section consists of four bodies of work that are directly relevant to the thesis: (i) LCA studies of plastic packaging, with a focus on PP and RPP; (ii) studies of the environmental burden of virgin PP and the comparative performance of RPP; (iii) studies of technical and operational recycling challenges for PP; and (iv) studies of circular economy in plastic packaging and of contextual factors in emerging economies. Studies of unrelated polymers (e.g. polylactide, PET, PE insulation panels, asphalt) are not treated as primary evidence but are cited only for methodological points

where their treatment of system boundaries is informative. Where the original draft cited sources that were not directly relevant to PP, the relevant content has been redirected here to the most directly applicable PP-focused studies in the reference list.

2.3.1 Introduction to the Literature

Plastic-packaging sustainability has attracted sustained academic and policy attention because of the volume of plastic produced, the persistence of plastic waste, and the visibility of marine and terrestrial leakage (Geyer et al., 2017; Hahladakis et al., 2018). LCA has become the dominant methodology for comparative environmental evaluation of packaging materials, and a substantial body of work now compares virgin and recycled polymers across a range of impact categories (Galve et al., 2022; Perugini et al., 2005; Tunçok-Çeşme et al., 2024).

However, several limitations of this body of work the predominance of European, North-American and East-Asian case data; the variability of system boundaries; and the limited integration of stakeholder perspectives leave a gap that perception studies in emerging-economy contexts can usefully fill. The present thesis does not claim that RPP has been investigated extensively in Bangladesh; the gap noted in Chapter 1 is precisely that it has not been. The literature reviewed below is therefore predominantly international, and its applicability to Bangladesh is treated as a question rather than as an assumption.

2.3.2 Application of Life Cycle Assessment in Plastic Packaging

Comparative LCA studies of plastic packaging have consistently identified the resin-production stage as a major contributor to GWP and CED, with end-of-life management and transport playing significant secondary roles (Galve et al., 2022; Perugini et al., 2005). Beyond this broad agreement, however, the LCA literature on PP packaging contains substantive disagreements that the perception study can speak to. System boundaries are the first source of disagreement: cradle-to-gate analyses, gate-to-gate analyses and full cradle-to-grave analyses produce different rankings of materials, and even within cradle-to-grave studies the inclusion or exclusion of avoided virgin

production (a credit for recycling) materially changes the outcome (Lazarevic et al., 2010; Niero et al., 2017).

Functional-unit choice is the second: studies that compare on a per-unit-of-packaged-product basis can yield different conclusions from studies that compare on a per-kg-of-resin basis, particularly when shelf-life, packaging-related food losses or distribution efficiencies differ (Pauer et al., 2019). Allocation is the third: open-loop versus closed-loop allocation rules yield different recycling credits, and the choice can dominate the overall result for RPP. These three sources of variability system boundary, functional unit and allocation make it difficult to read across LCA studies as if they were directly comparable. The present thesis is positioned against this backdrop: the perception data it provides should be discussed in relation to LCA evidence, but not treated as if they were measurements within a single shared methodology.

2.3.3 Environmental Burden of Virgin Polypropylene

Virgin PP is produced from petrochemical feedstocks via polymerisation of PE monomer, and its life-cycle burden is dominated by the upstream extraction and refining of fossil resources and by the energy-intensive polymerisation step (Galve et al., 2022; Hahladakis et al., 2018; Perugini et al., 2005). Comparative studies place virgin PP among the higher-burden commodity polymers in fossil-resource and GWP terms when assessed on a per-kg-of-resin basis, and as a packaging material it adds the further end-of-life burden of slow degradation and persistence in landfills and in the environment (Hahladakis et al., 2020). The present review focuses on these four burdens fossil-resource use, cumulative energy demand, GHG emissions, and end-of-life persistence because they translate directly into the survey categories used in Sec. C1 & Chapter 4.

Several earlier general statements in the field about the scale of PP's environmental contribution should be read carefully: the magnitude depends strongly on the energy mix assumed, on the allocation between PP and co-produced petrochemical streams, and on whether the comparison is to other polymers, to alternative materials or to no packaging at all (Maga et al., 2019; Tunçok-Çeşme et al., 2024). For the purposes of this

thesis, virgin PP is treated as a material with substantial and well-documented environmental burdens not as the single largest contributor in the packaging sector, which is a stronger claim than the LCA literature uniformly supports.

2.3.4 Environmental Performance of Recycled Polypropylene

The literature on RPP environmental performance is broadly favourable but conditional. Mechanical recycling of post-consumer PP into a secondary resin typically reduces GHG emissions and CED relative to virgin production by avoiding upstream extraction and polymerisation (Galve et al., 2022; Perugini et al., 2005). The size of the saving, however, depends on a recurring set of conditions identified across studies: collection coverage and contamination at the source; the efficiency of the sorting and washing steps; the energy mix used in reprocessing; transport distances within the recycling chain; and the yield of the recovered material once contamination and quality losses are taken into account (Geyer et al., 2017; Hahladakis et al., 2018; Tunçok-Çeşme et al., 2024).

Studies that apply favourable assumptions on each of these conditions tend to find large environmental savings; studies that apply less favourable assumptions, or that work with empirical data from less-developed sorting infrastructures, tend to find more modest savings, and in some boundary cases fossil-fuel-intensive electricity for reprocessing combined with long transport distances the saving can shrink substantially (Keller et al., 2022; Lazarevic et al., 2010). A further distinction matters and is sometimes blurred in policy discussion: post-consumer recycled PP is not the same as post-industrial recycled PP. The present study addresses RPP specifically, because that is the material relevant to CE transition at the system level, and the literature reviewed in Chapter 4 is filtered for this distinction wherever the source material is identifiable.

2.3.5 Technical and Operational Challenges in Recycling

Five technical and operational challenges recur across the recycling literature and translate directly into measurable themes in the questionnaire. The first is product-quality variability: mechanical recycling reduces molecular weight, increases melt-flow variability and can introduce inclusions, all of which raise the rate of off-specification

output (Caudle et al., 2025; Velásquez et al., 2023). This corresponds to item C3.1 in the questionnaire. The second is contamination: post-consumer PP carries food residues, additives, labels, adhesives and traces of incompatible polymers, all of which require additional washing, sorting and decontamination steps (Hahladakis et al., 2018; Pivnenko et al., 2016). This is reflected operationally in items B3.2 (waste-reduction practices) and B3.3 (process optimisation).

The third is processing-window constraints: the rheology of recycled feeds is more variable, which narrows the operating window of converters and increases reject rates (Ignacio et al., 2023). The fourth is cost: the additional steps and the residual quality risk push the per-tonne cost of RPP closer to virgin PP than a naive view would suggest, and at times above virgin PP when virgin resin prices fall (Galve et al., 2022). This corresponds to item C2.1. The fifth is application limitation, particularly for food-contact packaging where regulatory regimes may exclude general post-consumer RPP without specific authorisation (Caudle et al., 2025; Ignacio et al., 2023). Whether these five challenges are most pronounced in Bangladesh specifically, as opposed to PP recycling generally, cannot be determined from the international literature alone

2.3.6 Role of Circular Economy in Plastic Packaging

Recycling is only part of the discussion about plastic packaging and CE. Recent studies highlight four additional actions that could have a comparable or even larger impact at the packaging system level and that may be underrepresented in industry strategies, other than recycling. The first is the reduction of unnecessary packaging already at the design stage of packaging, such as by right-sizing, lightweighting and eliminating multi-layer construction if a mono-material solution is technically possible (Pauer et al., 2019). The second is reuse refillable type containers and reusable containers for some applications (Niero et al., 2017). The third one is design-for-recyclability which, as the name suggests, involves designing packaging from the source to be more compatible with downstream sorting and reprocessing (Keller et al., 2022; Matos et al., 2024).

The fourth is market pull for recycled content, which involves recycled-content targets set by brand owners and retailers, generating a certain level of market demand for recycled content that can incentivize investments in collection and sorting infrastructure (Reinales et al., 2020). None of these interventions should be seen as replacing RPP substitution but also supporting it; and several of them attempt to tackle bottlenecks that this empirical evidence identifies, especially the customer-acceptance constraint (C3.2), which has greater supportive brand-owner and retailer demand than relying solely on converter action. The framing of the present thesis with CET is thus in line with this strand of literature – one strategic lever of many, and the recommendations presented in Chapter 4 should be understood within this context.

2.3.7 Influence of Contextual Factors on Environmental Outcomes

The conditional environmental outcomes of RPP are transferred via contextual factors into the specific outcomes which can vary geographically. The one most consistently identified contextual factor found in the literature is energy-mix: jurisdictions with a higher share of low-carbon electricity generation show greater GWPs savings as a result of RPPs, while jurisdictions with a higher electricity generation share from fossil fuels show smaller GWPs savings, sometimes significantly smaller, resulting in RPPs (Galve et al., 2022; Keller et al., 2022). A second material sourcing factor is transport routes: Packaging transport is often one of the smaller impact contributors, but where the collection disruption is far and fragment, the resulting recycling savings can be detracted.

Sorting and contamination performance is third: the better the material is sorted and the more contaminables are taken out, the less material that will become reject and the quality of the resulting RPP, the better (Hahladakis et al., 2018; Velásquez et al., 2023). A fourth: extended-producer-responsibility regimes, packaging taxes and quality standards have been found to affect the realised performances of recycling systems (Reinales et al., 2020). However, these four factors: energy mix, transport, sorting, and policy, are more relevant in the context of Bangladesh where electricity generation is highly natural-gas dependent; collection chains involve some informal structures,

mechanical structures for sorting are still in development, and policy under EPR is in early stages.

They correspond to the four stakeholder groups that were surveyed in this study: manufacturers (energy and process), recyclers (sorting and quality), dual-activity companies (closed-loop integration) and the broader policy context in which they all operate. This is the point leading up to the perception data in Chapter 4 that is of particular relevance to the Bangladeshi setting.

2.3.8 Methodological Limitations in Existing Research

The methodological limitations of the existing literature, taken together, justify the addition of perception evidence rather than the addition of yet another LCA. Three limitations of the LCA literature are particularly relevant. The first is data quality: many published LCA studies rely on generic database inventories whose representativeness for specific industrial settings and especially for emerging-economy settings is uncertain (Niero et al., 2017; Ögmundarson et al., 2022). The second is comparability: the system-boundary, functional-unit and allocation choices discussed in Section 2.3.2 mean that direct numerical comparison across studies is rarely defensible, and meta-analytic conclusions are correspondingly fragile.

The third is impact-category coverage: most studies report a small number of well-quantified categories (predominantly GWP and CED) and underreport toxicity, biodiversity loss and marine-litter dimensions even where these are most relevant (Hahladakis et al., 2018). Perception studies, however, have their own limitations, and these must be acknowledged explicitly so that the present thesis can defend its methodology. Stakeholder perceptions can be biased by organisational interest (manufacturers may be more sceptical of RPP if they bear the quality risk; recyclers may be more enthusiastic because they own the supply); they can be unevenly informed and they can be shaped by social-desirability pressures, particularly on environmental items where the socially preferred answer is unambiguous (Bock and Meyerding, 2023).

The present study mitigates these risks through purposive selection of respondents with direct industry experience, through carefully neutral questionnaire wording, through anonymous administration, and through cautious interpretation of the environmental-benefit results in Chapter 4. The purpose of disclosing these limitations here is to make the methodological choice perception, rather than inventory defensible on its own terms rather than by default.

2.3.9 Research Gap and Justification

The research gap that this thesis addresses is precise. It is the absence of stakeholder-informed, context-specific evidence on the perceived sustainability implications and adoption conditions of post-consumer recycled polypropylene in plastic packaging in Bangladesh. The gap is not the absence of inventory or operational data that is a separate, larger gap that requires inventory-based work and the present thesis does not attempt to close it. The gap is also not the absence of LCA work in general; that work is extensive internationally. What is missing is structured evidence on how Bangladeshi practitioners themselves perceive the sustainability implications, opportunities and challenges of RPP, anchored in the LCA literature's vocabulary but generated by a method appropriate to the country's data environment.

2.4 Summary and Implications for the Research

The three implications of the literature of this chapter affect the methodology developed in Chapter 3. The first is that a perception-based survey approach is suitable for the question being asked in the Bangladeshi context; lacking inventory data, as described in this paper, and an emphasis on the value of evidence derived from stakeholder perceptions to the body of scholarship informed by LCA. The second is that the questionnaire variables get taken expressly from the most policy-relevant impact categories from the LCA literature, translated into plain language form that the respondent can reliably answer, as well as from the operational and technical challenges consistently highlighted by the recycling literature, and from the contextual factors that determine whether the RPP substitution has system-level circular effects.

The third is that the investigation should be set up to expose group differences, both within each group of stakeholders and between the different groups systemic differences between groups are exactly the sort of thing that perception research is well equipped to expose. The contribution of the empirical work that follows is therefore best described as a more nuanced view of perceived environmental performance, rather than of measured environmental performance. The latter is the proper subject of inventory-based LCA work that this thesis does not undertake. However, the study supplies a structured, replicable, theoretically grounded account of how Bangladeshi practitioners assess RPP and that account, set against the international LCA literature reviewed above, constitutes the contribution of the work.

3. Research Methodology

This chapter sets out the methodology of the completed study, which examined how industry stakeholders in Bangladesh perceive the sustainability implications of post-consumer recycled polypropylene in plastic packaging. The chapter is structured around six sections. Section 3.1 describes the research task and defines the target population precisely. Section 3.2 sets out the research design and analytical approach. Section 3.3 describes the data-collection method, including the questionnaire, language, piloting, recruitment and response rate. Section 3.4 specifies the data-analysis methods. Section 3.5 addresses reliability, validity and ethical considerations. Section 3.6 documents the actual research process as it was carried out.

An LCA-style measurement of the environmental performance of PP and RPP would have required firm-level inventory data on energy use, emissions, transport distances, material flows and waste volumes that the sampled organisations were not in a position to release, for reasons of commercial sensitivity and incomplete record-keeping. The study therefore did not attempt a quantitative LCA. It used Life Cycle Thinking, the impact-category vocabulary of LCA, and Circular Economy Theory as the conceptual and interpretive scaffolding for a structured perception survey, and analysed the resulting data using descriptive statistics, internal-consistency reliability analysis, non-parametric group-comparison tests and rank-order correlation analysis. The decisions explained in this chapter follow from that overall design.

3.1 Description of the Research Task

The research task was to characterise stakeholder perceptions of the sustainability implications, opportunities and challenges of post-consumer recycled polypropylene in Bangladesh's plastic-packaging sector, framed by Life Cycle Thinking, the impact-category vocabulary of LCA and Circular Economy Theory. The target population was defined precisely as professionals working in three categories of organisation in Bangladesh's plastic-packaging value chain: (i) manufacturers of plastic packaging using

PP as a primary input; (ii) dedicated recycling firms that collect, sort and reprocess post-consumer PP into secondary resin; and (iii) dual-activity firms that combine manufacturing and recycling within a single organisational structure.

Within each organisation, eligibility was restricted to professionals who held one of the following positions and had at least one year of direct operational exposure: production manager, plant manager, operations manager, quality-control engineer, sustainability or environment officer, recycling-line manager, or senior owner-operator with day-to-day operational responsibility. The study covered both current users of RPP and potential users that is, manufacturers familiar with RPP through industry experience, supplier interaction or sustainability training but not necessarily using it in current production. The presence of both current and potential users in the sample is deliberate, because it permits the comparison of usage-related perceptions across the dimension of actual use (Section 4.2).

3.2 Research Design and Approach

This research is conducted as quantitative, cross sectional and descriptive analytical research. It is quantitative because the data are the responses that are in order, which can be used for descriptive and inferential statistics. It is cross sectional since surveying was done for all respondents within a specific 3-month frame of data collection, therefore attitudes were measured at a single moment in time. Is descriptive-analytical in a complementary dual sense. Descriptive component utilizes means, standard deviations, medians and frequency distributions at the item level to summarize perceptions, organized. The analytical part test to see if there is a systematic difference in perception between stakeholder groups and stakeholder organizational characteristics and test association between constructs (rank order correlation).

Specifically, the analytical step involves the use of Kruskal-Wallis H tests for between-group comparisons based on organisation type and number of years working, and Spearman's rank-order correlations for inter-construct relationships due to the fact that these composites are expressed as ordinal measures with Likert items, and therefore do

not meet the assumption of normality (Field, 2018; Pallant, 2020). It is not a true hypothesis testing as it is deductively organized. The questionnaire variables were extracted from and the results were anchored in existing theoretical frameworks: Life Cycle Thinking, a set of terms used when talking about impact categories in LCA, and the Circular Economy Theory. An empirical test of hypotheses has explored and described there were no formal causal ones tested.

3.3 Data Collection Methods

Primary data were collected through a structured questionnaire administered online between January and March 2026 to purposively selected manufacturers, recyclers and dual-activity firms operating in the Dhaka, Narayanganj, Gazipur and Chattogram industrial corridors, which together account for the majority of formal plastic-packaging activity in Bangladesh. The questionnaire is reproduced in full in Appendix A. It contains 23 substantive items grouped into four sections. Section A captures three respondent-profile variables (organisation type, years of experience and organisation size). Section B captures eleven items grouped into four independent-variable indices: RPP usage (B1.1–B1.3), energy use (B2.1–B2.3), process efficiency (B3.1–B3.3) and transport (B4.1–B4.2).

Section C captures nine dependent-variable items grouped into three indices: environmental benefit (C1.1–C1.3), economic and operational impact (C2.1–C2.3), and usability and performance (C3.1–C3.3). Section D contains a single overall-perception item (D.1). All Section B, C and D items use a five-point ordered scale; the exact anchors are item-specific and are reproduced verbatim in Appendix A. Two open-text items at the end of the instrument invited respondents to comment on enabling factors and barriers; these were intended as a supplementary, qualitative aid to interpretation rather than as a primary data source, and are analysed thematically in Section 4.4.

The questionnaire was developed in English, the working language of professional communication in Bangladesh's manufacturing and recycling sectors, with key technical terms ("recycled polypropylene", "greenhouse-gas emissions", "environmental impact",

"sustainable production", "process efficiency") explained inline at first use to ensure consistent interpretation across respondents. A Bangla glossary was provided as a supplementary aid for any respondent who preferred to consult plain-language equivalents during completion. The instrument was tested with three industry respondents (one manufacturer, one recycler and one sustainability practitioner) In the pilot process, it was found that there were ambiguities in 8 items, which were clarified prior to major administration, without any additions or omissions as a result of the pilot.

An initial list of 200 eligible professionals was constructed from three sources: directories of registered plastic-packaging firms held by industry associations, recyclers identified through municipal recycling networks, and sustainability practitioners identified through professional networks. Each invited respondent received an email containing the participant information sheet, a consent statement and a unique survey link. Of the 200 invitations, 153 returned a response. Of these, seven were entirely blank and four were duplicates from the same respondent; both categories were removed during data cleaning. The final analytic sample comprised 142 usable responses, equivalent to a 71 per cent effective response rate a figure that is high for a survey of this type and that reflects the pre-screened, purposively recruited nature of the sample.

3.4 Data Analysis Methods

All analyses were performed using IBM SPSS Statistics version 28, with cross-validation of selected procedures in JASP version 0.18 for the non-parametric tests. Likert-scale responses were coded as integers from 1 to 5 in the direction reported in Appendix A, with reverse-scored items reverse-coded before composite-index calculation. No imputation was performed for missing data: respondents who skipped more than two items in any single index were excluded at the cleaning stage; the four respondents removed during cleaning were dropped for this reason or for duplication. The analytical procedure was done in four steps. This was followed by a purely descriptive analysis of the profile of the sample respondents and the distribution of the items, each shown in

terms of frequencies, percentages, means, standard deviations, and medians (coded +1 or -1) (Sec. 4.1.) and in full in Appendix B.

The second was to create seven composite indices by simply taking the unweighted average of the items in the index, following common usage in similar perception studies (Hair et al., 2019); the seven composite indices' internal consistency was measured by the Cronbach's alpha (Cronbach, 1951) which is reported in Section 4.1.2 and Appendix C. The cross-group comparison was done third – as Likert composites are ordinal and due to the fact that they do not follow normal distribution, Kruskal-Wallis H tests were used to test for systematic differences across the three types of organisations and across the four experience bands; statistical significance was set at the conventional level of less than the 5% ($p < 0.05$) and is reported up to three significance figures ($p < 0.001$) (Field, 2018; Pallant, 2020).

The fourth step was correlational analysis in which all the composite indices were correlated with each other by means of the Spearman rank order correlation coefficient due to flexibility and naturalness of the data. The two open text questions in the questionnaire were analysed thematically, and not statistically. The researcher coded the responses inductively, using emergent themes that occurred in at least the fifth of the respondents. The open text findings are presented in Section 4.4 and highlighted to illustrate and support specific quantitative results, but do not have an independent inferential value and are not presented as primary evidence.

3.5 Reliability, Validity, and Ethical Considerations

Reliability was addressed in three ways. First, the questionnaire used a structured format with consistent five-point ordered scales and identical instructions across respondents, which minimised measurement error from format inconsistency. Second, internal-consistency reliability was assessed using Cronbach’s alpha for each of the seven multi-item composite indices. The resulting alpha coefficients ranged from 0.672 (transport, two items) to 0.917 (environmental benefit), with five of the seven scales above the commonly applied 0.80 threshold and the process-efficiency scale above the

0.70 threshold (Field, 2018; Tabachnick and Fidell, 2019). The two-item transport index, which falls below the 0.70 threshold, is reported descriptively only on the well-established understanding that two-item scales tend to underestimate true reliability; results that depend on the transport index are interpreted with corresponding caution.

Third, the questionnaire was piloted with three respondents drawn from outside the final sampling frame, and items identified as ambiguous in the pilot were revised before main administration. Validity was addressed in three corresponding senses. Content validity rested on the explicit mapping between questionnaire items and the theoretical framework, set out in Chapter 2 and traceable item by item in Appendix A; an independent academic supervisor reviewed the mapping before piloting. Construct validity was supported empirically by the internal-consistency results above and by the inter-construct correlation pattern reported in Sec. 4.2.3, which shows that the overall-perception item correlates substantively with the environmental-benefit, economic and usability indices in the directions theory predicts a form of nomological-validity evidence.

External validity is more limited: the purposive sampling frame, while large for a study of this type and broadly representative of the formal Bangladeshi plastic-packaging sector, does not support claims of statistical generalisation to a defined population. The findings are best read as analytical generalisations to firms with similar profiles in similar industrial corridors. Ethical considerations were applied in line with the ethical guidelines of the University of Vaasa for non-clinical, low-risk social-research studies. Participation was entirely voluntary; potential respondents received a participant information sheet and a consent statement before they accessed the questionnaire, and could withdraw at any point before submission without consequence.

No identifying personal information was collected: respondents were asked only for organisation type, years of experience, organisation size and city; no names, contact details or organisation identifiers appear in the dataset. The online survey platform was configured not to log IP addresses or device metadata. The completed dataset is held on a password-protected institutional drive accessible only to the researcher and the

supervisor, in line with general data-protection good practice. Because the study involved no clinical intervention, no minors, no vulnerable groups and no sensitive personal data, formal institutional ethics committee approval beyond the standard departmental review was not required for the project under the host institution's guidelines applicable at the time of the study.

3.6 Description of the Research Process

The research process followed eight identifiable stages, each of which is documented here in concrete terms rather than as an ideal sequence. The first stage, in January 2026, was problem definition and the formulation of research objectives and the research question, informed by an initial scoping review. The second stage, between February 2026, was the systematic literature review reported in Chapter 2, which identified the three gaps motivating the study (Bangladesh-specificity, stakeholder perception, adoption conditions). The third stage, in February 2026, was the development of the conceptual framework and the mapping of theoretical concepts onto questionnaire variables documented in Chapter 2 and Appendix A.

The fourth stage, in February. 2026, was questionnaire drafting, supervisor review, and piloting with three industry respondents, followed by revision of eight items before main administration. The fifth stage, in March 2026, was the construction of the sampling frame from industry-association directories and professional networks, and the issuing of the 200 initial invitations together with the participant information sheet and consent statement. The sixth stage, March 2026, was the active data-collection period, during which two reminder rounds were sent at two-week intervals and the final analytic sample of 142 respondents was achieved. The seventh stage, in March and April 2026, was data cleaning, coding and analysis, including the descriptive, reliability, group-comparison and correlational analyses reported in Chapter 4.

The final stage, in April and May 2026, was thesis writing and revision in response to supervisor feedback, including the revisions reflected in the present chapters of the thesis. Each stage was documented in a working logbook held by the researcher, and

the audit trail is available to the supervisor on request. The purpose of recording the process at this level of concreteness is to support transparency and to allow other researchers to replicate or extend the study with full knowledge of how it was actually carried out, rather than only how it was planned.

4. Results and Analysis

Life Cycle Thinking and Circular Economy Theory informed the research, which aimed at understanding the perceptions of sustainability of post-consumer recycled polypropylene (RPP) among industry stakeholders in the Bangladeshi plastic-packaging industry. The structured questionnaire was used to collect primary data from 142 respondents drawn from manufacturing, recycling, and dual-activity organisations in Dhaka, Narayanganj, Gazipur, and Chattogram between January and March 2026. As is typical of survey research on sustainability, descriptive statistics, internal-consistency reliability analysis, non-parametric group-comparison tests and rank-order correlation analysis were employed in analysing the data (Field, 2018; Pallant, 2020).

The chapter is divided into five parts. Section 4.1 introduces the empirical results, showing the sample profile along with the reliability of the measurement tool, and then describes item- and index-level distributions of each construct. Section 4.2 makes sense of these findings, with particular care given to differences between organisation types and to the inter-construct relationships that emerge from the data. Section 4.3 compares the empirical findings to the theoretical framework proposed in Chapter 2. Section 4.4 reflects on the practical implications of the findings for manufacturers, recyclers and policymakers in Bangladesh, and Section 4.5 summarises the contribution of the study to the field.

4.1 Presentation of Findings

This section reports the empirical results of the survey in the order in which the questionnaire was administered. It begins with the sample profile and the reliability of the measurement scales, then presents descriptive results for the questionnaire's "independent" blocks (material use, energy use, process efficiency, and transportation) and its "dependent" blocks (perceived environmental, economic, and usability outcomes), and concludes with the overall sustainability perception. The labels "independent" and "dependent" are used as questionnaire-block descriptors only and

do not imply causal status: the cross-sectional, perception-based design supports description and association testing, not causal inference.

4.1.1 Sample Profile and Response Characteristics

Affected by the seven blank returns and four duplicate ones 142 respondents resulted in a useful response rate of 71% of the 200 invitations given. The sample is representative of the distribution selected in the sampling process. Manufacturers (n=74, 52.1%), organisations that make and recycle (n=30, 21.1%) and dedicated recycling firms (n=38, 26.8%) are the three largest stakeholder groups. The presence of plastic manufacturers is in line with the fact that there are many more converters than formal recyclers in the Bangladeshi plastic-packaging system (Hahladakis et al., 2020). Most respondents have substantive industry experience: 53 (37.3%) report 2–5 years, 43 (30.3%) report 6–10 years, 27 (19.0%) have over ten years, and only 19 (13.4%) have less than two years.

This means that a sample of more experienced practitioners is emphasised, and hence, that the perception data are more credible (Bryman, 2016). Organisation sizes are now fairly even with small organisations (1-50 employees) making 41.5%, medium organisations (51-250) 40.8% and large organisations (>250) 17.6%. These three profile distributions are summarised in Figure 2 and tabulated over in Table 1. The target has been built based on the proportional structure of registered plastic-packaging companies as reported by industry Associations, where converters significantly outnumber formal recyclers, and as this scenario was considered representative of the overall status, the decision was to weight the recruitment frame upwards towards the manufacturers, in what is called a "recycling bias" (Hahladakis et al., 2020).

There are three additional caveats to representativeness. Firstly, the sample is concentrated in formally registered firms, that are also accessible by professional networks, and informal recyclers and informally established converter should not be generalised to the perceptions reported here. Secondly, there is a skewing of the sample towards medium and small organisations and thus the voices of smallest informal

converters remain unheard. Third, as participation was voluntary and the survey was positioned as being about sustainability, it is plausible that the range of views represented is skewed towards those firms that already consider sustainability issues as part of their everyday activities compared to those that have not yet considered RPP at all. None of these pitfalls is a constraint on internal validity; instead, they are seen as constraints on external generalisation and are revisited in Section 5.4.

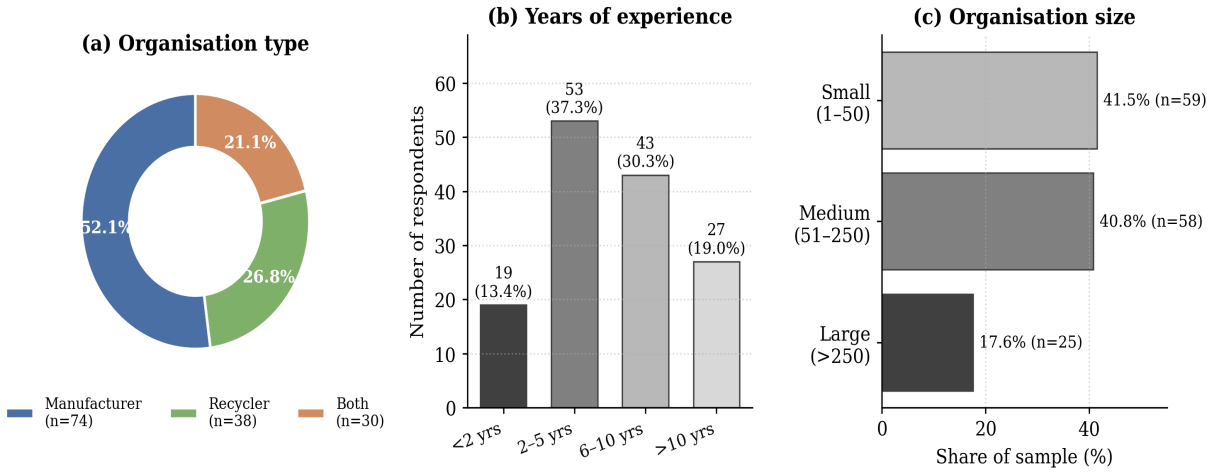

Figure 2. Sample profile by (a) organisation type, (b) years of experience and (c) organisation size (n = 142).

Table 1. Sample profile of survey respondents (n = 142).

Variable	Category	n	%
Organisation type	Manufacturer	74	52.1
	Recycling firm	38	26.8
	Both	30	21.1
Years of experience	<2 years	19	13.4
	2–5 years	53	37.3
	6–10 years	43	30.3

Variable	Category	n	%
	>10 years	27	19.0
Organisation size	Small (1–50)	59	41.5
	Medium (51–250)	58	40.8
	Large (>250)	25	17.6

4.1.2 Reliability of the Measurement Indices

The internal consistency of the seven multi-item indices was assessed using Cronbach's alpha prior to any substantive interpretation (Cronbach, 1951). The measurement model used in this thesis comprises seven multi-item composite indices (RPP usage, energy use, process efficiency, transport, environmental benefit, economic, and usability), supplemented by one single-item overall-perception measure (D.1); only the seven multi-item indices are reported in Table 2, and Table 3 separately reports the single-item measure for transparency. Five of the seven multi-item scales return alpha values well above the conventional 0.80 threshold for good reliability (Field, 2018), and the process-efficiency index exceeds the 0.70 threshold of acceptable reliability.

The two-item transport index returns $\alpha = 0.672$, which is below the 0.70 cut-off. Two-item scales are well known to understate true reliability (Tabachnick and Fidell, 2019), but the present thesis takes the cautious view that the transport index does not constitute strong measurement evidence: any results that involve transport are therefore reported descriptively only, are not used as the basis for inferential claims about transport-related sustainability perceptions, and would need to be re-developed in any future replication. Subject to this caveat, the measurement model is adequate to support the descriptive and comparative analysis that follows.

Table 2. Internal-consistency reliability of the seven measurement indices. Two-item scales typically show lower alpha values; the transport index is retained for descriptive purposes.

Construct	Items	Cronbach's α	Interpretation
RPP usage (B1)	3	0.889	Good
Energy use (B2)	3	0.838	Good
Process efficiency (B3)	3	0.803	Good
Transport (B4)	2	0.672	Acceptable*
Environmental benefit (C1)	3	0.917	Excellent
Economic (C2)	3	0.914	Excellent
Usability (C3)	3	0.899	Good

4.1.3 Patterns of Recycled Polypropylene Usage

The first independent construct measures the extent to which respondents' organisations use post-consumer recycled polypropylene. The composite RPP-usage index has a mean score of 3.04 on the five-point scale (SD = 0.97), suggesting moderate overall integration with wide dispersion. This trend is reflected at the item level. On the proportion of polypropylene recycled in production (B1.1), 10% of respondents use none, 24% use 1–25%, 37% use 26–50%, 25% use 51–75% and 5% use 76–100%. The frequency item (B1.2) has a similar shape: 28% never or rarely; 35% sometimes; and 38% often or always use recycled material.

These data, together, suggest that the integration of RPP in this sector is not evenly distributed, but rather presents a continuous spectrum of RPP usage, with the bulk of the companies in the middle, a large percentage of the firms already high into the levels of RPP integration, and another large percentage still well dependent on virgin PP. These markers for uptake are all characteristic of a segmented uptake pattern, which is typical

of the literature on emerging-economy recycling systems, where transition has been typified by uneven uptake and concurrent formal and informal supply pathways (Hopewell et al., 2009; Velásquez, et al., 2023). The RPP-usage score is significantly higher for recyclers (mean = 3.64) than for manufacturers (mean = 2.57), and likewise for the manufacturers in dual-activity (mean = 3.43).

4.1.4 Energy Use and Process Efficiency

The energy-use construct has a mean of 2.72 (SD = 0.83), which is the lowest of all constructs measured. This is certainly the most outstanding result in this framework and one of the most robust analytic indicator of the dataset, the opposition between renewable-energy use and measures related to the operation of processes. By production, renewable-energy use (B2.3) scores a mean of 2.23 on the five-point scale, with 59% of respondents scoring "no use" or "very low use" and no one rating the use as "very high. Items which measure production energy efficiency (B2.1, mean = 2.92), and energy-saving technologies (B2.2, mean = 3.01), by contrast, lie near the midpoint of the scale, and the process-efficiency items, below, are measurably above the midpoint.

The substantive implication is that respondents perceive their own operations as reasonably efficient at the equipment and waste-reduction level while still operating within an energy context that is itself fossil-heavy, in line with documented dependence on natural-gas-fired grid power and captive generation in Bangladesh’s manufacturing sector (Boyd et al., 2021; Kim et al., 2023). This asymmetry firm-level efficiency without low-carbon energy materially limits the life-cycle gains that material-substitution strategies alone can deliver, and is one of the clearest perception-based echoes of the burden-shifting risk that Life Cycle Thinking exists to expose.

The process-efficiency index is more favourable: respondents return a mean of 3.49 (SD = 0.75). Just over half (51%) rate their production operations as "efficient" or "very efficient", and 50% report waste-reduction practices implemented "often" or "always". The transport index sits closer to the scale midpoint (M = 3.10, SD = 0.71); item B4.2 in

particular indicates that 23% of respondents perceive distance-related transport as having a "high" or "very high" environmental impact, while a majority (51%) place the impact at the midpoint, in line with empirical findings on the carbon-intensity of fragmented, road-dominated logistics chains in South Asia (Lazarevic et al., 2010). The combined distributions for Sec. B are shown in Figure 3. As noted in SeC. 4.1.2, the transport index is reported descriptively only and is not used as the basis for inferential claims.

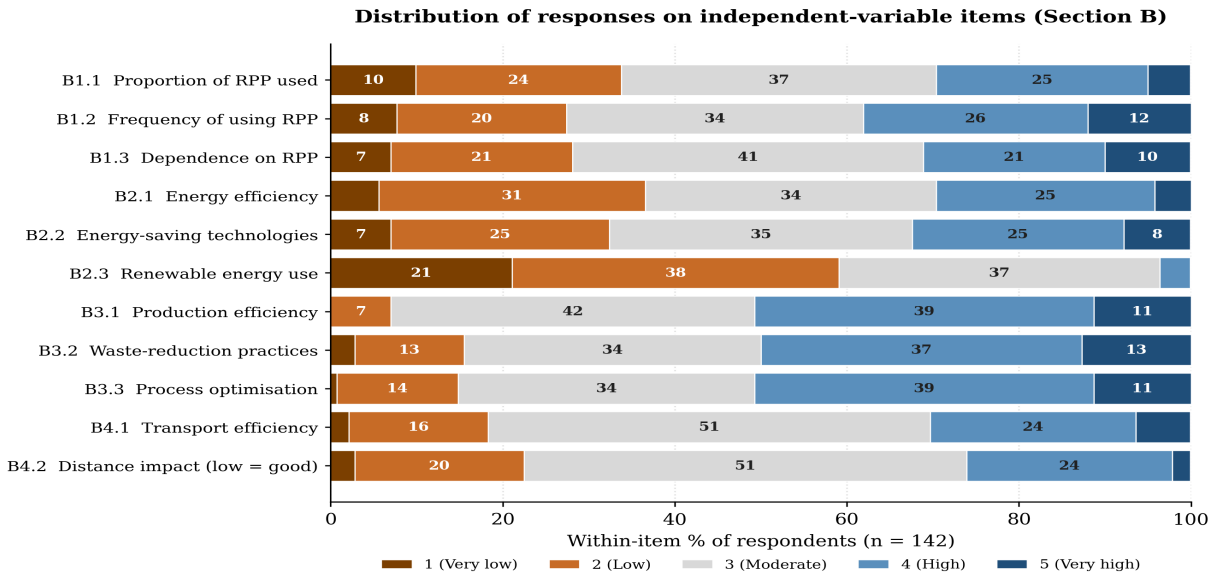

Figure 3. Distribution of responses on the independent-variable items (Section B). Cells show within-row percentages; n = 142.

4.1.5 Perceived Environmental Benefit (Environmental Benefit Index)

The Environmental Benefit Index relabelled here from the “welfare/environment” working title used during data collection, because “welfare” in social-research usage often signals human or social welfare rather than environmental benefit captures perceived environmental benefits of RPP relative to virgin polypropylene, expressed in the impact-category vocabulary of LCA. It returns the highest mean of all dependent constructs (M = 3.81, SD = 0.93). Item-level distributions are strongly positive: 65% of respondents agree or strongly agree that RPP use reduces greenhouse-gas emissions (C1.1, M = 3.78); 59% agree or strongly agree that it reduces overall environmental

impact (C1.2, M = 3.78); and 65% agree or strongly agree that it contributes to sustainable production (C1.3, M = 3.86). The proportion of clearly disagreeing responses (1–2) does not exceed 12% on any item.

The intensity of the environmental signal is in line with the general pattern in the comparative LCA literature, which reports lower GHG and resource footprint for mechanically recycled pathways but with varying magnitudes, depending on system boundaries and energy mixes (Galve et al., 2022; Tunköz-Ceşme et al., 2024). Because the environmental-benefit score is high, this is at the descriptive level in line with international evidence base. It is, however, a question whether this idea of alignment also means that in Bangladesh stakeholders think in the full "LC" of LCA. This is addressed through a comparison of LCT under the LCT comparison in Section 4.3.

4.1.6 Perceived Economic and Operational Impact (Economic Index)

The Economic Index is an indicator of cost efficiency, profitability impact and operational performance improvement. It has a mean of 3.18 (SD = 0.98); slightly above the middle of the scale, and the highest standard deviation of any independent construct. The point here is not the central tendency; that is, people are not clumping around the 'moderate consensus' option, it's the dispersion, the result obtained when respondents can be seen to be splitting into distinct clusters. The split is obvious in the cost-efficiency item (C2.1, M 3.11), with 36% found RPP to be high or very high cost-efficient, 30% found it to be low cost-efficient and the remaining responses put them in the neutral zone. Profitability impact (C2.2, M = 3.30) is slightly more positive, operational performance (C2.3, M = 3.12) is closer to the midpoint and the three-way split is similar.

Combining readings of these distributions, approximately one-third of the sample feels that there is a strong economic rationale for RPP, approximately one-third of the sample feels that there is no economic rationale for RPP, and about one-third of the sample is on the fence. This is not just a statistical inconvenience but an actual difference of substance. Apart from Environmental belief, which was measured by the Environmental Benefit Index, the dimensions measured here, being perceived cost efficiency,

profitability and operational performance, are also significant for the adoption of RPP at the firm level. A split recognition of the economy thus sets the groundwork for the later claim that in Bangladesh, the development of RPP is hampered even if environmental awareness is strong by technical-and commercial issues.

4.1.7 Perceived Usability and Performance (Usability Index)

Product quality and acceptance by customers, ease of integration into the system (Usability Index) (M = 2.91, SD = 0.94) is the lowest of all dependent constructs. Three item distribution reports convey a clear message. The product-quality item (C3.1, M = 2.94) indicates that 38% of the respondents perceive as “poor” or “very poor” the level of quality of the products that are produced using RPP, while 32% of them consider it is of “average” quality and only 30% regards it as “good” or “excellent”. The lowest rating of the total questionnaire for dependent measures is customer acceptance (C3.2 M=2,84) with only 27% of respondents indicating customer acceptance to be “high” or “very high”. The curve of ease of integration (C3.3, M = 2.95) is similar.

These scores have a concrete meaning; low and moderate usability scores reflect concrete concerns by participants regarding the quality of the product and downstream customer acceptance and recycling feed easy to be integrated with existing production lines, respectively. Measures such as reject rates, customer complaints, line stoppages and a risk to reputation are real, firm-level issues corresponding to these and they are real issues on which the decision whether to adopt RPP, or whether to adopt it on any meaningful scale, hinges. Technical publishing references on mechanical-recycling pathways for polypropylene have described the common quality risks of reduction in the polymer's molecular weight and variable melt-flow index, as well as contamination from incompatible polymers as common issues (Caudle et al., 2025; Ignacio et al., 2023).

Deeper comparison with that literature, and with the LCA-vocabulary expectations set in Chapter 2 is taken up in Section (4.3). The total Likert distribution for the dependent variable items are given in Figure 4.

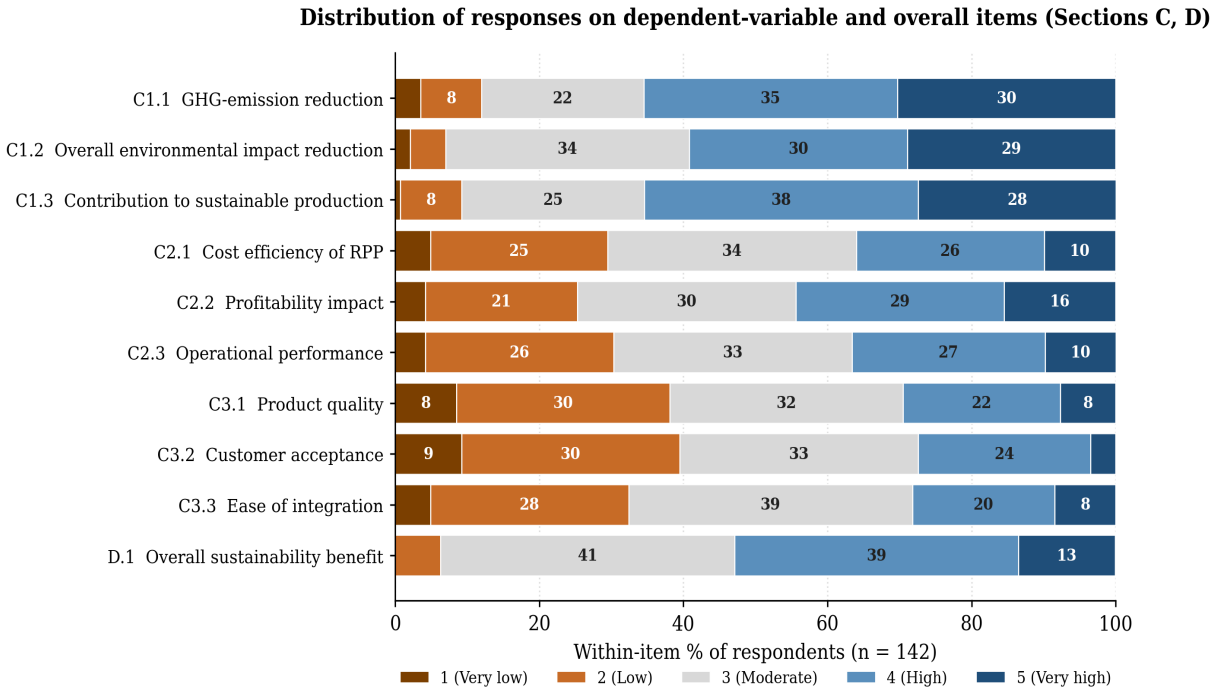

Figure 4. Distribution of responses on the dependent-variable and overall items (Sections C and D). Cells show within-row percentages; n = 142.

4.1.8 Overall Sustainability Perception

The single overall-perception item (D.1, “What is the overall sustainability benefit of recycled polypropylene?”) returns a mean of 3.60 (SD = 0.80), with 52% of respondents selecting “high” or “very high”, 41% selecting “moderate”, and only 6% selecting “low” or “very low”. As a single item, D.1 is not equivalent in psychometric reliability to the multi-item composite indices reported above and is therefore interpreted not as a stand-alone construct but as a summary judgement that complements the Environmental Benefit, Economic and Usability indices. Read alongside those indices, the overall-perception result reveals an analytically important tension: respondents return a clearly positive overall sustainability judgement (M = 3.60) at the same time as registering a markedly weaker view of usability (M = 2.91) and a divided view of economic performance (M = 3.18, SD = 0.98).

In other words, the holistic verdict is more favourable than would be predicted by simply averaging the underlying outcome-construct scores. Whilst reflecting the Life Cycle Thinking frame there has been used in this study, this indicates that an overall benefit judgement should not be based only on the operational and commercial friction identified in Sections 4.1.6 and 4.1.7, but also upon the environment. The overall distribution and cross-tabulation by type of organisation is shown in Figure 5.

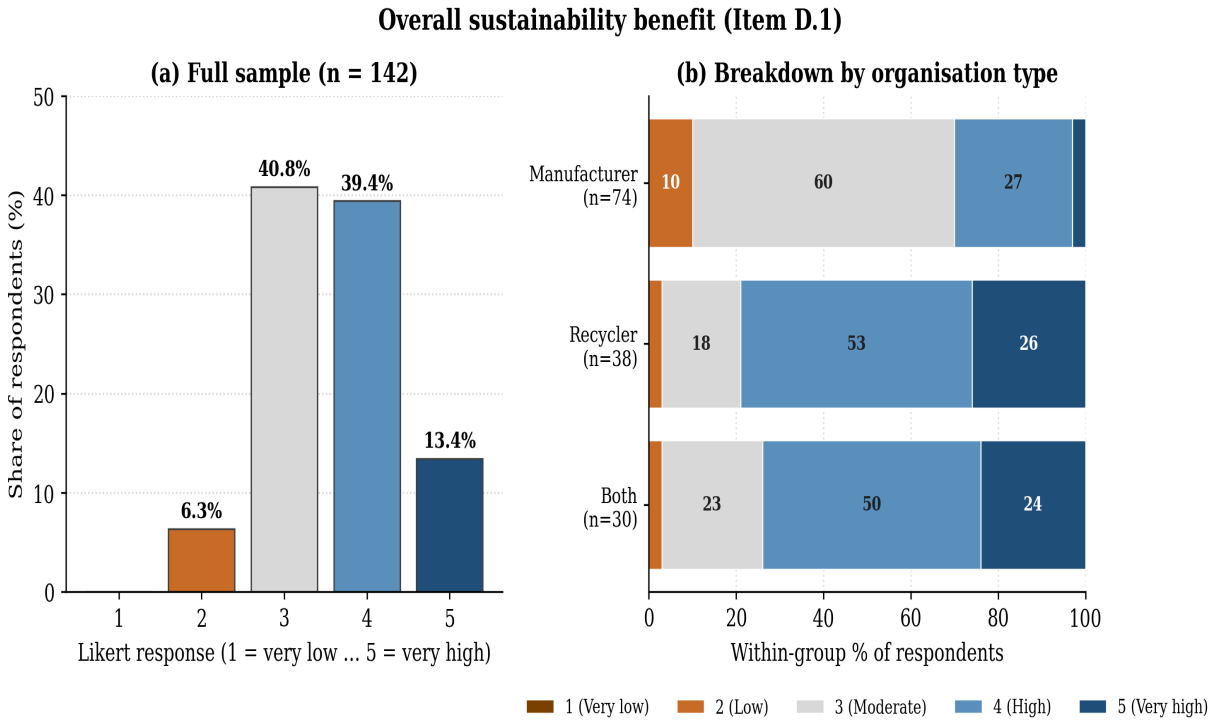

Figure 5. Overall perceived sustainability benefit of RPP: (a) full distribution; (b) breakdown by organisation type.

Consolidates the composite-index means and standard deviations for the full sample, permitting a direct comparison across constructs.

Table 3. Descriptive statistics for the eight composite indices and the overall-perception item (n = 142, scale 1–5).

Composite index	Items	Mean	SD	Median	Direction
RPP usage (B1)	3	3.04	0.97	3.0	Slightly above midpoint
Energy use (B2)	3	2.72	0.83	2.7	Below midpoint
Process efficiency (B3)	3	3.49	0.75	3.7	Above midpoint
Transport (B4)	2	3.10	0.71	3.0	Around midpoint
Environmental benefit (C1)	3	3.81	0.93	4.0	Clearly positive
Economic (C2)	3	3.18	0.98	3.0	Slightly above midpoint
Usability (C3)	3	2.91	0.94	3.0	Slightly below midpoint
Overall benefit (D)	1	3.60	0.80	4.0	Clearly positive

4.2 Interpretation of Results

This section is all about the tension: the descriptive results provide a fairly consistent but tensioned picture. Stakeholders believe RPP is good for the environment but the usability (quality, customer perception, integration), economic perception (not uniformly positive), and lack of strong life-cycle integration (energy and transport perceptions not well associated with outcome perceptions) act as barriers to adoption.

The other sub-sections of the review do not present other interpretations; rather, they continuously revisit this core conflict and illustrate the respective advantages and disadvantages of each of the tests (cross-group comparability, experience-band comparability and inter-construct correlation).

Content analysis was then used to investigate how the data indicated systematic variation across organization type (in 4.2.1), across years of experience (in 4.2.2), across the underlying constructs (in 4.2.3), and to aggregate the resulting pattern as a bridge into a focus on the theoretical comparison in Section 4.3.

4.2.1 Cross-Group Comparison by Organisation Type

Since the dependent variables used are composites that are ordinal in nature and normality cannot be assumed, the Kruskal-Wallis H test was employed to establish if there are a systematic difference in perceptions across the different types of organisations (Pallant, 2020). Test results and group means are reported in Table 4. Statistically significant differences ($p < 0.05$) emerge for six of the eight indices: RPP usage ($H = 38.69$, $p < 0.001$), energy use ($H = 7.71$, $p = 0.021$), environmental benefit ($H = 12.20$, $p = 0.002$), economic ($H = 27.72$, $p < 0.001$), usability ($H = 24.33$, $p < 0.001$), and overall perception ($H = 32.59$, $p < 0.001$). No significant differences were found for process efficiency or transport, indicating that these dimensions are conditioned by sector-wide factors rather than by organisation-type-specific experience.

The Kruskal-Wallis test is an omnibus procedure: it indicates that at least one group differs from the others, but does not, on its own, identify which pairs differ. Pairwise post-hoc comparisons (e.g. Dunn's test with Bonferroni correction) were not performed in the present analysis. The discussion below therefore reports group-mean patterns descriptively and avoids strong claims about which specific pairs of organisation types differ statistically; formal pairwise testing is recommended as part of the future replication work outlined in Section 5.5.

Table 4. Composite-index means by organisation type and Kruskal-Wallis tests (n = 142). *p < 0.05, **p < 0.01, ***p < 0.001.

Index	Manufacturer M (SD)	Recycler M (SD)	Both M (SD)	Kruskal-Wallis H	p
RPP usage	2.57 (0.93)	3.64 (0.78)	3.43 (0.85)	38.69	<0.001***
Energy use	2.57 (0.86)	2.71 (0.78)	3.10 (0.74)	7.71	0.021*
Process efficiency	3.55 (0.79)	3.34 (0.71)	3.52 (0.66)	1.94	0.379
Transport	3.13 (0.74)	3.15 (0.66)	2.95 (0.71)	3.27	0.195
Environmental benefit	3.55 (0.99)	3.98 (0.83)	4.21 (0.74)	12.20	0.002**
Economic	2.83 (0.96)	3.84 (0.84)	3.20 (0.93)	27.72	<0.001***
Usability	2.54 (0.94)	3.43 (0.83)	3.17 (0.81)	24.33	<0.001***
Overall benefit	3.23 (0.79)	4.03 (0.66)	3.97 (0.69)	32.59	<0.001***

Three broad patterns emerge from Table 4. First, recyclers and dual-activity firms register markedly higher RPP-usage scores than manufacturers a result that is structurally expected, but which also confirms that the sample successfully discriminates between RPP-experienced and RPP-light respondents. Second, recyclers and dual-activity firms hold consistently more positive perceptions of the environmental, economic and usability outcomes of RPP than do manufacturers. The manufacturer-recycler gap on the overall-perception item is 0.80 of a scale point (3.23 vs. 4.03), which is substantively large on a five-point scale; in the absence of formal post-hoc testing, this gap is reported as a descriptive pattern rather than as a confirmed pairwise contrast.

The plausible explanation for manufacturer reservation lies in the structural exposure that this group carries: manufacturers, more directly than recyclers, bear the consequences of RPP-related quality variation in the form of product-performance risk, customer complaints, line stoppages, downstream returns, and the integration costs of qualifying new feed material. For a recyclers, or dual-activity firms, the incentive to internalise supply side RPP benefits (margin on reprocessed feed, throughput, regulatory positioning) increases, while the incentive to internalise downstream risks, decreases.

Third, the dual-activity group which is halfway in terms of usage has the most positive attitude towards the environmental advantage (M = 4.21) (which is intuitively understandable since dual-activity firms are more stratified by circular concept flows and thus more directly affected by the systemic benefits of closed-loop activity (Niero et al., 2017)). The differences are visualized in the composite-index bars in figure 6 (values labeled: figure 6, with 1-standard error whiskers).

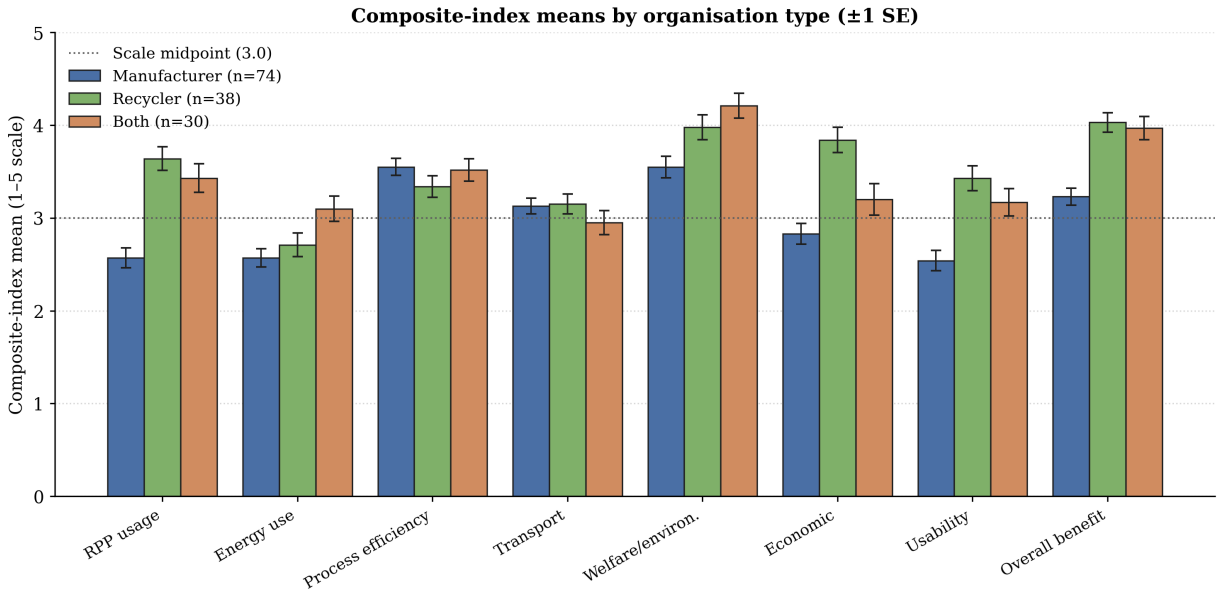

Figure 6. Composite-index means by organisation type, with ±1 standard-error bars (n = 142). The dotted reference line marks the scale midpoint of 3.

Figure 7 examines the distributional spread for the three substantively most important indices: environmental benefit, usability, and overall perception. The box plots show

that not only the central tendency but also the spread of opinion is more compressed and more positive among recyclers and dual-activity firms, while manufacturers show wider distributions consistent with a heterogeneous population of more and less RPP-engaged respondents.

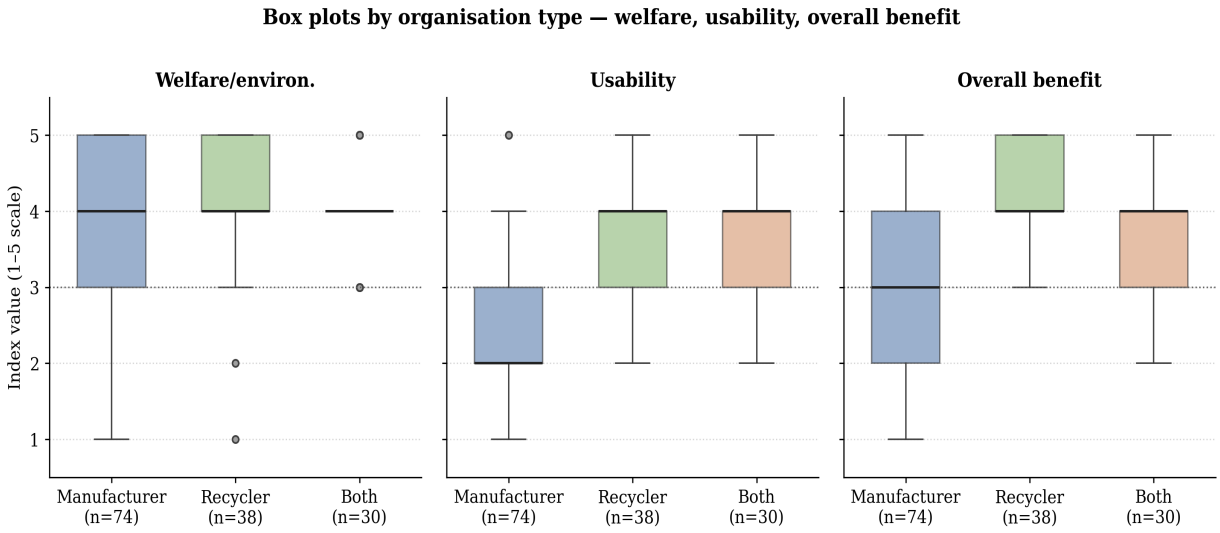

Figure 7. Box plots of environmental-benefit, usability, and overall-benefit indices by organisation type (n = 142).

4.2.2 Differences by Years of Experience

Parallel Kruskal-Wallis tests with years of experience as the grouping variable were largely non-significant, with one exception: the usability index, where H = 11.99, p = 0.007. The pattern of group means indicates that respondents with more than ten years of experience hold the most reserved view of usability outcomes (M = 2.66), while respondents in the 2–5-year band hold the most positive view (M = 3.10). The overall-perception index showed a trend in the same direction (H = 7.72, p = 0.052), but at p > 0.05 this is not statistically significant under the test threshold adopted in Chapter 3 and is treated here as a directional pattern only, not as a finding.

One possible explanation for the experience effect on usability offered as interpretation rather than as a confirmed finding is that long-tenured practitioners may anchor on legacy quality experiences with first-generation recycled feedstocks, while newer practitioners encounter a technologically more mature recycling supply chain that has

progressively absorbed advances in sorting, washing and compatibilisation (Velásquez et al., 2023). This aligns with the other organisational learning processes, generational exposure to sustainability discourses during professionalisation and incremental innovation of technology in the mechanical recycling stack.

4.2.3 Inter-Construct Relationships

Spearman rank-order correlations were used to examine relationships between the composite indices, consistent with the ordinal nature of Likert composites (Field, 2018). The correlation matrix is visualised in Figure 8. The strongest correlations are between the overall-perception item and the three substantive dependent constructs: environmental benefit ($\rho = 0.43$, $p < 0.001$), economic ($\rho = 0.48$, $p < 0.001$), and usability ($\rho = 0.41$, $p < 0.001$). Correlation does not imply causation, and the cross-sectional design does not permit causal inference; the pattern is best read as nomological-validity evidence that respondents' holistic sustainability judgement is associated with environmental, economic and operational considerations jointly rather than driven by any single dimension.

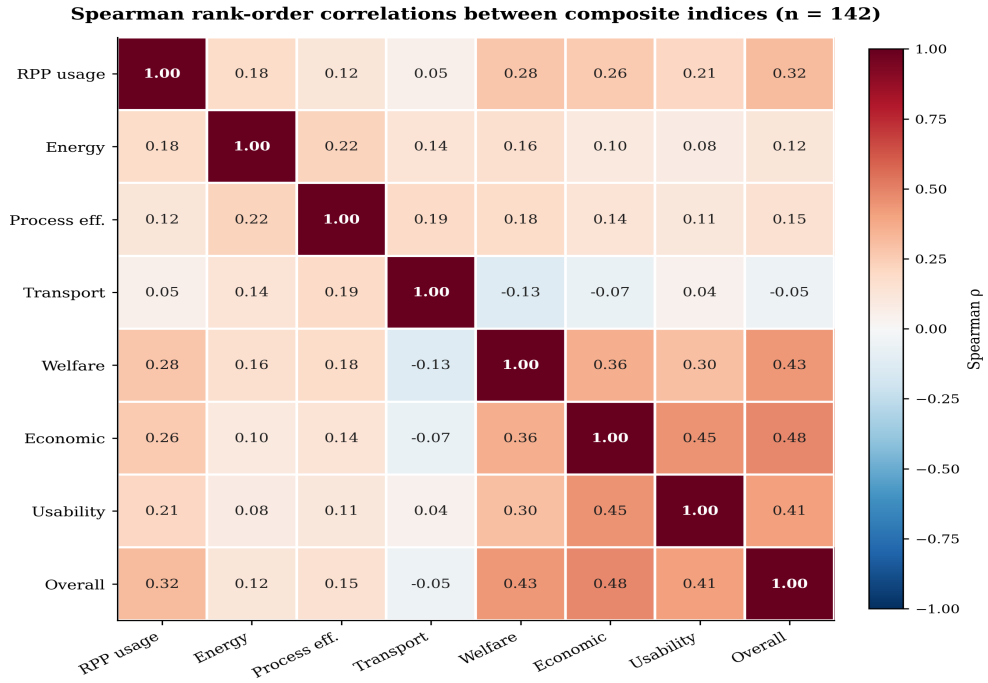

Figure 8. Spearman rank-order correlations between composite indices (n = 142). Cell labels report ρ.

A second substantive finding is the moderately positive association between RPP usage and each of the three dependent constructs (ρ = 0.19-0.28). Those companies that already have a higher content of recycled matter in their production more positively perceive environmental, economical and usability aspects of it. This is a reflection of the experiential-learning narratives of technology adoption, but with an analytical proviso – a cross-sectional design can help answer the question of whether use causes a perception or vice versa (Bock and Meyerding, 2023).

The energy-use, process-efficiency indices show weak correlations with the dependent constructs while the transport index shows weak correlations with the process-efficiency and dependent constructs. Indices of environmental benefits and economics are also not directly related to the transport index (ρ = -0.13 and -0.07, respectively, the first only marginally significant) and there are similarly low connections between energy use and indices of the outcome constructs. But, the more serious impression that emerges from this pattern, taken with a pinch of salt, is that with Bangladeshi stakeholders, the definition of RPP sustainability is mostly about material substitution and not a cradle to grave reading that considers upstream energy use and downstream logistics.

This is an important trend substantively as all LCA literature also clearly highlighted that transport-related emissions typically account for a non-trivial fraction of overall impact in fragmented, road-dominated logistics chains (Lazarevic et al., 2010; Ma et al., 2019); and impact on energy-mix is of critical importance to whether mechanical-recycling pathways deliver measurable GHG savings under emerging-economy grid conditions. The weak correlation pattern thus indicates a perception-level blind spot relative to the analytical structure of LCA: respondents agree to the principle that RPP is environmentally beneficial; but the reasoning with respect to the upstream and downstream components that will determine whether this is the case in practice does not seem to be apparent to the respondents. This is the main LCT finding of the thesis, which is developed in detail in section 4.3. The transport result is interpreted with the extra caution indicated in Section 4.1.2.

4.2.4 Synthesis of Key Patterns

Sections 4.1 and 4.2 produce three findings together, which together make up the empirical answer to the central research question. First, perceived environmental benefit is the strongest positive signal found in the data in that it had the highest mean across all dependent constructs, the lowest percentage of negative answers and the highest percentage of agreement among stakeholder clusters. Secondly, reservations assess each criterion of the Usability Index (quality, customer acceptance, ease of integration) and certain aspects of the Economic Index (cost efficiency, operational improvement) and are expressed in a systematic manner more strongly by manufacturers than by recyclers and dual-activity firms as a result of the downstream consequences due to variable-quality feed.

Third, there is no consistent correlation between the enabling conditions in the energy, process-efficiency and transport indices and stakeholder perceptions of RPP outcomes a "perception" discrepancy from cradle-to-grave LCA arguments. If read as one sentence, the empirical answer is that, while stakeholders in Bangladesh see potential for the environment in RPP, it does not go beyond factors related to the usability of the technology, divided economic perception and incomplete integration of life-cycle reasoning in stakeholders' judgement. This conclusion forms a link into Section 4.3 whereby each strand is compared with the theory outlined in Chapter 2.

4.3 Comparison with Theoretical Framework

Empirical findings are interpreted through the lens of the theoretical framework presented in Chapter 2, which is a combination of Life Cycle Thinking, the impact category vocabulary of Life Cycle Assessment and Circular Economy Theory. This does not generalise as to whether the results based on the framework, but rather each strand is broken down individually and it is explicitly shown where the data are consistent with the prediction and where they support or contradict this prediction. There then are three sub-sections: 4.3.1 LCT, 4.3.2 LCA-derived impact-category vocabulary, and 4.3.3 CET.

4.3.1 Life Cycle Thinking

The confirmation lies in the high Environmental Benefit Index scores: respondents recognise the production-stage environmental advantages of RPP relative to virgin polypropylene, in line with the resource-extraction and polymerisation savings that the LCA literature documents (Geyer et al., 2017; Galve et al., 2022). The qualification, and the more substantively interesting finding, lies in the weak inter-construct correlations between the outcome indices on one side and the energy-mix and transport variables on the other. LCT requires reasoning across all life-cycle stages, precisely so that gains at one stage are not cancelled by losses at another. Yet the data show that respondents' outcome judgements are largely uncoupled from their assessments of energy use (where renewable-energy use was rated at M = 2.23) and transport.

This is a perception-level instance of the burden-shifting risk that LCT exists to expose (TunÇok-Çeşme et al., 2024): stakeholders accept the principle of life-cycle reasoning, but their day-to-day evaluation of RPP is anchored closer to material substitution than to systemic, cradle-to-grave assessment. The implication is that LCT operates here as a partially-internalised framework, useful for vocabulary and for production-stage judgement, but not yet structuring stakeholder reasoning across the full life cycle.

4.3.2 LCA-Derived Impact-Category Vocabulary

The strongest empirical alignment is with the LCA-derived impact-category vocabulary that structured Section C1 of the questionnaire. Items framed in standard LCA categories greenhouse-gas emission reduction, overall environmental-impact reduction, contribution to sustainable production were salient, discriminating, and used confidently by respondents. Item-level patterns mirror the structure of recent comparative LCA studies that find reduced global-warming potential and resource use for mechanical-recycling pathways while flagging quality variability as a continuing challenge (Caudle et al., 2025; Keller et al., 2022).

The high mean (M = 3.81) and the low share of disagreement on these items indicate that LCA-derived language carries directly into stakeholder reasoning about RPP, even

where formal LCA studies have not been conducted in the local setting. The implication for research design is that the impact-category vocabulary of LCA can serve as a structuring instrument for perception research in emerging economies, even when no numerical inventory analysis is performed; this supports the design choice taken in Chapter 3. The instrument should be re-tested before being used in adjacent settings.

4.3.3 Circular Economy Theory

CET finds its strongest empirical signal in the dual-activity sub-sample, whose Environmental Benefit Index scores are the highest in the dataset (M = 4.21) and whose RPP-usage levels reflect the closed-loop operational profile that CET prescribes. Plausibly, dual-activity firms internalise both the upstream value of recovered feedstock and the downstream pressure to demonstrate sustainability credentials, so they perceive the systemic benefits of closed-loop operation more directly than firms that operate on only one side of the loop (Niero et al., 2017). This aligns with previous studies that suggested that the materialisation of circular performance is furrowed through companies managing forward and reverse supply chains under a single roof (Matos et al., 2024; Reinales et al., 2020).

The data at the same time warn of an uninsightful reading of CET. There are two findings that counter the framework. However, there are still issues with usability, even in the most possible-to-recycle sub-sample, so just being vertically-integrated is not a solution to mechanical recycling technical issues. Second, the low level of penetration of renewables throughout the full sample (M = 2.23 for B2.3) indicates that a circular-material strategy does not automatically lead to a circular-energy version. Hence the data aligns with the situationocontingent and contingent reading of CET (cf the reading in Chapter 2) whereby circular structure is a necessary but not sufficient prerequisite for circular performance and there is a constraint energy stack, which material strategies are unable to outsmart.

4.4 Practical Implications of the Results

The results have practical implications for three groups of readers — manufacturers, recyclers and policymakers in Bangladesh. The implications below are kept proportional to the evidence: survey-supported implications, derived directly from the perception data reported in this thesis, are distinguished from broader inferences that draw on the wider literature reviewed in Chapter 2 and on theoretical reasoning. The latter are presented as areas for further evidence-based development rather than as ready-to-implement prescriptions, since the perception-based design supports description of stakeholder views but cannot, on its own, demonstrate the measured effects of any policy or operational lever.

For manufacturers, the survey-supported implication is that the principal perceived barrier to higher RPP adoption is no longer awareness; it is technical and commercial. The Environmental Benefit Index sits at 3.81, but the Usability Index is 2.91 and the cost-efficiency item (C2.1) is 3.11, with significant fractions of respondents reporting concern. From this evidence, four concrete responses follow. First, incoming-material quality control: stricter incoming-feed specifications, supplier audits, and lot-level acceptance testing reduce the variability that underlies the C3.1 quality concern. Second, customer communication: through the technical data sheets and by stating and certifying the percentage of recycled content on the products directly, recycled content is transformed from a problem to a specification, which is a refreshing contrast to the switch from concern to clarity.

Third, supplier selection: Preferential sourcing from recyclers with controlled washing, decontamination and pelletising will move the economic dispersion that is always seen in C2 towards an improved end of the curve, increasing the base feed quality. Fourth, gradual integration: a multi-layer strategy with stepping in places of ever greater RPP fractions (e.g. starting with non food-contact and less critical applications) helps firms to accumulate some in-house experience before adopting the higher RPP fractions at a critical level. Dual activity companies, currently the most positively perceiving

sustainability in the data, provide good use cases for organisational learning forward and backward.

The implication for recyclers, is one of quality consistency, not expansion, and is based on the survey. The export economics rating on recyclers is favourable (M = 3.84) while the score on the usability from manufacturers side is less favourable (M = 2.54), indicating that the perception on the output of recyclers in the eyes of the manufacturers is not as good as they perceive themselves. Two concrete answers ensue. Firstly, contamination control throughout the recycling line: investment in colour sorting, near-infrared (NIR) detection, washing capacity, melt filtration and pellet homogenisation can directly tackle contamination and variability issues which are at the heart of the manufacturer's concerns regarding C3.1 product quality.

Second, lot-level documentation: providing certificates of analysis, melt-flow indices and contamination data at the pellet-batch level converts an unmeasured quality risk into a documented specification, which is the standard mechanism by which downstream customers re-rate a supplier. Beyond these two firm-level steps, the formalisation of currently informal collection networks remains a sector-level enabler that improves both feed quality and feed volume (Hopewell et al., 2009), but is more accurately framed as a policy condition than as a recycler-only action.

For policymakers, the perception evidence reported here is not a sufficient basis for finalised regulation, and the implications below are presented as priority areas for further evidence-based policy development supported by inventory data, cost-benefit analysis and sector consultation. Three areas emerge most directly from the survey. First, formal-collection infrastructure: the contrast between strong perceived environmental benefit and persistent usability concerns suggests that increasing the quantity and quality of post-consumer feed entering the formal recycling system is foundational, and a structured extended-producer-responsibility (EPR) regime that channels levies into formal collection is one mechanism worth assessing.

Second, energy-side complementarities: the low rating in energy-use (composite M = 2.72; renewable-energy use M = 2.23) suggests that policies promoting the use of

renewable materials can only unlock a fraction of the potential life-cycle benefit if they are not complemented with support for renewable energy; tailored energy-side incentives for companies combining RPP use with professed renewable-energy sourcing should therefore be considered in addition to RPP-specific incentives and not as a substitute. Third, RPP quality standards: manufacturer-side usability scores show that the variation in standards affects customer acceptance, and a national RPP standard that sets a minimum level of quality for RPPs (food-contact, semi-critical and non-critical applications) should mitigate reputational and quality risks that now limit demand.

4.5 Contribution to the Field

It's important to remember that the chapter's empirical contribution is best thought of as a whole, not three separate claims. The thesis consolidates stakeholders' evidence from Bangladesh, perception categories informed by an LCA and a structured comparison across organisations' types into one overview of the perception of RPP sustainability inroteri of the plastic-packaging value chain in Bangladesh. Read as a single contribution, this combination addresses the regional gap noted in Chapter 2, in which most LCA-related work has been conducted in European, North-American and East-Asian settings (Geyer et al., 2017; Hahladakis et al., 2018), and supplies practitioner-grounded evidence that complements rather than duplicates technical LCA work.

The questionnaire instrument that operationalises this approach delivers acceptable-to-excellent internal-consistency reliability ($\alpha = 0.67–0.92$) across seven multi-item scales on the present sample. The instrument is offered as a research-grade tool that can be adapted and re-tested in adjacent emerging-economy settings, not as a fully validated industry standard ready for routine reuse; full validation would require confirmatory factor analysis, multi-country replication and longitudinal re-testing, as flagged in Section 5.5. The third strand of the contribution is the analytically specific finding that perceived environmental benefit ($M = 3.81$) is asymmetrically stronger than perceived usability ($M = 2.91$) and is divided on perceived economics ($M = 3.18$, $SD = 0.98$).

5. Conclusion and Discussion

This final chapter is used to summarise the results of the empirical studies, address the research question based on the evidence presented in Chapter 3 and 4, state the contributions, and the limitations of this study, and ends with reflections on the researcher's development. The empirical content of the thesis is limited and focused: The 142 respondents from among the plastic-packaging stakeholders in Bangladesh who were polled from January to March 2026 using a 23-item perception-based questionnaire. The top thread that was seen to cross those dates – the surrounding optimism, with a chance of a serious adoption on the horizon – provides the foundation of the rest that follows in this chapter; usability, economics and life cycle integration become the clear hurdles.

No new literature is introduced in the discussion that was not already included in the literature developed in Chapters 2–4 and claims of an empirical nature do not go beyond what is substantiated by 142 perception based responses.There are six sections in the chapter. The research and the main results are summarised in Section 5.1. Section 5.2 comments on the main research question and the new findings generated through the empirics. The integrity of the work, and reaffirmation of ethics, is examined in section 5.3. The limitations of study are acknowledged in section 5.4. In Section 5.5, some suggestions for future research were presented. A personal statement about what the researcher learned and developed from the project is included in Section 5.6 as a conclusion.

5.1 Summary of the Research and Key Results

The study aimed to understand industry perceptions of the use of post consumer recycled polypropylene (PCR PP) in plastic packaging in terms of sustainability. It was a cross-sectional quantitative survey based on perception, used a 23 item structured questionnaire and surveyed 142 selected manufacturers, recyclers or dual activity firms and the data was analysed through descriptive statistics, internal-consistency reliability

analysis, Kruskal-Wallis group comparison tests as well as Spearman rank order correlations. The conceptual framework brought together Life Cycle Thinking, the impact-category language of LCA and Circular Economy Theory in a single coherent view.

The research question and sub-questions have 5 findings. The perception of the environmental value of RPP is clearly positive, at least among the first (SQ1), with a mean score of 3.81 out of 5, and 65% agreeing that RPP reduces green-house gas emissions. However, this positive environmental orientation is accompanied by relatively more conservative usability (mean 2.91), considering Customer acceptance problem areas important but also noting Product quality concerns, and usability problems were perceived as the biggest barriers to the use of the products. The Economic Index is the dimension, which is most split, with cost-efficiency and operational performance producing a split of the sample into more or less one-third (mean 3.18, SD 0.98).

There are substantial differences between types of organisations on the fourth dimension (SQ4): recyclers and dual-activity firms score higher on environmental and economic, on usability, and on overall scores than manufacturers do; and between manufacturers and recyclers is 0.80 of a scale point on the item overall benefit. The contextual indicators, especially the use of renewable energy, which is well below the scale midpoint (M = 2.23), are only weakly related to stakeholder ratings of RPP. This last finding is the closest to respondents perception level example of the burden-shifting-risk the LCT is specifically targeting: respondents agree with the idea of the Life Cycle reasoning, but their evaluation of RPP is more oriented towards material change than to seeing the system as a whole and taking a cradle to grave approach.

5.2 Reflection on the Research Question and New Insights

The research question of the study was, "What are the perspectives of industry stakeholders on the sustainability issue, opportunities and challenges of using post-consumer waste recycled PP for plastic packaging in Bangladesh? The empirical findings offer a response in three intended dimensions (implications, opportunities and challenges) and also in a fourth, conditional dimension which was not originally planned

in the beginning. The term “new insights” is used in a careful way below because it refers not to the generic notion that RPP can contribute to the reduction in environmental impact (which has been presented in the LCA literature) but rather to the nature of the perceptions as detailed in the Bangladeshi context and the structured comparison between the organisations types.

As to implications, Bangladeshi stakeholders view RPP as providing concrete sustainability advantages in terms of minimizing the environmental impact in comparison to virgin polypropylene, and minimizing the greenhouse-gas emissions. What is new about this perception is that it has been expressed confidently by Bangladesh practitioners using language derived from LCA and is in the opposite direction to the perception of achieving success through capital punishment: fighting crime would most effectively be done by restricting the freedom of criminals, so their freedom could be curtailed or taken away.

However, in the area of opportunities, the data reveal a well-defined strategic opportunity in Dual Activity companies that include manufacturing and recycling, as evidenced by the highest scores in terms of the EBI (M = 4.21) and second-highest scores in terms of overall-benefit (M = 3.97), standing in line with the closed-loop approach of the CE theory (Reinales et al., 2020). What is new in this context is that being vertically integrated recycling and manufacturing operations is linked to an especially positive attitude toward sustainability that is absent for single activity firms, in the Bangladeshi context. In contests, the toughest frictions are around product quality, customer acceptance and cost-effectiveness – the techno-commercial heart of all recent technical literature for mechanical recycling of PP (Caudle et al., 2025; Ignacio et al., 2023).

This is a new one in that the its respondents do not only express a strong environmental conviction but also hold concrete operational reservations. The fourth unexpected aspect is the conditional realization of the sustainability benefits. The low correlations between process efficiency and transport indices and environmental and overall constructs suggest that the RPP sustainability is evaluated at a finer level, not yet to incorporate upstream and downstream stages of the systems. This is the most

distinctively analytical finding of the study: that in addition to diffusion of recycled material, systemic, life-cycle reasoning has to be diffused among practitioners if it will become a reality in Bangladesh.

5.3 Evaluation of the Work and Ethical Considerations

In assessing the empirical work that underpinned the methodological claims made in Chapter 3, two points should be underscored. But the strengths are very real: the questionnaire has been internally designed to capture the behaviours and impacts of social behaviors described by its items, the questionnaire has been pre-tested and has produced internally consistent measurement on six of the seven, (Cronbach's alpha ranging from 0.838 to 0.917), and there is strong content-validity case rooted in the explicit mapping between the behaviour items measured by the questionnaire and the impact categories derived from the LCA (Geyer et al., 2017; Field, 2018).

Multiple items per construct provided a stronger measurement model as compared with single-item operationalisation (Hair et al., 2019) while the realised sample of 142 respondents was a fairly large sample for a perception study of this nature. The two No-Detentions are equally important. In the first instance, the two-item transport index obtained $\alpha = 0.672$ – not meeting the 0.70 suggested by the thesis, future replication should attempt to build this up to 2 or more items. Secondly, the perception based design puts a structural cap on the conclusions: the thesis can only report on the perceived implications of RPP for sustainability, but not (on its own) on measured environmental performance or measured causal effects.

The conclusions are best interpreted as having been reasonably described as stakeholder perception by the defensible measurement model with claims made at a level the data can support. In addition, the study adheres to the ethical principles outlined in Chapter 3, and the ethical guidelines of the University of Vaasa: the participation was voluntary and obtained a consent in written form; the survey platform did not store any IP address or metadata about the device; responses were anonymous

when collected; the data is stored in a password-protected institutional storage driver; it is impossible to identify any participant or organisation from any reported result.

It is important to note that the data was shaped in two particular ways because of the ethical protections: first, firm identifying details were eliminated to enable less detailed triangulation; second, participation was voluntary and required, which may have led to the selection of those already engaged in understanding sustainability issues. Both effects are restrictions on the claims that can be made from the data; they are not failures in execution. The researcher does not have any conflict of interest in the process of the project and do not have any commercial relationship with any firm in the sampling frame.

5.4 Limitations of the Study

The findings should be read in the light of seven limitations, each of which has a specific consequence for what the thesis can and cannot claim. First, the design is perception-based: data are stakeholder judgements, not LCT measurements. The thesis therefore can describe stakeholder perceptions of RPP's sustainability implications, but cannot prove actual environmental benefits or deliver measured GHG, energy or resource savings; reported perceptions should be triangulated against inventory studies rather than treated as a substitute for them. Second, sampling is purposive: the recruitment frame was constructed from formal-sector directories and professional networks, which means external generalisation is limited to firms with similar profiles in the four industrial corridors covered (Dhaka, Narayanganj, Gazipur, Chattogram).

Informal recyclers and unregistered converters are under-represented, and statistical generalisation to a defined population is not supported. Third, the data are self-reported and exposed to social-desirability bias, particularly on the environmental items where the socially preferred answer is unambiguous; reported environmental-benefit scores should be read as the upper bound of what stakeholders are willing to disclose, not as a behaviourally verified estimate. Fourth, no measured inventory data were collected, so

the relationship between perception and actual operational performance cannot be assessed within the present design.

Fifth, the design is cross-sectional: stakeholder views were captured at a single point in time, in early 2026, and the Bangladeshi plastic-packaging industry is in a phase of regulatory and technological change in which views may shift in response to forthcoming EPR rules, retail-customer sustainability commitments or changes in the price of virgin resin (Wandosell et al., 2021); causal inference and inferences about stability over time are therefore not supported.

Sixth, common-method bias cannot be ruled out: independent-block and dependent-block items were administered to the same respondent through the same instrument, so observed associations between Section B and Section C may be inflated by shared method variance; the more conservative reading is that strong associations within Section C–Section C and the noteworthy weakness of Section B–Section C correlations are particularly informative against this baseline. Seventh, the questionnaire instrument has been pre-tested but not subjected to confirmatory factor analysis or multi-country replication; the two-item transport index in particular returned $\alpha = 0.672$ and is reported descriptively only. Each of these limitations is read below as a constraint on interpretation, and Section 5.5 maps them onto specific directions for future research.

5.5 Suggestions for Future Research

Section 5.4 outlines the need for future research that stemmed from the limitations identified. There are six concrete directions. First, as indicated above, and perceived only inventories approach has different limitations that don't allow direct comparison with measures based on actual inventory data on energy use and transport distances, contamination yields (and reject rates) with data collected from a subset of cooperating firms in Bangladesh, would test whether the perception level Environmental Benefit Index is equivalent to LCA measures, and would allow direct comparison between perception and inventory data. An aggregated-data design, where firm-level reporting

is anonymised to avoid commercial sensitivities, can handle cases where confidentiality may pose limitations.

Second, addressing the cross-sectional limitation: a longitudinal panel study of the same firms at two or three points over the years would shed light on the pace of change in perceptions in the face of the regulatory and technological pressures that now face the industry, and it would potentially distinguish cohort versus exposure effects cited in Section 4.2.2. Third, addressing the sampling-frame limitation: a larger probability-based sample, where feasible, would support statistical generalisation, and a deliberate over-sampling of the informal recycling segment would address the gap noted in Section 4.1.1.

Fourth, addressing the instrument-validation limitation: confirmatory factor analysis on a larger sample, followed by structural-equation-modelling treatment of the same constructs, would permit formal testing of the implied pathways from RPP usage and contextual enablers to the environmental, economic and usability outcomes (Hair et al., 2019), and would convert the present research-grade instrument into a validated industry tool. Fifth, addressing the production-side limitation: a stakeholder-extension study including consumers, retail buyers and regulators would test how far the present findings generalise beyond the production-side practitioners surveyed here, given evidence elsewhere that consumer perceptions can diverge significantly from LCA results (Bock and Meyerding, 2023).

Sixth, a single-country limitation: a cross-country comparison of the patterns reported here in the context of emerging-economy institutions including Vietnam, Indonesia or Pakistan would be useful for determining whether the patterns reported here are due to Bangladesh specific institutional features, or a more general emerging-economy regularity. These directions are intended to be complementary to guide a perception study from the current point to fuller, evidence-based account of RPP sustainability in emerging economies.

5.6 Personal Learning and Development

The thesis project led to forms of ongoing learning in three interrelated areas. The first is of a methodological type. It involved many conscious and repeated compromises between ambition and feasibility, to develop a questionnaire that actually reflects the LCA literature without going over that line into inventory data. Looking back, the pre-testing and revision of eight items, based on three pilot respondents, was one of the most influential individual actions taken during the project.

The second domain is analytical. Non-parametric tests were chosen over t-tests and ANOVA, and Spearman over Pearson correlation as a result of visual inspection of the data - the use of non-parametric was not a methodological default. A more conscious statistical approach has been reinforced by the need for the discipline of selection of tests based on the results and data obtained from their distribution and not by habit. Cronbach's alpha for the two item transport scale was a good reminder that the length and content of a scale determines the level of defensibility of a single coefficient.

The third Domain is substantive. The literature on plastic packaging and the commentaries from 142 industry experts shifted the researcher's perceptions of sustainability research in three particular ways: the idea that there may be different conceptual and evidentiary traditions between LCA and perception-based work, the need to tailor pitch levels and claims to the type of data available, in particular for perception-based work, and the perspective of contested or weak results – like the transport result, or the contrast of experience – as informative limits on inference rather than simply failures of the research design. These three skills – methodological discipline, statistical caution and substantive humility – are the core academic skills of the project.

References

Alzubi, E., Kassem, A., & Noche, B. (2022). A comparative life cycle assessment: Polystyrene or polypropylene packaging crates to reduce citrus loss and waste in transportation? Sustainability, 14, 12644. https://doi.org/10.3390/su141912644

Arena, U., Mastellone, M. L., & Perugini, F. (2003). Life cycle assessment of a plastic packaging recycling system. International Journal of Life Cycle Assessment, 8, 92. https://doi.org/10.1007/BF02978432

Baltrocchi, A. P. D., Romagnoli, F., Carnevale Miino, M., & Torretta, V. (2025). Improving environmental sustainability of food-contact polypropylene packaging production. Clean Technologies, 7, 70. https://doi.org/10.3390/cleantechnol7030070

Bock, M., & Meyerding, S. G. H. (2023). Consumer perception of food product packaging materials sustainability versus life cycle assessment results: The case of processed tomatoes — A quantitative study in Germany. Sustainability, 15, 16370. https://doi.org/10.3390/su152316370

Boyd, H. B., Møller, L., & Larsen, P. B. (2021). Tentative assessment of recycled post-consumer plastic for packaging of cosmetic products. Toxicology Letters, 350, S235. https://doi.org/10.1016/S0378-4274(21)00784-0

Bryman, A. (2016). Social research methods (5th ed.). Oxford University Press.

Caudle, B., Nguyen, T. T. H., & Kataoka, S. (2025). Evaluation of three solvent-based recycling pathways for circular polypropylene. Green Chemistry, 27, 1667–1678. https://doi.org/10.1039/D4GC02646B

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16(3), 297–334. https://doi.org/10.1007/BF02310555

Durrani, H., Clarke-Sather, A. R., & Alves, P. H. T. F. (2024). Prospective life cycle assessment of nonwoven mat manufacturing: Comparing pre-consumer wood waste fibers to post-consumer recycled apparel fibers. In Volume 5: 29th Design

for Manufacturing and the Life Cycle Conference (DFMLC) (p. V005T05A020). American Society of Mechanical Engineers. https://doi.org/10.1115/DETC2024-143955

Ferrara, C., & De Feo, G. (2023). Comparative life cycle assessment of two different packaging systems for extra-virgin olive oil: Glass bottle vs. 100% recycled polyethylene terephthalate (PET) bottle. Sustainability, 15, 3665. https://doi.org/10.3390/su15043665

Field, A. (2018). Discovering statistics using IBM SPSS Statistics (5th ed.). SAGE Publications.

Galve, J. E., Elduque, D., Pina, C., & Javierre, C. (2022). Life cycle assessment of a plastic part injected with recycled polypropylene: A comparison with alternative virgin materials. International Journal of Precision Engineering and Manufacturing — Green Technology, 9, 919–932. https://doi.org/10.1007/s40684-021-00363-2

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3, e1700782. https://doi.org/10.1126/sciadv.1700782

Hahladakis, J. N., Iacovidou, E., & Gerassimidou, S. (2020). Plastic waste in a circular economy. In Plastic Waste and Recycling (pp. 481–512). Elsevier. https://doi.org/10.1016/B978-0-12-817880-5.00019-0

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. Journal of Hazardous Materials, 344, 179–199. https://doi.org/10.1016/j.jhazmat.2017.10.014

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). Multivariate data analysis (8th ed.). Cengage Learning.

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: Challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences, 364, 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Ignacio, M. C. C. D., Tumu, K. N., Munshi, M., Vorst, K. L., & Curtzwiler, G. W. (2023). Suitability of MRF recovered post-consumer polypropylene applications in extrusion blow molded bottle food packaging. Polymers, 15, 3471. https://doi.org/10.3390/polym15163471

Intini, F., & Kühtz, S. (2011). Recycling in buildings: An LCA case study of a thermal insulation panel made of polyester fiber, recycled from post-consumer PET bottles. International Journal of Life Cycle Assessment, 16, 306–315. https://doi.org/10.1007/s11367-011-0267-9

ISO. (2006a). ISO 14040:2006 — Environmental management — Life cycle assessment — Principles and framework. International Organization for Standardization.

ISO. (2006b). ISO 14044:2006 — Environmental management — Life cycle assessment — Requirements and guidelines. International Organization for Standardization.

Keller, J., Scagnetti, C., & Albrecht, S. (2022). The relevance of recyclability for the life cycle assessment of packaging based on design for life cycle. Sustainability, 14, 4076. https://doi.org/10.3390/su14074076

Kim, S., & Park, J. (2020). Comparative life cycle assessment of multiple liquid laundry detergent packaging formats. Sustainability, 12, 4669. https://doi.org/10.3390/su12114669

Kim, S. Y., Kang, D. H., Charoensri, K., Ryu, J. R., Shin, Y. J., & Park, H. J. (2023). Comparative life cycle assessment of reusable and disposable distribution packaging for fresh food. Sustainability, 15, 16448. https://doi.org/10.3390/su152316448

Lazarevic, D., Aoustin, E., Buclet, N., & Brandt, N. (2010). Plastic waste management in the context of a European recycling society: Comparing results and uncertainties in a life cycle perspective. Resources, Conservation and Recycling, 55, 246–259. https://doi.org/10.1016/j.resconrec.2010.09.014

Ma, X., Li, C., & Li, B. (2019). Carbon emissions of China's cement packaging: Life cycle assessment. Sustainability, 11, 5554. https://doi.org/10.3390/su11205554

Maga, D., Hiebel, M., & Aryan, V. (2019). A comparative life cycle assessment of meat trays made of various packaging materials. Sustainability, 11, 5324. https://doi.org/10.3390/su11195324

Matos, J., Martins, C. I., & Simoes, R. (2024). Circularity micro-indicators for plastic packaging and their relation to circular economy principles and design tools. Sustainability, 16, 2182. https://doi.org/10.3390/su16052182

Ncube, L. K., Ude, A. U., Ogunmuyiwa, E. N., Zulkifli, R., & Beas, I. N. (2021). An overview of plastic waste generation and management in food packaging industries. Recycling, 6, 12. https://doi.org/10.3390/recycling6010012

Niero, M., Hauschild, M. Z., Hoffmeyer, S. B., & Olsen, S. I. (2017). Combining eco-efficiency and eco-effectiveness for continuous loop beverage packaging systems: Lessons from the Carlsberg Circular Community. Journal of Industrial Ecology, 21, 742–753. https://doi.org/10.1111/jiec.12554

Ögmundarson, Ó., Kalweit, L. S., Venkatachalam, V., Kristjánsdóttir, R., Endres, H.-J., & Spierling, S. (2022). Plastic packaging waste management in Iceland: Challenges and opportunities from a life cycle assessment perspective. Sustainability, 14, 16837. https://doi.org/10.3390/su142416837

Osorto, M. R. R., & Casagrande, M. D. T. (2023). Environmental impact comparison analysis between a traditional hot mixed asphalt (HMA) and with the addition of recycled post-consumer polyethylene terephthalate (RPET) through the life cycle assessment (LCA) methodology. Sustainability, 15, 1102. https://doi.org/10.3390/su15021102

Pallant, J. (2020). SPSS survival manual: A step by step guide to data analysis using IBM SPSS (7th ed.). Open University Press.

Pauer, E., Wohner, B., Heinrich, V., & Tacker, M. (2019). Assessing the environmental sustainability of food packaging: An extended life cycle assessment including packaging-related food losses and waste and circularity assessment. Sustainability, 11, 925. https://doi.org/10.3390/su11030925

Perugini, F., Mastellone, M. L., & Arena, U. (2005). A life cycle assessment of mechanical and feedstock recycling options for management of plastic packaging wastes. Environmental Progress, 24, 137–154. https://doi.org/10.1002/ep.10078

Pivnenko, K., Eriksen, M. K., Martín-Fernández, J. A., Eriksson, E., & Astrup, T. F. (2016). Recycling of plastic waste: Presence of phthalates in plastics from households and industry. Waste Management, 54, 44–52. https://doi.org/10.1016/j.wasman.2016.05.014

Reinales, D., Zambrana-Vasquez, D., & Saez-De-Guinoa, A. (2020). Social life cycle assessment of product value chains under a circular economy approach: A case study in the plastic packaging sector. Sustainability, 12, 6671. https://doi.org/10.3390/su12166671

Rossi, V., Cleeve-Edwards, N., Lundquist, L., Schenker, U., Dubois, C., Humbert, S., & Jolliet, O. (2015). Life cycle assessment of end-of-life options for two biodegradable packaging materials: Sound application of the European waste hierarchy. Journal of Cleaner Production, 86, 132–145. https://doi.org/10.1016/j.jclepro.2014.08.049

Santos, R., & Abreu, M. J. (2025). Impact assessment and product life cycle analysis of different jersey fabrics using conventional, post-industrial, and post-consumer recycled cotton fibers. Sustainability, 17, 5700. https://doi.org/10.3390/su17135700

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education.

Siracusa, V., Rocculi, P., Romani, S., & Rosa, M. D. (2008). Biodegradable polymers for food packaging: A review. Trends in Food Science and Technology, 19, 634–643. https://doi.org/10.1016/j.tifs.2008.07.003

Spierling, S., Knüpffer, E., Behnsen, H., Mudersbach, M., Krieg, H., Springer, S., Albrecht, S., Herrmann, C., & Endres, H.-J. (2018). Bio-based plastics — A review of

environmental, social and economic impact assessments. Journal of Cleaner Production, 185, 476–491. https://doi.org/10.1016/j.jclepro.2018.03.014

Tabachnick, B. G., & Fidell, L. S. (2019). Using multivariate statistics (7th ed.). Pearson.

Tunçok-Çeşme, B., Yıldız-Geyhan, E., & Çiftçioğlu, G. A. (2024). Environmental life cycle assessment of two types of flexible plastic packaging under a sustainable circular economy approach. Sustainability, 16, 3149. https://doi.org/10.3390/su16083149

Vassallo, N., & Refalo, P. (2024). Reducing the environmental impacts of plastic cosmetic packaging: A multi-attribute life cycle assessment. Cosmetics, 11, 34. https://doi.org/10.3390/cosmetics11020034

Velásquez, E., Garrido, L., Valenzuela, X., Galotto, M. J., Guarda, A., & López De Dicastillo, C. (2023). Valorization of post-consumer recycled polypropylene through their reinforcement with amine and amine/silane organically modified clays for potential use in food packaging. Food Packaging and Shelf Life, 38, 101121. https://doi.org/10.1016/j.fpsl.2023.101121

Verghese, K., & Carre, A. (2012). Applying life cycle assessment. In K. Verghese, H. Lewis, & L. Fitzpatrick (Eds.), Packaging for Sustainability (pp. 171–210). Springer London. https://doi.org/10.1007/978-0-85729-988-8_5

Vink, E. T. H., & Davies, S. (2015). Life cycle inventory and impact assessment data for 2014 Ingeo polylactide production. Industrial Biotechnology, 11, 167–180. https://doi.org/10.1089/ind.2015.0003

Walichnowska, P., Tomporowski, A., Kłos, Z., Rudawska, A., & Bembenek, M. (2025). Sustainability in beverage packaging technology: Life cycle analysis and waste management scenarios. Sustainability, 17, 6594. https://doi.org/10.3390/su17146594

Wandosell, G., Parra-Meroño, M. C., Alcayde, A., & Baños, R. (2021). Green packaging from consumer and business perspectives. Sustainability, 13, 1356. https://doi.org/10.3390/su13031356

Widyaningsih, N. (2019). Life cycle assessment approach on food packaging to build sustainable consumption awareness in developing countries. Indonesian Journal of Life Cycle Assessment and Sustainability. https://doi.org/10.52394/ijolcas.v2i2.52

Yin, R. K. (2017). Case study research and applications: Design and methods (6th ed.). SAGE Publications.

Appendices

Appendix A: Survey Questionnaire

Title: Life Cycle Assessment of Post-Consumer Recycled Polypropylene in Plastic Packaging — Sustainability Implications.

Instructions: Please indicate your response by selecting the most appropriate option. All responses are treated confidentially and used only for academic research.

Section A: Respondent Profile (Control Variables)

A1. Type of organisation. 1 = Manufacturer; 2 = Recycling firm; 3 = Both

A2. Years of experience. 1 = <2 years; 2 = 2–5 years; 3 = 6–10 years; 4 = >10 years

A3. Organisation size (employees). 1 = Small (1–50); 2 = Medium (51–250); 3 = Large (>250)

Section B: Independent Variables (Material Use and Operations)

B1. Recycled polypropylene usage (RPP index)

B1.1 Proportion of recycled polypropylene used in production. 1 = 0%; 2 = 1–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100%

B1.2 Frequency of using recycled materials in production. 1 = Never; 2 = Rarely; 3 = Sometimes; 4 = Often; 5 = Always

B1.3 Level of dependence on recycled polypropylene. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

B2. Energy use (EU index)

B2.1 Energy efficiency of production process. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

B2.2 Use of energy-saving technologies. 1 = Not used; 2 = Rarely used; 3 = Moderately used; 4 = Frequently used; 5 = Fully implemented

B2.3 Use of renewable energy sources. 1 = None; 2 = Very low; 3 = Moderate; 4 = High; 5 = Very high

B3. Process efficiency (PE index)

B3.1 Efficiency of production operations. 1 = Very inefficient; 2 = Inefficient; 3 = Neutral; 4 = Efficient; 5 = Very efficient

B3.2 Waste-reduction practices in production. 1 = Not practiced; 2 = Rarely; 3 = Sometimes; 4 = Often; 5 = Always

B3.3 Level of process optimisation. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

B4. Transportation impact (TR index)

B4.1 Transportation efficiency (fuel/logistics optimisation). 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

B4.2 Distance-related environmental impact perception. 1 = Very high impact; 2 = High; 3 = Moderate; 4 = Low; 5 = Very low

Section C: Dependent Variables

C1. Environmental impact (Environmental Benefit Index)

C1.1 Use of recycled materials reduces greenhouse-gas emissions. 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

C1.2 Use of recycled materials reduces overall environmental impact. 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

C1.3 Use of recycled materials contributes to sustainable production. 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

C2. Economic and operational impact (economic index)

C2.1 Cost efficiency of using recycled polypropylene. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

C2.2 Profitability impact of recycled-material usage. 1 = Very negative; 2 = Negative; 3 = Neutral; 4 = Positive; 5 = Very positive

C2.3 Operational performance improvement. 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

C3. Usability and performance (use index)

C3.1 Product quality using recycled polypropylene. 1 = Very poor; 2 = Poor; 3 = Average; 4 = Good; 5 = Excellent

C3.2 Customer acceptance of recycled packaging. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

C3.3 Ease of integration of recycled materials in production. 1 = Very difficult; 2 = Difficult; 3 = Neutral; 4 = Easy; 5 = Very easy

Section D: Overall Perception

D.1 Overall sustainability benefit of recycled polypropylene. 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very high

Appendix B: Full Item-Level Descriptive Statistics

Table B1 reports item-level frequencies (within-row %) and means for all 23 substantive items in the questionnaire. Percentages may not sum to 100 due to rounding.

Item	Description	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	SD
B1.1	Proportion of RPP used	9.9	23.9	36.6	24.6	4.9	2.91	1.04
B1.2	Frequency of using RPP	7.7	19.7	34.5	26.1	12.0	3.15	1.11
B1.3	Dependence on RPP	7.0	21.1	40.8	21.1	9.9	3.06	1.05

Item	Description	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	SD
B2.1	Energy efficiency	5.6	31.0	33.8	25.4	4.2	2.92	0.98
B2.2	Energy-saving technologies	7.0	25.4	35.2	24.6	7.7	3.01	1.05
B2.3	Renewable energy use	21.1	38.0	37.3	3.5	0.0	2.23	0.82
B3.1	Production efficiency	0.0	7.0	42.3	39.4	11.3	3.55	0.79
B3.2	Waste-reduction practices	2.8	12.7	34.5	37.3	12.7	3.44	0.96
B3.3	Process optimisation	0.7	14.1	34.5	39.4	11.3	3.46	0.90
B4.1	Transport efficiency	2.1	16.2	51.4	23.9	6.3	3.16	0.85
B4.2	Distance impact (low = good)	2.8	19.7	51.4	23.9	2.1	3.03	0.80
C1.1	GHG-emission reduction	3.5	8.5	22.5	35.2	30.3	3.80	1.07
C1.2	Overall environmental	2.1	4.9	33.8	30.3	28.9	3.79	0.99

Item	Description	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	SD
	impact reduction							
C1.3	Contribution to sustainable production	0.7	8.5	25.4	38.0	27.5	3.83	0.95
C2.1	Cost efficiency of RPP	4.9	24.6	34.5	26.1	9.9	3.11	1.05
C2.2	Profitability impact	4.2	21.1	30.3	28.9	15.5	3.30	1.10
C2.3	Operational performance	4.2	26.1	33.1	26.8	9.9	3.12	1.04
C3.1	Product quality	8.5	29.6	32.4	21.8	7.7	2.91	1.08
C3.2	Customer acceptance	9.2	30.3	33.1	23.9	3.5	2.82	1.01
C3.3	Ease of integration	4.9	27.5	39.4	19.7	8.5	2.99	1.01
D.1	Overall sustainability benefit	0.0	6.3	40.8	39.4	13.4	3.60	0.80

Table B1. Full item-level distributions and descriptive statistics (n = 142, scale 1–5).

Appendix C: Composite-Index Composition and Reliability

Table C1 documents the composition and internal consistency of the seven multi-item indices used in the analysis. Index scores are computed as the unweighted mean of the constituent items, consistent with the equal-weighting convention used in similar perception studies (Hair et al., 2019).

Composite index	**Constituent items**	**Items (k)**	**Cronbach's α**
RPP usage (B1)	B1.1, B1.2, B1.3	3	0.889
Energy use (B2)	B2.1, B2.2, B2.3	3	0.838
Process efficiency (B3)	B3.1, B3.2, B3.3	3	0.803
Transport (B4)	B4.1, B4.2	2	0.672
Environmental benefit (C1)	C1.1, C1.2, C1.3	3	0.917
Economic (C2)	C2.1, C2.2, C2.3	3	0.914
Usability (C3)	C3.1, C3.2, C3.3	3	0.899

Table C1. Composite-index composition and internal-consistency reliability (n = 142).