Recycling of Plastic Waste: Sustainable Product Strategy for Bangladesh

Institute of
Business
Administration

DBA Program
IBA, Dhaka University

Recycling of Plastic Waste: Sustainable Product Strategy for Bangladesh

By

Mohammad Hanif

Registration no: 05/2016-2017

Re-registration no: 18/2020-2021

A Dissertation

Submitted to the Institute of Business Administration (IBA),

University of Dhaka

For the Requirements

of the Degree

Of

DOCTOR OF BUSINESS ADMINISTRATION (DBA)

Under the supervision of

Professor Mohammad Abdul Momen, Director

Institute of Business Administration

UNIVERSITY OF DHAKA

Dhaka-1000

Submission

August 8, 2023

Institute of Business Administration (IBA)

UNIVERSITY OF DHAKA

AUTHOR'S DECLARATION

I, the undersigned, hereby declare that this submission is entirely my own work, in my own words, and all resource materials from various published and unpublished sources used in researching it are fully acknowledged. All quotations and paraphrases are properly identified and attributed. It has not been submitted, in whole or in part, by me or any other person, for the purpose of obtaining any other credit/grade. I understand the ethical implications of my research, and this work meets the requirements of the University of Dhaka.

Mohammad Hanif

Registration no: 05/2016-2017 (Session: 2016 2017)

Re-registration no: 18/2020-2021 (Session: 2020-2021)

Doctor of Business Administration (DBA)

Institute of Business Administration

University of Dhaka

CERTIFICATE FROM THE SUPERVISOR

This is to certify that the thesis entitled "Recycling of Plastic Waste: Sustainable Product Strategy for Bangladesh" is a piece of research work carried out by Mr. Mohammad Hanif, Registration no: 05/2016-2017 Session: 2016-2017, Re-registration no: 18/2020-2021, Session: 2020-2021 under my guidance and supervision for the degree of Doctor of Business Administration to be awarded by University of Dhaka, Bangladesh and that the candidate has spent significant time with me.

To the best of my knowledge and belief this thesis

1) Embodies the work of the candidate himself
2) Has duly completed and fulfilled the requirements of the ordinance related to the DBA degree of the University of Dhaka.
3) Is up to the desired standard in respect of both contents and language for being referred to the examiners.
4) The thesis contents don't form the basis for the award of any other degree, diploma, or similar title to the candidate or to anybody else from this or any other University or Institution.

I wish him all the success.

Professor Mohammad Abdul Momen, Director

Institute of Business Administration

University of Dhaka

Dhaka-1000

August 8, 2023

To

Professor Mohammad Abdul Momen

Director

Institute of Business Administration (IBA)

University of Dhaka

Subject: Submission of Thesis entitled "Recycling of Plastic Waste: Sustainable Product Strategy for Bangladesh"

Dear Sir,

This is to inform you that I have completed the thesis you supervised in fulfillment of the requirements for the Doctor of Business Administration (DBA) degree. In writing this report, I have followed all the guidelines and instructions that you have given and I have also applied them. This report supports the attainment of a sustainable product strategy for Bangladesh from recycled plastic waste from a circular economy perspective.

Employing qualitative research, this paper unfolds in diverse contexts with a strong emphasis on assessments of the prevailing plastic recycling value chain through open-field interviews with the actors involved, relevant literature reviews, case studies, desktop research, and policy formulation.

The broad objective of this study is therefore to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh that will facilitate the circular economy and to propose policy packages with a facilitated process to challenge existing business model assumptions, identify new opportunities and catalyze changes that will support the implementation of a sustainable product strategy from recycled plastic waste.

I hope this report lives up to your expectations. Please let me know if any rectifications are required.

Sincerely yours,

Mohammad Hanif

Registration no: 05/2016-2017 (Session: 2016 2017)

Re-registration no: 18/2020-2021 (Session: 2020-2021)

Doctor of Business Administration (DBA)

Institute of Business Administration, University of Dhaka

ACKNOWLEDGEMENT

The DBA program has been a long journey for me. When I boarded this ride, I was certain that it would be one of the greatest challenges of my life. I am highly grateful to my DBA supervisor Professor M A Momen for his continuous support and prompt guidance over this prolonged journey without which I would not have been able to complete this thesis. He has always been a continuous source of inspiration for me. He gave me the freedom and confidence to conduct the research process with precise directions when the path was unclear. I am also grateful for the guidance from our Ex-DBA Program Coordinator, Dr. Ziaulhaq Mamun, and Professor Dr. Syed Ferhat Anwar, Ex-Director, IBA, University of Dhaka. Additionally, our faculties taught us with their utmost endeavor during our coursework.

I am also indebted to my DBA classmates and friends for their accompany, guidance, and encouragement.

Special thanks to the interviewees and senior officials of TerraCycle, ByFusion, IntegriCo, Gemini, Daisaku, Shunhua, Union, Ganesha, BPCL, and RPL for their valuable time, input, and sharing experience about their respective organizations & market scenario of plastic recycling sector during the interview. In addition, I would like to thank the industry practitioners working in the plastic industry across the world. Their sharing of thoughts and ideas helped me develop the research work.

I would like to convey my appreciation to my DBA classmates, friends, and colleagues. Many of them guided me from time to time with their input. Besides, thanks to the program offices of IBA, and other office staff.

In addition, special gratitude to my team members and colleagues at Grow Biz Industries Ltd.

Finally, my family, and relatives for their exceptional support. Deepest thanks to my wife Bithi, my son Waseef and my late mother Amirunnesa Chowdhury who departed during the COVID-19 pandemic time and have given me care, endurance, and continual worship through my study and research.

DEDICATION

To my deceased parents

TABLE OF CONTENTS

CHAPTER 5-EVALUATION OF THE CURRENT PLASTIC WASTE RECYCLING VALUE CHAIN

CHAPTER 6- CASE STUDIES: FINDINGS AND DISCUSSIONS

CHAPTER 7-SUSTAINABLE PRODUCT STRATEGY

CHAPTER 8- BENCHMARKING, CONTRIBUTIONS, LIMITATIONS AND CONCLUSION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABS	Acrylonitrile butadiene styrene resin
ACC	The American Chemistry Council
APR	The Association of Plastic Recyclers
ARA System	Application Release Automation System
ASA	Acrylonitrile styrene acrylate resin
BCC Research	Business Communications Company Research
BPCL	Bangladesh Petrochemical Company Limited
BGMEA	Bangladesh Garments Manufacturers and Exporters Association
BPF	The British Plastic Federation
BPGMEA	Bangladesh Plastic Goods Manufacturers and Exporters Associations
CAGR	Compound Annual Growth Rate
CPA	Canadian Plastic Association
COWI	Cambridge Oxford Warwick Imperial
EU	European Union
EPR	Extended Producers Responsibility
EPRO	European Association of Plastics Recycling and Recovery Organizations
EPS	Expandable polystyrene
ETP	Engineering Thermoplastics
GDP	Gross domestic product
IoT	Internet of Things
IR	Infrared
IUT	Implementation Under Test
JICA	Japan International Cooperation Agency
JRC	Joint Research Center
LDPE	Low Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
NAFTA	North American Free Trade Agreement
NGO	Non-Governmental Organizations
OECD	Organization for Economic Cooperation and Development

OS	Optical Sorter
PA	Polyamides
PBT	Polybutylene terephthalate
PC	Polycarbonate
PE	Polyethylene
PEEK	Polyetheretherketone
PE-HD	Polyethylene, high density
PE-LD	Polyethylene, low density
PE-LLD	Polyethylene, linear low density
PE-MD	Polyethylene, medium density
PEMRG	Plastics Europe Market Research Group
PET	Polyethylene terephthalate
PLA	Poly Lactic Acid
PMMA	Polymethyl methacrylate
POM	Polyoxymethylene
PP	Polypropylene
PS	Polystyrene
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PVC	Polyvinyl chloride
RPL	Royal Polyware Limited
SWM	Solid Waste Management
UN	United Nations
UNDP	United Nations Development Programme
UN Environment	United Nations Environment Programme
UNHCR	United Nations High Commissioner for Refugees
USD	United States Dollar
UV	Ultraviolet
WASH	Water, Sanitation & Hygiene
WB	World Bank
WC	Waste Concern
WEE	Waste Electrical & Electronic Equipment
WEP	World Economic Forum
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

This study on “Recycling Plastic Wastes: Sustainable Product Strategy for Bangladesh” proposes an approach to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh. A feasible plastics recycling industry mostly envisages two predominant targets: 1) Economic gain and 2) Environment sustainability.

In terms of economic gain, the noteworthy impact of the plastic recycling industry could definitely improve Bangladesh’s balance of trade by reducing dependence on virgin plastic raw material imports as well as producing value-added products which will increase the economic competitiveness of plastic manufacturers & marketers, increase export potential, and create new jobs, enhance working environments, particularly for actors of the informal sector.
In the context of environmental sustainability, the environmental benefits of using recycled plastics can be immense since it diverts plastic waste away from landfills and has a nominal carbon footprint compared to the plastic recycling industry's significant impact could be positive to lighten prevailing plastic pollution, which can eventually provide a more sustainable alternative to virgin plastic raw materials for producing raw materials for the production of materials and is resource-efficient in production.

This study is consequential in the contemporary world swamped with plastic waste. The study offers a comprehensive evaluation of the current state of plastic waste recycling in Bangladesh as well as benchmarking the factors explicit to the recycling companies in Bangladesh and other successful recycling companies in the world with recommendations for establishing an economically viable and environmentally sustainable plastic waste recycling sector in Bangladesh. This is exploratory research. The study includes in-depth qualitative analysis, verifiable data from reliable sources, and projections of current plastic market trends and future possibilities compiled through extensive primary, secondary, and tertiary research where the primary research is done through open field interviews, in-depth expert interviews, observations, and case studies. The open field interviews are based on the value chain actors of plastic waste recycling in Bangladesh and the sample groups are heterogeneous, based on purposive (waste collectors, middle dealers) and convenience (wholesale dealers, recyclers) sampling. The respondents include waste collectors, middle dealers, wholesale dealers and recyclers. The study has adopted the case study method of purposeful case selection and has selected large and notable plastic recycling business models across the world to find the critical success factors and the possible replication option from Bangladesh’s perspective. The analysis is structured using the Business Model Canvas (BMC) framework as developed by Alexander Osterwalder and Pigneur (2010) and the Lowell Center Framework for Sustainable Products (Sally Edward, 2010) by following the Circular Economy Business Model Case Studies developed by the R2Pi project of the European Union in 2017. The study has reviewed and analyzed 250 previous studies of similar fields done by different researchers across the globe by focusing on literature sources, insights, and key drivers of the kinds of literature. Interviews with industry experts and the organization’s personnel have provided primary information that facilitated the analysis of the business model of the Circular Economy. The analysis is mainly

exploratory which is based on open field interviews, case studies, expert interviews, and literature reviews.

The research addresses the general concept of plastic and plastic waste recycling, prevailing value chain investigation, exploration of global practices, and assessing the prospect and opportunities for replication of the business model in Bangladesh on a circular economy notion. The broad research objective is to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh. The operational objectives of the study are: 1) To evaluate the current state of the plastic waste recycling value chain; 2) To study the existing plastic waste recycling industry for replication and scalability of the business model on the circular economy principles; 3) To formulate a sustainable product strategy from recycled plastic waste in Bangladesh.

A conceptual framework has been developed coping with a "system-thinking approach" (OECD, 2017) focusing on the plastic recycling value chain that involves a multitude of actors from the collection, transport, dismantling, sorting, and finally to recycling & product manufacturing from a circular economy perspective.

Open field interviews and expert interviews revealed that the plastic recycling industry in Bangladesh is highly polluting in its current state due to the informal sector's dominance, inferior feedstock quality, lack of funding, substandard recycling technology, waste treatment infrastructure, and thus throwing away the opportunities to extract ultimate benefits. On the contrary, developed countries are far ahead of Bangladesh because of the vibrant informal sector, strong recycling infrastructure, superior quality feedstock, and advanced technology with adequate funding as revealed from case studies and literature reviews.

Finally, this study recommends the main priorities to be addressed to develop a feasible plastics recycling industry in Bangladesh; 1) Recyclable plastic waste escalation in terms of value and volume; 2) Integrate informal sector actors into the mainstream economy to improve the effectiveness of collection, sorting, and segregation and legitimize their identity and profession; 3) Form and Institutionalize the Extended Producer Responsibility (EPR) structure towards funding for the growth and development of recycling infrastructure; 4) Inspire innovation, and match recyclers with prospective business opportunities by establishing a transparent and viable secondary raw material marketplace. However, a joint and coordinated approach is required among all where policymakers, researchers, students, industry experts, social activists, international donors, and businesses interested and engaged in the transition toward a circular plastics economy are the intended audiences.

REPORT STRUCTURE

The report is structured in a logical manner where **Chapter 1** provides background, problem statement, justification of the study, significance of the study, research questions, objectives and scopes of the study.

Chapter 2 motivates in a logical manner because countries, including Bangladesh, must proactively seek solutions to manage plastic waste to achieve economic gain and environmental sustainability. With the general information on plastic & plastic waste recycling, its position in the hierarchy of plastic waste management, plastic recycling glossary terms, operational definition of terms, the growth potential of plastic recycling, a brief presentation of innovative plastic recycling companies, an overview of plastic waste recycling the plastic recycling in Bangladesh and importance of plastic circularity from Bangladesh perspective.

Chapter 3 provides a comprehensive review of available literature related to the study topic where studies related to plastic and plastic waste recycling have been reviewed meticulously and have been incorporated in this study as a major source of qualitative data. While conducting the study, previously available studies haven't been ignored as those would help to check up on the changes, alterations, modifications, or replication in the present study. Thus, one can find what studies have been conducted, what can be replicated, what can be modified, and what remains to go. The study has considered a review of previous studies in a similar field of study. This chapter started by reviewing some studies from a global perspective considering the growth and development of the plastic recycling sector, the plastic recycling value chain, and its phases. The chapter also has exemplified some studies on Bangladesh's perspective. The study has found an unequal distribution of research across the different value chain stages where a significant number of published and unpublished articles focus on the waste-management phase, and comparatively fewer studies deal with product design, production, and use phases. This is an important knowledge gap, as most research has been focused on the end-of-life phase, despite the increased political, economic, and scientific prominence on the circular economy perspective that, ideally, would include recycling as just one aspect. It has been observed that there is a cohesive relationship between the plastic recycling value chain and the conceptual framework of this study. In this consideration, the value chain is premiered and the conceptual framework is designed afterward. It also has provided detail about the stakeholders across the value chain. Considering value chain stages and its stakeholders a conceptual framework has been developed applying the "System Thinking Approach."

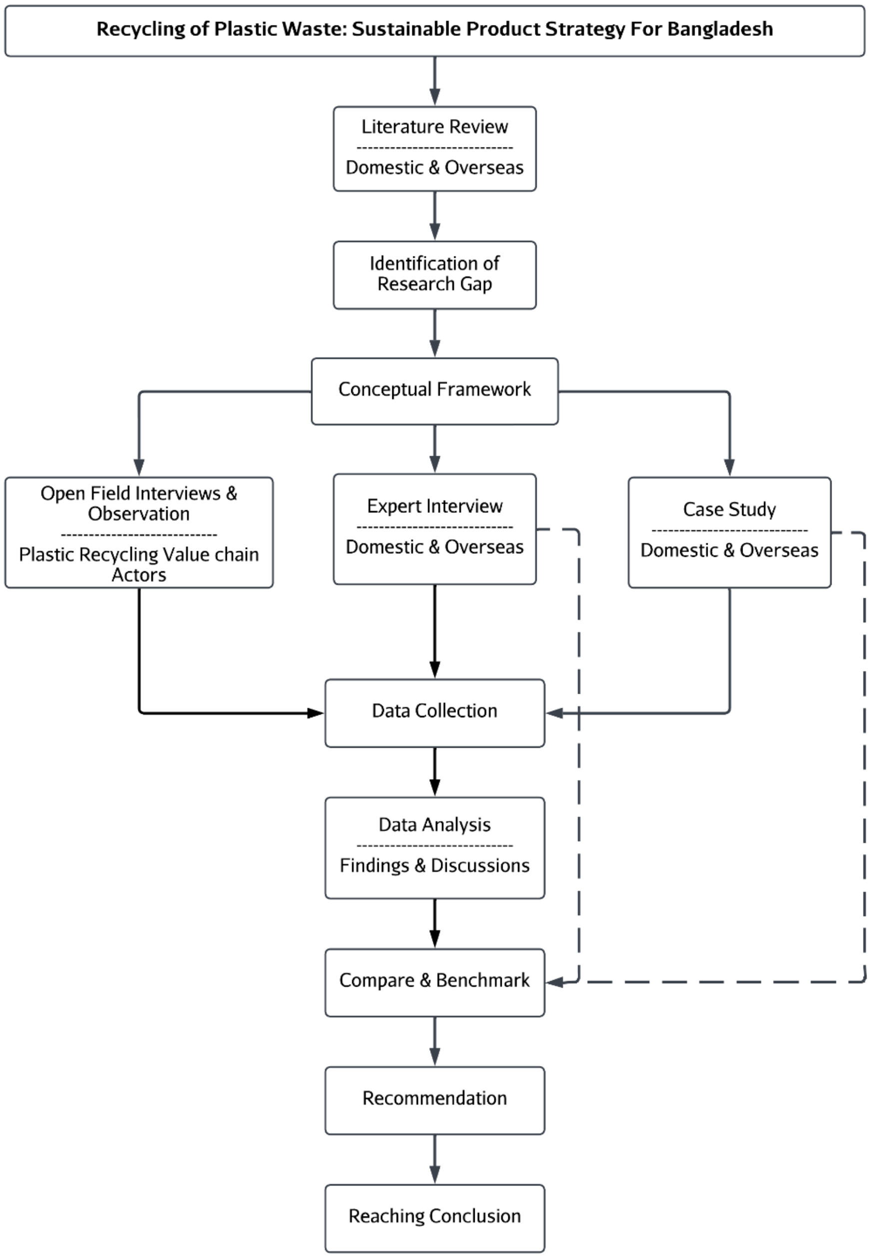
Chapter 4 explains the methodology that is used in this thesis. The types of methods, research philosophy, literature, journal articles, open-field interviews, case studies, document studies, expert interviews, and online sources are studied. In addition, it reviews the quality of this thesis by discussing its validity and reliability. The researcher hopes to provide a sincere and rich description of the methodology used in this thesis. The overall research design of this study is based on a 'systems-thinking' approach (OECD, 2017) that emphasizes the cohesive investigation of the problems seeing multifaceted connections between elements within the system. Thus, the system-thinking approach is distinct from a linear, and causal theory of change, as it clearly reflects feedback loops from any change in one part of a system, which produces change across the system due to its interconnection (Olivier et.al, 2011). Therefore, the system thinking approach emphasizes establishing "leverage points" (Metabolic 2020), where one minor modification can create a major net effect across the system. Since plastic waste recycling loops are equipped with multifaceted connections between actors within the whole system the study adopted the "System Thinking "approach where any change in one element produces change across the whole system. The chapter also has exemplified detailed methodology and an overview of Business Model Canvas and The Lowell Center Framework for Sustainable Products through which case studies have been conducted.

Chapter 5 of the study has documented the outcome of open field interviews with fifty waste pickers, twenty-five middle dealers, twenty-five wholesale dealers, and ten recyclers in both city corporations. Apart from this, expert interviews were undertaken along with the analysis of prevailing legislative groundwork of the plastic recycling value chain to document the economics of waste retrieval by studying how waste is regained and chart its journey towards the recovery and recycling markets in terms of value addition. Aiming to extract the ultimate benefit from this potential sector, the study has evaluated the current state of the plastic recycling value chain through open-field interviews with the value chain actors such as waste pickers, middle dealers, wholesale dealers, and re-processors. Similarly, the study also considered expert interviews for knowing the same and incorporated them into this report. Thus, this chapter provides a total overview of findings from open field interviews, existing legislative groundwork, and expert interviews related to the prevailing plastic recycling value chain in Bangladesh, and the future growth and development of the plastic recycling sector, aligning with the global practices for the same that enables to meet the first objective. This chapter started with the findings and analysis of information obtained from open-field in-depth interviews with value chain actors in plastic recycling value chain and presented the outcomes along with the summarized findings from expert interviews. This chapter has also exemplified the implications of the evolution of Initiatives, Policies, and Regulations related to addressing plastic issues in Bangladesh. There are numerous issues explored in this chapter where plastic recycling value chains are mostly unstructured, unregulated, unauthorized, and unmonitored. As a consequence, this sector causes noteworthy ecological hazards along with negative health effects on the community assuming their lack of required knowledge, lack of waste treatment infrastructure, supply chain constraints, lack of funding, and inadequate data related to plastic waste recycling. On top of that adoption of substandard crude recycling technology could not make any significant impact for getting economic gain and environmental sustainability. These aspects are discussed extensively.

Chapter 6 includes the case study of the organizations that are on the journey towards developing circular economy principles, as well as those who have the ambition of the same. The transition from Linear Economy to Circular Economy is a global agenda focused on enabling organizations and their value chains to transform towards a more feasible, sustainable, and competitive economic model. Based on this, the study's mission is to explore the feasibility of a viable plastic recycling industry in Bangladesh. Through these engagements, the study aimed to carry out an independent analysis of eight selected foreign organizations and two domestic organizations, and identify new opportunities for Bangladesh, to change and thus, presented in this chapter. This aspect appears predominantly important for Bangladesh when judging the prospect and opportunities for replication and scalability of the business model on the circular economy notion. The process of accumulating information, desk research, and interviews was conducted in the period December 2018- January 2020. The preparation of the final report on these case studies ended in June 2022 with additional changes implemented later. Based on the information obtained, a representation of the case organization's business model has been developed using the Business Model Canvas template, while showing relationships between the elements and adopting Lowell Center Framework for sustainable products to understand how companies are offering products that are greener, safer, and healthier from a sustainability perspective. Through studying cases across the world as stated above, it can be ascertained that measuring sustainable production is a complex process. With the growing number of organizations, attempts to be sustainable, their measurement processes must change from easier compliance and regulatory-driven models of performance appraisal. In this study, all eight international companies studied employed all the levels of indicators. In the case of Bangladesh BPCL is on its way to accomplishing its journey toward sustainability despite having serious constraints related to the supply chain that is highly volatile and fragmented. On the other hand, RPL is mainly focusing on making money from recycling where environmental, social, and other related factors are highly ignored and thus it doesn't focus on sustainability. The case studies mentioned above revealed that sustainable production indicators are beneficial for organizations, firms, community groups, government agencies, and many other stakeholders. All stakeholders need to measure and manage their respective accomplishments. NGOs, communities, organizations, policymakers, researchers, municipalities, and governments need to assess companies' performance meticulously to reward the leaders and determine how best to inspire the stragglers the improvement of their performance toward sustainability. The purpose of the Lowell Center Framework is to deliver companies with a classification structure indicator and direction for evaluating their advancement toward sustainability. Sustainability indicators of industries stress one part of the sustainable development equation i.e., environment over the others i.e., social and economic where social and economic parts include economic possibility, social impartiality, community development, and employee safety and health development. This chapter provides a detailed analysis of ten different cases from various regions of the world including two from Bangladesh applying Business Model Canvas (Alexander Osterwalder, 2010) and Lowell Center Framework for Sustainable Products (Sally Edward, 2010). The study discovered that skilled resources, advanced technology, continuous R& D, strong infrastructure, sound financial strength, favorable state policies, and a vibrant supply chain play key roles in the growth and development of plastic recycling companies which are widely practiced in the other part of the world. As a consequence, successful recycling companies are emerging. On the contrary, Bangladesh is lagging far in that successful journey towards attaining a circular economy because unregulated, unstructured, and unmonitored plastic recycling sector that has been described in this chapter. Therefore, this chapter addresses the possible replicability of the business models, and the overall findings will help to find further gaps and to provide anticipated solutions with the proper benchmark for establishing a feasible plastic waste recycling industry in Bangladesh.

Chapter 7 of the study provides an outline of probable strategies to formulate a feasible recycled plastics market in Bangladesh. The study has found that plastic recycling is unstructured, unregulated, unauthorized, and unmonitored so it has been proven difficult and uneconomical. In addition, there is a dearth of information regarding plastic types, the composition of plastic wastes, disposal and reprocessing of plastic waste to achieve economic gain and environmental sustainability where Western countries and other developing countries are clearly ahead of Bangladesh in handling plastic and plastic waste to extract ultimate benefit from it, From reviewing the literature, case study analysis and through in-depth expert interviews, this chapter of the study offers an outline of probable strategies to formulate a feasible recycled plastic industry in Bangladesh. This chapter also provides recommendations for short-term and long-term roadmaps. The supremacy of the informal sector actors, which mostly apply substandard technology along with a lack of adequate infrastructure and waste treatment methods, has yielded disadvantageous economic and environmental consequences. For example, in the Old Town's recycling hub (the main hub for plastics scrap collection, sorting, and recycling in Bangladesh), 30-35% of plastics wastes used to collect for recycling, and a million liters of wastewater from washing is discharged daily into open landfills, municipal's drains, and canals with inappropriate treatment. Hence, proper investments into reforming and assimilating the informal sector with the mainstream economy will not only increase environmental competence but also reduce waste leakage into the environment and largely augment economic gain. Henceforth, favorable rules and strategies for supporting this sector could ease regulatory pressure, while extinguishing economic losses and environmental risks. Beyond these, global trends toward acquiring anticipated sustainability and resource efficiency beckon an outstanding economic prospect to build a feasible plastics recycling sector. Based on above mentioned findings from interviews with value chain actors, expert interviews, and literature this chapter depicted strategies to build a feasible plastics recycling sector in Bangladesh where policymakers, researchers, students, industry experts, social activists, donors, and businesses are the intended audiences.

Chapter 8 provides benchmarking, contribution, limitations, conclusion, and scope for future researchers. The contemporary studies on the Recycling of Plastic Waste and its Sustainable Product Strategy for Bangladesh are insufficient. Besides this, the contemporary studies gave conflicting or inconclusive results to some extent. Thus, the chapter displays the benchmarking of the aspects explicit to the study outcomes and previous studies on plastic waste recycling. A set of specific impacts in this study has been defined that will be indispensable to assure the achievement, exclusivity, and urgency of the study rationale. In this connection, the indicators would have been developed to measure both the impact and contribution of the study for various stakeholders. This study will be interesting for state authorities, policymakers, municipalities, circular economy entrepreneurs, businesses, researchers, and students as empirical, practical, and methodological contributions. This study attempts to inspire plastic recycling by giving an overview of the surplus plastic waste of Bangladesh: what is in the millions of tons of plastic waste that is brought daily to scrap shops and recyclers? Where does it end up? And, especially, what can be done with it? The world is moving towards a linear to a circular economy. This transition will not happen without further research in each phase and collaboration across the value chain, to prevent implications both within each phase and also affecting other phases. This study calls for additional research into design, pure waste streams, processing, new product strategy, and modified consumer behavior. Future research should take a holistic approach to the transition to circular. This can be done by mapping the implications, identifying where in the value chain these occur, and promoting stakeholder involvement and collaboration. The report structure is depicted below in the illustrative form:



CHAPTER 1: INTRODUCTION

CHAPTER CONTENTS

This chapter provides background, problem statement, justification of the research, significance of the research, research questions, objectives, scopes

CHAPTER 1: INTRODUCTION

1.1 Background

Plastic products are omnipresent in our everyday life, providing us with plentiful advantages and benefits. Due to their distinctive properties, they are an extensively used material in a number of sectors. With continuously growing innovation applications, the trend in the production and consumption of plastics will continue to increase at a faster pace (Tons Emans, 2012). Thus, the plastic industry is an important sector of the global economy. Global plastics production almost reached 368 million tons in 2019 (PEMRG, 2020). Rising demand for plastics in numerous sectors and advantageous government initiatives toward balanced uses of plastic and plastic waste has strengthened the growth of this market. Coping with global warming awareness, producers of plastic materials across the world are highly concentrating on developing new recycling ideas to reduce greenhouse gas emissions and maintain environmental sustainability. On the contrary, the growing use of virgin plastics and the lack of a proper plastic collection, sorting, and reprocessing structure has hindered the progress of this market in many parts of the world. Thus, the lack of a well-organized waste collection, sorting & reprocessing system for plastic waste is posturing a challenge for this market (Research & Market, 2022). The global plastic waste business is currently in a messy state, predominantly since China's ban on scrap imports in 2018. The way countries across the world invest and develop solutions to plastic waste produces significant economic competitiveness and environmental and social dividends going forward. However, in 2021, the Global Plastic Recycling Market is estimated to be USD 45.5 Billion and is expected to reach USD 65.3 Billion by 2026, mounting at a Compound Annual Growth Rate (CAGR) of 7.5 % (Research & Market, 2022).

Likewise, global trend, the plastic sector is developing rapidly in Bangladesh and it has become one of the remarkable sectors in Bangladesh. Bangladesh consumed approximately 1.5 million tons of plastic polymer in 2017 (Ijaz, 2019) and the consumption has been rapidly increasing. This ever-rising trend in plastic consumption in Bangladesh leads to plastic waste that needs proper reprocessing to achieve economic gain and environmental sustainability. At present, 50-60% of plastic waste is used to recycle (Ijaz, 2019) where the collection process & work environment is hazardous and unhealthy; sorting & reprocessing in cramped conditions with crude processing machinery (Waste Concern, 2015).

According to market study reports obtained from Research and Markets (2022), favorable growth circumstances for the plastics recycling industry are mainly driven by the following global trends:

1) Higher demand from renowned brand producers and customers. Complying with SDG, renowned brands, such as Nestle, Coca-Cola, Pepsi, Evian, P&G, Nike, Adidas, Puma and Unilever have devoted themselves to striving for sustainability goals and started applying a higher percentage of recycled plastics in producing various end-products, motivated by "corporate social responsibility" and customer demand for sustainable products as a whole.
2) Strict environmental policies and regulations, with an increasing number of countries directing increased recycling percentage, stricter 3R (Reduce, Reuse, Recycle) policies at all levels, circular design guidelines for the product manufacturers, and a minimum percentage of the recycled plastic content requirement for certain products (European Council, 2019).
3) Incessant R&D in Plastic Recycling Industry helps increase technological modernization, replicability, scalability and cost-efficiency due to more effective recycling machinery and the growing application of circular design (Plastics Europe, 2019).

Apart from producing value-added new end-products, higher production of recycled plastic granules can support the plastic industry to lessen its dependency on imported virgin plastic raw materials in Bangladesh. Planned investments in plastic raw material manufacturing will alleviate some dependence on imports, and strategic investments are completely focused on manufacturing virgin granules, which rely on petrochemical feedstock. Henceforth, increasing the supply of recycled plastic pellets could lessen the vulnerability of the plastic industry to the instabilities of product markets by reducing dependence on virgin granules in Bangladesh.

1.2 Problem Statement

Bangladesh is fronting a sharp increase in plastic production and consumption leading to generating plastic waste with rapid growth and urbanization. Although Bangladesh was the world's first country to ban plastic shopping bags and progressively took steps in restricting plastic waste generation and pollution in 2002; however, plastic use, waste generation, and mismanagement increased again after some time. Consequently, this uncontrollable ever-rising trend in plastic consumption and plastic waste generation in Bangladesh is in need of proper reprocessing to achieve economic and environmental sustainability.

A recent study conducted by World Bank (World Bank, 2021) has revealed that over the last 15 years, Bangladesh's annual per capita plastic consumption in urban areas increased to 9.0 kg in 2020 from 3.0 Kg in 2005; while per capita plastic consumption of the capital Dhaka is more than three times the national average urban area and stands at 22.25 kg. Against the aggregate consumption of 977,000 tons of plastic in 2020, only 31 percent was recycled in Bangladesh, and in Dhaka, about 646 tons of plastic waste is collected daily whose 37.2% is recycled. (Waste Concern, 2020) which is higher than the global average of about 9% (Geyer et al. (2017). Even though the annual percentage of plastic waste recycling is higher than the global average, Bangladesh's annual plastic waste recycling percentage is declining gradually over the last 10 years, and it was more than 50% (Waste concern, JICA, BPGMEA 2014).

The review of the literature suggests that the transition from the prevailing linear to the circular economy cannot be achieved without the inclusion of new recycling technologies along with the process of design, production, and use of plastic products. According to Milios et al. (2018), one of the flashpoints found in the value chain is a lack of communication and coordination, which results in a lack of traceability, and affects the whole system. Moreover, the literature review reveals that there is a knowledge gap in the design, production, and use phase that may hinder both the transition to a circular and the operation of waste-management procedures with limited attention given to opportunities for the prevention of plastic waste, redesign, new product development despite the fact that these aspects are often regarded as the most desirable on the circular-economy notion. According to Nielsen et al. (2020), most of the legislation issues are about regulating the end-of-life phase (i.e., waste-management legislation), paying little attention to the remaining stages of the plastic recycling value chain. There is another problem concerning the circular business model in the current research, where the majority of the research focuses on the recycling of plastic, leaving out other aspects of the circular plastic economy. Another challenge mentioned is that the existing literature focuses on recycling and reducing the amount of plastic consumed, ignoring the strategy formulation of making sustainable products from recycled plastic.

In Bangladesh, plastic recycling has been proven difficult and uneconomical, because of a well-developed legal framework, institutional structure, and industrial base for plastic recycling (K.G Moazzem, 2016). In addition, there is a dearth of information regarding plastic types, the composition of plastic wastes, disposal and reprocessing of plastic waste to achieve economic gain and environmental sustainability where Western countries and other developing countries are clearly ahead of Bangladesh in handling plastic and plastic waste to extract ultimate benefit from it.

There are also research gaps to integrate design for recycling; including recycled materials in the production process; increasing the demand for recyclable materials; new product development strategy from recycled plastics, and raising required investment in the development of recycling technologies (and technology systems that integrate or combine mechanical and chemical recycling technologies).

1.3 Justification of the Research

The stoppage of using plastic materials would have been an extremely challenging task and may have had a negative impact on the whole economy as plastics are ubiquitous in our daily lives. However, the administration of plastic surplus through proper recycling is based on the UN circular economy principle instead of the linear economy principle with due care to health, safety, and environmental issues. The problem and the prospect of plastic waste along with the impact it has created in numerous sectors of Bangladesh have to be addressed for achieving economic gain and environmental sustainability.

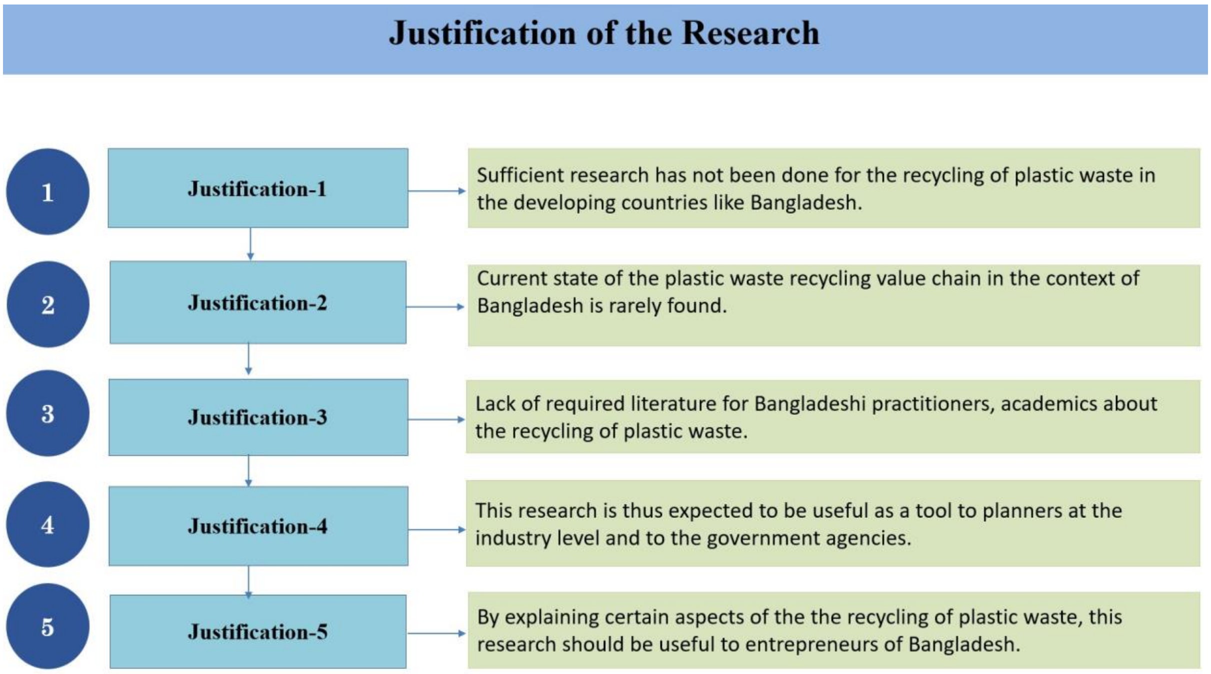
Since the alternative of plastic materials is not considered to be cost-effective and user-friendly, hence the production and consumption of plastic materials, as well as plastic waste, would grow simultaneously in the days ahead with the growth of the economy of the country. Managing plastic waste by extracting the ultimate benefit from it will be significant for achieving Bangladesh's vision of becoming an upper-middle-income country by 2031 since it cannot stop production, consumption, and waste generation (World Bank, 2021). For this, the country desires realistic achievement plans to convert plastic waste into resources and become a forerunner in green development.

In such a scenario, the best sustainable approach is to encourage the recycling of plastic waste from at present 31% (World Bank, 2021) to a noteworthy level. There is no "silver bullet" answer to meaningfully decrease plastic waste generation and disposal rather deploying arduous (pre-consumer, such as factual reshaping, plastic decrease, and replacement) and downstream (post-consumer, such as power-driven and chemical recycling) solutions together which are complementary for attaining the most effective output (SYSTEMIQ, 2022). To this end, all these have a key protagonist to play in the days ahead of the arrangement of the upcoming plastic in Bangladesh, and none can be left out, but none are adequate on themselves.

Regarding the production, consumption, and waste generation of plastic, many experts suggest taking expressive action, the economic, fiscal, environmental, and societal inferences of different paths are often indistinct, making it challenging to regulate which movements should be arranged for the collection, sorting and reprocessing of different types of plastic wastes, or to comprehend the interactions between different answers. It has been observed that the literature available on this specific field especially in the context of Bangladesh is inadequate. Furthermore, research involving an all-inclusive approach toward attaining a feasible plastic waste recycling value chain is yet to be seen. The study attempts to fill those gaps by focusing on the best-case scenario to transform the existing system in Bangladesh into a standard system practiced across the globe and is intended to provide firsthand information on the subject to governments, policymakers, industrialists, business people, academicians, researchers, students, and the common people.

The major justifications or rationales are illustrated below:

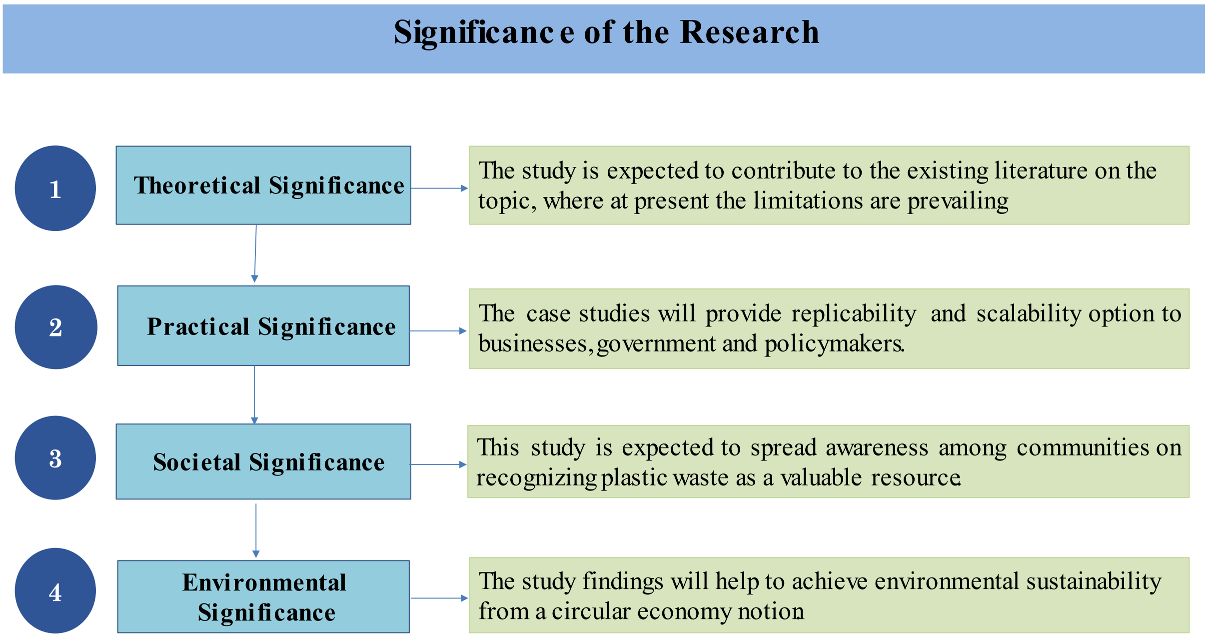
Figure 1.1: Justification of the Research



1.4 Significance of the Research

The literature on the Recycling of Plastic Waste and its Sustainable Product Strategy for Bangladesh is insufficient in the context of Bangladesh. Besides this, contemporary studies gave conflicting or inconclusive results. Through the comprehensive exploration of this study, the impact of plastic waste will be scrutinized, emphasized and unraveled. Since the study has conducted case studies regarding successful plastic waste recycling companies, it will fulfill the purpose of making replicable and scalable on a circular economy notion for the context of Bangladesh. Thus, the study will provide a practical significance for businesses, government and policymakers. This study covers information involving plastic waste recycling as an approach to converting plastic waste into valuable resources. Thus, the results of the study may serve as a tool for further studies to innovate the current method employed in the plastic waste recycling Industry. Furthermore, this study spreads awareness to society on recognizing plastic waste as a valuable resource and how plastic recycling can be a valuable approach to attain economic gain and environmental sustainability. The major significance of the research is illustrated below:

Figure 1.2: Significance of the Research



Overall, the significance of the topic "Recycling of Plastic Waste: Sustainable Product Strategy for Bangladesh" are found in the study. Aiming to bridge the gaps in contemporary research, this study attempts to document the actors involved in the plastic recycling value chain. The study is indicative that provides an opportunity for a deeper investigation of the existing plastic recycling value chain. In addition, case studies and expert interviews have been undertaken to formulate a sustainable product strategy from recycled plastic strategy in the context of Bangladesh.

1.5 Research Question

The main concern of the study is aimed at reducing or eliminating plastic waste to discover the feasibility of a sustainable plastic waste recycling industry in Bangladesh by devising a sustainable product strategy. The business models of selected plastic recycling companies across different regions of the world have been analyzed to compare and identify the gaps. It also follows and relies on various relevant studies listed as sources in this study. Thus, the study builds on open-field interviews with the actors involved in the existing value chain, many other types of research, cases, and experts' opinions to provide an evidence-based, data-driven, solution-focused, full system approach aimed at answering the following key question about the plastic waste recycling system in Bangladesh:

How can plastic waste properly be utilized for making sustainable products in Bangladesh?

1.6 Research Objective

Broad Objective

The broad objective of the study is:
To explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh.
The operational objectives of the study are the following:

1. To evaluate the current state of the plastic waste recycling value chain
2. To study the existing plastic waste recycling industry for replication and scalability of the business model on the circular economy principles
3. To formulate a sustainable product strategy from recycled plastic waste in Bangladesh

1.7 Scope of the Study

The study aims to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh by adopting a qualitative approach. The research will evaluate the current state of the plastic waste recycling value chain and for doing this Dhaka Metropolitan City has been chosen as the study area. Dhaka consumed and recycled significant plastic waste and eventually portrayed Bangladesh. The study will also involve expert interviews and case studies of plastic waste recycling companies of varied types from different countries for possible replication and scalability of the business model on the circular economy principles and to formulate a sustainable product strategy from recycled plastic waste in Bangladesh. Therefore, the research will involve detailed qualitative analysis of data obtained from open-field interviews with the value chain actors of plastic waste, expert interviews and case studies. Finally, the study aims to build a reliable and pragmatic model that can help businesses, governments, policymakers, and subsequent researchers to identify and prevent plastic waste to go into landfill, waterways and incinerations. The below table summarizes the scope of the study and the expected results.

Table1.1: Synthesis of the Scope

Subject	Scope/Description
Theoretical/Generic	Plastic, Plastic Recycling, Circular Economy, Economic & Environmental Sustainability
Actors covered	The whole value chain of plastic waste recycling is considered. A particular focus is directed toward the needs of end-users.
Geographic	Detailed analysis of plastic the waste value chain for the Dhaka Metropolitan City as Dhaka consumed and recycled most waste in Bangladesh and thus extrapolation at the whole country level
Cases	Detailed analysis of the Business Model of 10 selected cases across the globe including two cases from Bangladesh.
Waste Flows & Streams	Types of plastic wastes generated from households, industrial and commercial
Indicators	• Economic: Investment and potential revenue • Environmental: Positive impacts on land, air and water • Social: Direct jobs

The overarching objective of this study is to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh on a circular economy notion while developing specific measures in a more holistic manner. Therefore, the blueprint of this study has developed as follows:

Starting Point: Evaluation of the prevailing plastic recycling value chain of Bangladesh along with studying differentiated plastic recycling endeavors of successful cases across the world for probable replication and scalability of the Business Model on the circular economy principles.

Scope: All types of plastic waste except medical waste but all types of end users and stakeholders.

Focus: Improving the performance of the whole value chain in a holistic manner.

Output: A set of rationalized measures for attaining a sustainable plastic waste recycling industry in Bangladesh.

Therefore, the study identifies solutions based on handling plastic waste properly considering collection, sorting, re-processing, and producing secondary raw material for production/new product making that eventually meet the actual needs of end users in terms of quantities and quality of plastics.

CHAPTER 2: PLASTIC WASTE RECYCLING-CONTEXT AND ISSUES

CHAPTER CONTENTS

This chapter motivates in a logical manner why countries, including Bangladesh, must proactively seek solutions to manage plastic waste to achieve economic gain and environmental sustainability. With the general information on plastics & plastic waste recycling, its position in the hierarchy of plastic waste management, plastic recycling glossary terms and operational definition of terms

CHAPTER 2: PLASTIC WASTE RECYCLING-CONTEXT AND ISSUES

This chapter motivates in a logical manner why countries, including Bangladesh, must proactively seek solutions to manage plastic waste to achieve economic gain and environmental sustainability. With the general information on plastics & plastic waste recycling, its position in the hierarchy of plastic waste management, plastic recycling glossary terms, operational definition of terms, the growth potential of plastic recycling, a brief presentation of innovative plastic recycling companies, and an overview of plastic waste recycling in Bangladesh.

2.1 Plastics: Innovation-Driven Materials

"Plastics" are considered mostly a single material by the commoners, but that is not the true cause. Plastics are a unique, versatile, and extended family of different resources. Science and invention are in the DNA of plastics and were designed with explicit features that make them perfect for the application for which it is envisioned, providing alternative and sustainable resource-efficient solutions to society's needs and challenges (Plastics Europe, 2020). Therefore, plastic materials are important resources that we can use either as raw materials or as the source of alternative energy once used in energy recovery facilities whatsoever their origin, at the end of their service life.

According to the British Plastics Federation (BPF), plastic material was invented for the first time in the world in the middle of the 19^{th} century and since then, plastics have largely shaped the world in many ways and continue to offer sustainable solutions to our fast-changing and ever-increasing needs because of their ground-breaking potential.

The American Chemistry Council defined that plastic materials can be produced from different sources such as fossil origin (crude oil, gas, etc.) or renewable (sugar cane, starch, vegetable oils, etc.) or even mineral base (salt). Apart from their raw materials, few plastics are also biodegradable provided they are appropriately collected and processed together with organic waste, they can biodegrade and become compost.

In the present contemporary world, plastics are resource-efficient materials that allow humankind to access fresh water & useful sewage systems, safe food, energy-efficient homes, industries, green transport, global connectivity, renewable energies, and affordable and hygienic healthcare, just to reference a few since plastics family is composed of numerous-fit for countless purposes.

2.2 Categories of Plastics

The plastics family is composed of a variety of materials designed to meet numerous requirements of thousands of end products which can be categorized as Thermoplastics and Thermosets plastics.

Table 2.1: Categories of Plastics

Thermoplastics	Thermosets
Thermoplastics can be melted when heated and hardened when cooled and these characteristics, which lend the material its name, are reversible. Thus, it can be reheated, reshaped, and frozen repeatedly.	Thermosets plastics experience a chemical change when heated, creating a three-dimensional network. These plastics cannot be re-melted and reformed after heating & forming.
Polyethylene (PE) Polypropylene (PP) Polyvinyl-chloride (PVC) Polyethylene Terephthalate (PET) Polystyrene (PS) Expanded polystyrene (EPS) Acrylonitrile butadiene styrene(ABS) Styrene-acrylonitrile copolymer(SAN) Polyamides (PA) Polycarbonate (PC) Poly methyl methacrylate (PMMA) Thermoplastic elastomers (TPE) Polyarylsulfone (PSU) Fluoropolymers Polyether ether ketone(PEEK) Polyoxymethylene(POM) Polybutylene terephthalate (PBT) Ethylene-vinyl alcohol copolymer (EVOH) Etc	Polyurethane (PUR) Unsaturated polyesters Epoxy resins Vinyl esters Silicone Melamine resin Phenol - formaldehyde resins Urea - formaldehyde resins Phenolic resins Acrylic resins Etc.

Sources of information: American Chemistry Council, British Plastic Federation, Plastic Europe

2.3 Plastic Recycling

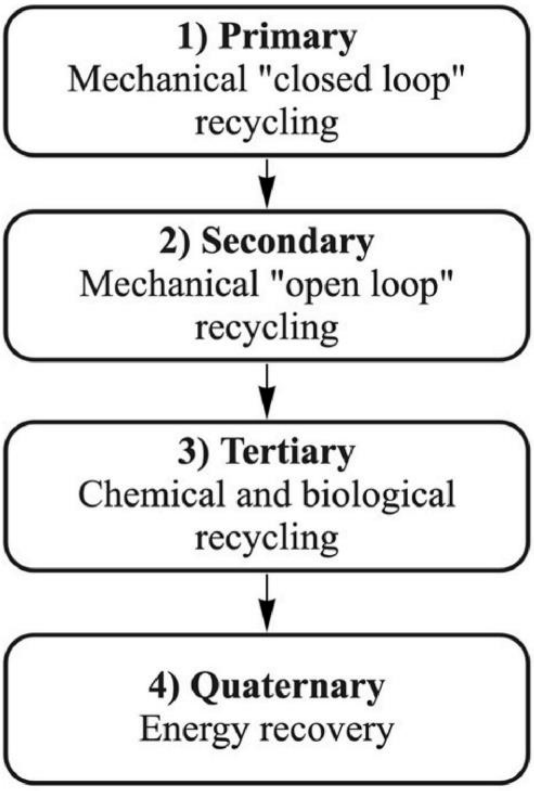
Plastic recycling can generally be defined as the process of recovering scrap or waste plastics and reprocessing the materials into functional and valuable products, sometimes fully dissimilar in form, characteristics & shape from their original state (Adrian, 2011). Based on the type of end product, plastic recycling processes are typically categorized into four distinct groups.

Table 2.2: Types of recycling, in order of prioritization according to both environmental and circular value

Category	Description
Primary recycling: Closed-loop recycling	Closed-loop recycling refers to the manufacturing process that leverages the recycling and reuse of post-consumer products to supply the material used to create a new version of the same product. It is appropriate when scrap plastics have a minimum number of contaminants.
Secondary recycling: Downgrading	Secondary recycling is the creation of products from reclaimed material with less demanding specifications, such as the creation of composite lumber from waste plastics. It is appropriate when the recycled plastic product does not need to meet similar quality standards (e.g., food-safe grade).
Tertiary recycling: Feedstock recycling	Tertiary recycling uses recycled plastic as a chemical raw material through de-polymerization (chemical recycling) which breaks down plastic products into their chemical constituents It is appropriate when the feedstock is difficult or challenging to recycle due to the type of plastic polymer, or is a mix-material plastic good.
Quaternary recycling: Energy recovery	Quaternary recycling uses plastic as a source of energy. It is often preferred as a last-resort solution, due to its high energy intensity and risk of release of toxic pollutants

Adapted from Schyns and Shaver (2021)

Figure 2.1: Plastic Recycling Process Types



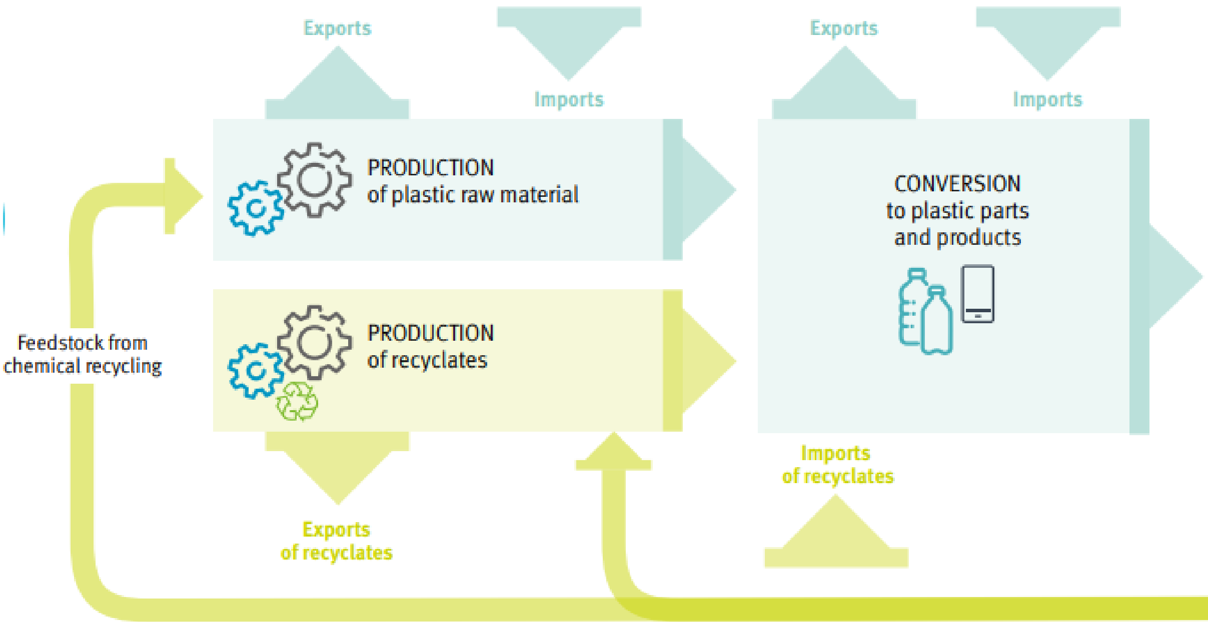
Adapted from Schyns and Shaver (2021)

2.4 Plastics: Key resource for the Circular Economy

The circular plastic economy is a feasible substitute for the prevailing linear economy, where the plastic is manufactured, used, and disposed of aiming to rise the plastic amount that is reused or recycled back into the system (Calleja, 2019; European Commission, 2020). A circular plastic economy could contribute to fewer plastic being down-cycled, landfilled, and incinerated, and contribute to making plastic waste a resource for new products in a closed-loop production and consumption system (Calleja, 2019; MacArthur, E. 2013).

Thus, a circular economy works according to the 3R approach of "Reduce, Reuse & Recycle where value is created by converging on value retention. By keeping plastic streams as pure as possible during the complete value chain, their value of this is retained" (PlasticsEurope, 2019). It is important to analyze the life cycle of plastics to increase the circularity, from production to recycling and closing the loop (Kowszyk, Y., & Maher, R. 2018, PlasticsEurope, E. P. R. O. 2019). The use-phase is critical to understand its life cycle. At present, 60% of plastic products have a use phase between 1 and 50 years, or even more. This gap of time determines when they will possibly become waste (Camilleri, M. A. 2020, Wbcsd, B. C. G. ,2018). AS a consequence, in a single year, the volume of collected plastic waste does not match the volume of production or consumption. Therefore, the Plastic Circular Economy is a viable alternative to the traditional linear economy, and is a key resource for the Circular Economy. The below figure depicts the Circularity of Plastics:

Figure 2.2: The Circularity of Plastics



Source: PlasticsEurope (2019)

2.5 Recyclability of Plastic Products

There is an ongoing public misperception that the Resin Identification Code (RIC) indicates recyclability. In the real sense, the recyclability of the plastic product entirely depends on local recycling infrastructure where not all labeled plastic products can be recycled. Resin Identification Code (RIC) was developed in order to meet the fundamental requirements of recyclers and manufacturers for a uniform and consistent coding system that can be significantly applied worldwide (ASTM 2020) and does not specify recyclability. Table (4) below shows the major plastic resins, their common usage, and recyclability.

Table 2.3: Types of Plastic Resins, Common uses, and Recyclability

Resin Identification Code (RIC)	Type & general features of Plastic	Acceptable for Recycling	Not acceptable for Recycling	Recycled into
1 PET	PET (Polyethylene Terephthalate) Tough and shatterproof	Jars, narrow neck containers such as for detergents, mouth wash, salad dressing beverage and water bottles etc.	Thin, brittle plastics and clamshell packaging often used to hold various items.	Bottles, carpeting, insulations for jackets and t-shirts, tennis ball, paint brushes etc.
2 HDPE	HDPE (High Density Polyethylene) Flexible and often translucent	Water and milk jugs, juice bottles, dairy tubes, liquid detergent bottles, kitty litter jugs, medicine bottles, grocery bags etc.	Materials made from Tyvek such as envelope and protective gears etc.	Buckets, traffic barriers, detergent and bleach bottles, plastic lumber, toys, trash cans, flyswatters etc.
3 PVC	PVC (Polyvinyl Chloride) Tough and heat resistance	Bottles for shampoo, cooking oil, salad dressing etc.	Lawn furniture, PVC pipes or objects too large to fit in a recycling cart (instead can be taken into the customized recycling bin)	Pipes, hoses, mud flaps, mats, computer and electric accessories etc.
4 LDPE	LDPE (Low Density Polyethylene) Flexible and tough	Shopping and laundry bags, food storage containers and dairy containers lids etc.	Bags without RIC codes.	Toys, plastic lumber, frisbees, lawn furniture, garbage can liners etc.
5 PP	PP (Polypropylene) Chemical and heat resistance	Yogurt containers, medicine bottles, rigid plastic cups, nursery plant packs and pots etc.	Thin, brittle #5 plastics such as disposable plastic items, PP fabrics etc.	Paint buckets, brooms, spun fiber fabrics, toothbrushes, PSF, padding, sleeping bags, blankets etc.
6 PS	PS (Polystyrene) Soft and soft opaque foam	Medicine and vitamin bottles, dairy containers, flower pots etc.	Disposable foam items such as cups, plats, foam egg cartons, anything Styrofoam etc.	Building insulation, varied cases, rulers, trash cans, flower pots, food trays etc.
07 OTHER	Other (Other Plastics)	Bottles such as syrup, catch up, window cleaner, water cooler etc.	Object too large to fit in a recycling cart and object without a RIC imprinted on them.	Pens, street signs, concrete supports, building materials etc.

Sources of information: American Chemistry Council, Polystar USA, The Association of Plastic Recyclers (APR), British Plastic Federation

2.6 Plastic Recycling Glossary

During the development and improvement of the study a specific glossary has been used of which a brief listing can be found below:

Table 2.4: Plastic Recycling Glossary

Plastic	A synthetic material made from a wide range of organic polymers such as Polyethylene terephthalate, nylon, PVC, high-density polyethylene, vinyl, low density polyethylene, polypropylene etc., that can be moulded into shape while soft, and then set into a rigid or slightly elastic form.
Plastic Waste	Discarded plastic after intended use is over. Material that did not meet the quality requirements for the fully acceptable product. The scrap can be pellets that did not meet the specifications of converted goods. The scrap can be ground to reprocess and used again or sold or disposed of, depending on levels of degradation and contamination.
Waste Management	The collection, transportation, reduction, recovery, recycling, composting disposal.
Waste Generation	Every person or group of persons or institution, residential and commercial establishments.
Post-Consumer	The status after an item has been used for its intended use. This intended user maybe at another industrial site or as transportation packaging or by household consumers.
Post Industrial	Material that has been processed initially and failed to meet specifications or otherwise not sold as prime material and sold to another party for reuse or reprocessing. Reproduction can be postindustrial material. Postindustrial material must not be treated as postconsumer material unless the produced items have been used for their intended use and are directed toward disposal.
Raw material	The materials that are used to fabricate or manufacture items of commerce.
Collectors	Individual/Entities are waste pickers/haulers/carters that collect recyclables from generators and deliver them to processors or markets.
Curbside Collection	Collection method whereby householders place specified used items in special containers adjacent to containers of household waste for periodic collection bothers.
Drop-Off	Form of collection of household recyclables wherein the householder takes the items to a central aggregation point.

Drop-Off Recycling Site	The facility often serves rural areas, where the public can actively deliver recyclables into the recovery stream.
Converter	Businesses that buy raw material and convert it into finished goods. In the case of plastics, plastic pellets of specific polymers are melted and processed into items such as fibers, films, sheets, and rigid packaging, along with durable and semi-durable goods.
Re-claimer	The commercial entity that accepts aggregated plastic wastes and accomplish a sequence of processes allowing them to return to commerce as useful secondary raw materials or new finished items.
Recyclables	Those materials are identified for collection, processing, recovery, or reuse as part of a local government, business, or other recycling collection program.
Recovery	The successful diversion of recyclable materials out of landfill disposal to recycling collection and reuse systems and the European definition includes incineration with energy detention.
Source Separation	A municipal, commercial or industrial recycling practice that requires sorting of different recyclable materials such as glass, metals, paper, and plastics at the point of the generation prior to collection. Source-separated materials may still be taken to an MRF for baling ,
Recycling	Process of transforming segregated plastic waste into a new product or raw material for producing new products otherwise would have been disposed of.
Industrial Recycling	The practice of long-standing one company selling its useful waste materials or process scrap to another company that uses those materials to make new items. A change of ownership is needed.
Commercial Recycling	The practice of collecting recyclables from retail or commercial businesses, not including single-family households but frequently includes multi-family residences such as condominiums or apartments.
Reprocess	Converting used materials into new materials that can be used.
Middle Dealers	An intermediary or agent between two parties especially
Dealer	An intermediary who buys and sells waste for their own account, whether through a waste picker, middle dealer, broker or otherwise.
Manufacturer	Person or unit or agency engaged in the production of plastic raw material to be used as raw material by the producer.
Plastic Recycling Facility	The industrial location sorts mixed plastic items into streams of discrete plastic resin types. A PRF can also conduct preliminary recycling operations such as size reduction to plastic fake.

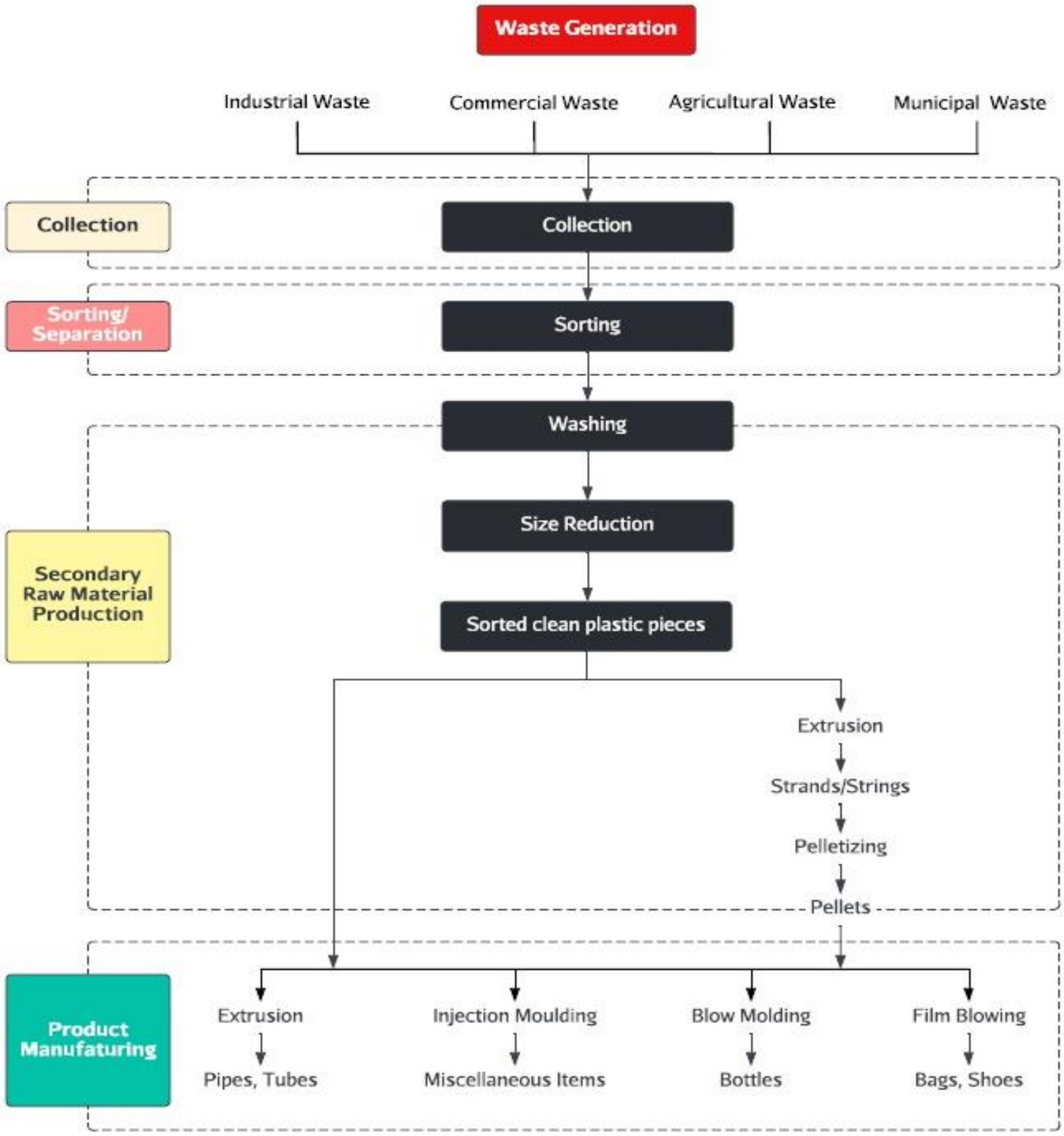
Grinder	General term for devices that chop large items into flakes that are nominally fractional inches in dimension.
Bale	Bale is a compacted and wire-bound cube or block of recyclable material.
Optical Sorter	An optical sorter is such a type of machinery used to automate the process of identifying and sorting recyclable wastes into their dissimilar types for baling purposes.
Near-Infrared Sorter	Type of optical sorting machinery wherein the light used is near-infrared (NIR)Light and the detection made is of plastic-type.
Compactor	Type of equipment that uses pressure to densify and contain recyclable material.
Multi-layered Packaging	Any material used or to be used for packaging and having at least one layer of plastic as the main ingredients with one or more layers of materials such as paper.
Resin Identification Code	A coding system is placed on plastics to identify the polymer

Sources of information: American Chemistry Council, Polystar USA, The Association of Plastic Recyclers (APR), British Plastic Federation

2.7 Plastic Recycling Value Chain

Though not exactly the same, the plastic recycling value chain structure is practically comparable all over the world and the classical assembly of the plastic recycling value chain is depicted in Figure 1.5. In this study, the plastic recycling value chain discusses the holistic procedure by which the waste is collected, sorted, processed, and finally send into the manufacturing procedure. Therefore, it does not cover the steps of recycling, whose efficacy cannot be measured independently from the other entangled steps. In addition, the dissimilar steps of the chain affect each other. The varied characteristics of plastic wastes will affect the choice of technology, eventually affecting output quality and what applications the secondary plastic can be used. The waste may either be collected from pre-consumer sources or from post-consumer sources. The further steps will mostly rely on the waste source and composition. Comparatively with low impurity levels, pre-consumer plastic wastes often have mono-material collection while post-consumer plastic waste usually needs more intensive treatment because of high impurity levels. Because of the high quality of the waste stream, pre-consumer plastic waste is often commercially viable to recycle.

Figure 2.3: Plastic Recycling Value Chain



2.7.1 Collection

The collection systems of plastic waste can be roughly divided into three different types that provide an impression of the quality and characteristics of the collected waste.

Mono-material collection: The collection is planned to get only one source-sorted material. In this mechanism, several plastic types of plastic waste (together or targeting specific plastic types) can be collected. **Co-mingled collection:** This system is considered to collect several source-separated recyclable materials such as metals, glass, and plastics (dry recyclables). **Mixed MSW collection:** This is the most complicated waste collection system since waste originating from such collection type is highly dirty and requires rigorous treatment (JRC 2011, P 39), and the waste flow mostly includes organic waste.

The mono-material collection of plastic waste can be considered for single or few polymers. Volumetric plastic waste in the collection scheme of single or few types will be collected for potential recycling. Conversely, a Volumetric plastic waste of varied plastic types entails a more systematic sorting subsequently yielding a higher amount of disallowed material and substandard quality of the output fraction.

Relatively, co-mingled materials deliver an inexpensive range collection but add some extra sorting steps before the actual secondary raw materials production. The residual plastic waste can also be organized that yielding the extra retrieval of recyclable materials. The best outcomes can be availed from dry waste sorting and if the organic waste is collected separately.

2.7.2 Sorting and Separation

Sorting and separating plastic waste have the general purpose of getting superior-quality recycling. The sorting and separation technologies reduce less important plastics as well as non–plastics such as metal, glass, oil, soils, contaminants, additives within the plastic matrix, etc. Based on the input material and anticipated quality, several technologies are typically applied in a specific combination for the output material and the output can be a single plastic or different types of mixed plastics (Christensen & Fruergaard, 2011).

A brief description of major types of separation technologies/equipment covering is described below:

1) Size Separation
2) Gravity/Density Separation
3) Metal Separation
4) Optical/Sensor Separation
5) Manual Separation/ Quality Control

For advanced recycling of plastic waste, sorting plants equipped with the above-mentioned technologies to avail anticipated outcomes by applying an economical and efficient sorting. According to input materials and required output quantity, the configuration of the specific plant can be accustomed (JRC, 2011).

2.7.3 Reprocessing

Reprocessing of plastic waste materials comprises acceptable categorization and secondary raw material and usually does after the separation of mixed plastic waste flows or directly from industries. The input for secondary raw material will often be single plastic for superior quality plastic products such as PET or PP with no or little pollutants and no targeted plastic materials. On the other hand, for lower quality plastic wastes (often mixed) impurities are higher. The secondary raw materials that are used for manufacturing various plastic products are typically pellets, but sometimes can also be flakes or profiles.

Besides the orderly method, sorting and separation techniques can also be applied upon requirements or in between reprocessing. In a typical plant, reprocessing is equipped with a Bale opener, acceptable sorting (size reduction, vacuum reactor, extrusion, screening ballistic separator/NIR infrared separator/magnet/eddy-current separator), and hot washing, micro-filtration of water extraction, and pelletizing.

2.7.4 Product Manufacturing

Reprocessed plastic pellets originating from plastic waste are being used as secondary raw materials often fully or partially substituting the production of virgin plastic materials. Reprocessed plastic from various sources will usually produce secondary raw materials of dissimilar qualities and quantities. High qualities from NIR and reprocessing can yield various types of pellets such as HDPE, LDPE, LLDPE, PP, PET, and PS for superior plastic products. On the other hand, inferior or substandard mixed plastic, can either be used for making substandard products or for energy purposes.

2.8 The Exciting Market Growth Potential of Plastic Recycling

Plastic recycling has steadily been expanding in the world and has abundant room for further growth. Favorable pricing and increased sorting and recycling capacity in the world help increase the supply of plastic waste absorbed into the plastic market. Plastic recycling will progressively replace virgin plastics production considering the global transformation towards circular economies and lower carbon emissions where market participants consider recycled plastic to be the best alternative to virgin plastics. This view is supported by various government, policymakers, and renowned companies which focus strongly on litter reduction and thereby recycling, rather than bio-based or bio-degradable plastics. Strict environmental regulations, higher demand from customers and brand producers, and rising technological innovations are the growing momentum for the mounting plastic recycling business spreading across the world. Renowned Consumer Product Manufacturers and chemical companies across the world are incessantly doing research and development from their respective ends to improve prevailing plastic recycling activities aiming to transform into a plastic circular economy which eventually helps achieve potential market growth.

2.8.1 Consumer Product Manufacturers

Most renowned consumer product companies like COCA-COLA, UNILEVER, PEPSICO, EVIAN, WALMART, and many others in the world have set ambitious targets for incorporating recycled plastic into their packages and therefore, to replace virgin resins with recycled once by 2025.

Table 2.5: Recycling Targets by Renowned Consumer Companies

Name of Company	Targets
Proctor & Gamble (P& G)	P&G invented the solvent process for Polypropylene (PP) purification and used it by applying Pure Cycle Technology in various plants located in different parts of the world. The company has targeted to recycle 50% of plastic waste by 2025.
PEPSICO	PEPSICO has started converting all Pepsi-branded products in the US to 100% recycled PET by 2030 while 50% recycled plastic by 2030 across the world.
COCACOLA	COCA-COLA has started rolling out 100% recycled bottles in the US in 2021and 50% Recycled Plastic from a global perspective by 2030.
DANONE	DANONE launched 100% recycled Evian bottles in Europe in 2020 and 50% Recycled Plastic by 2025 in the world.
NESTLE	Nestle is highly motivated and committed to spending $1.6 billion to pay premiums for recycled plastic and aimed to recycle 50% of plastic waste by 2025.
KEURIG DR PEPPER	KEURIG DR PEPPER finished converting K-Cups to recyclable polypropylene in late 2020 and is targeted on recycling 25% of plastic waste by 2025.

Adapted from Research and Markets, 2022

2.8.2 Chemical Companies

The global leading chemical companies engaged in manufacturing raw materials for producing plastic products are taking initiatives across the whole plastic value chain to improve the quality of recycled plastics as well as address sorting challenges.

Table 2.6: Initiatives taken by chemical companies for attaining quality recycled plastics

		Making the Plastic Recyclable		Collection, Sorting & Transportation		Recycling
	Plastic compounding	Growing focus across the world to develop additives and masterbatches to improve rPET recyclability, color, odor, and appearance. NIR detectable black pigment is growing as a dispersion filler to improve the recyclability of HDPE/LDPE plastics	Major challenge: sorting the feedstock	Dissimilar packaging design & colors make the sorting task complex and expensive. Due to sorting issues, countries lose 20-30% of the feedstock. More than 50% of waste material in the EU, is not used for recycling but rather used for energy recovery and landfill	The dominance of mechanical recycling	As of 2021, more than 90% of plastic wastes are recycled through mechanical recycling across the world. Mechanical recycling cannot tackle contamination and high varieties in the plastic waste stream
Company Name & Initiative		**AVIENT**		**VEOLIA**		**BASF**
	Initiative	To reduce yellowing by 50% during the mechanical recycling process AVENT has launched a low-haze, non-polyamide-based oxygen scavenger	Initiative	VEOLIA is using artificial intelligence (AI) robot equipped with a camera vision system to remove nonferrous waste	Initiative	To address limited processability, poor long-term thermal stability, and insufficient protection from weathering for mechanically recycled polymers BASF has successfully launched Irga Cycle additives.
		BRITEC		**TREBO**		**EASTMAN**
	Initiative	To maintain physical properties e.g., Izod impact strength and flexural modulus of regrinds and recycled resins BRITEC has developed BTec REA360 Regrind Enhancing Additive.	Initiative	TREBO has developed a sorting machine that uses fluid mechanics to sort plastic mix by density, shape, and size	Initiative	EASTMAN is planning to build a $250 million polyethylene terephthalate (PET) depolymerization (Metahnolysis) plant at its Kingsport, Tennessee, complex by the end of 2022.

Adapted from Research and Markets, 2022

2.8.3 Innovative Plastic Recycling Companies in the World (Lacy et al., 2020)

TOMRA

TOMRA Sorting Solutions is the leader in the resource revolution with sensor-based recycling solutions which help customers become even more sustainable while also improving their bottom line. With a wide range of products specifically engineered for the plastic recycling, this unique technology simultaneously detects and sorts plastic fractions by color and material types, resulting in higher quality and more valuable yields. Flying beam technology enables to detection and sort plastic fractions by color and material types.

Banyan Nation

They have developed a revolutionary technology highly capable of converting collected post-consumer and postindustrial plastic wastes into high-quality recycled granules which can widely be used to make numerous value-added goods, known as Better Plastic™.

Perpetual

They developed and brought to market a sustainable and cost-effective technological process that modifies post-consumer PET bottles into high-quality, sustainable polyester used to make various types of value-added products such as new bottles, packaging film, and textiles. This ester can directly replace other types of esters that have a higher carbon footprint.

Green Toys

Green Toys is a California, USA-based company that makes toys by using 100% recycled plastic waste originating from milk jugs, yogurt cups, etc. complying with environmental and safety laws. From ideation to implementation, they build toys with purpose which enables open play, imagination, and creativity, and encourage child development. Unique and innovative ideas and technology enable to be sustainability in the market.

Loop Industries (In Partnership with Evian)

Loop Industries has developed and launched a high-end technological solution that enables the creation of superior-quality plastic resin for Evian's bottles without making any more plastic by using a catalyst that can separate PET Plastic into its individual monomers without any heat or pressure. And these monomers can then be remolded & reshaped into plastic resin and can subsequently filter out impurities, creating PET plastic resynthesis similar to the virginal scale. Innovative technology to produce virgin quality PET resin from PET Bottle wastes.

ByFusion

ByFusion is a USA-based company that recycles unrecyclable mixed plastic wastes to produce building and construction materials without any chemicals, additives, adhesives, or fillers and thus protects the planet, oceans, waterways, and wildlife. The world's first technology enables to make building materials made entirely of 100% recycled plastic waste.

Bureo

Bureo's 'Netplus' materials such as sunglasses, board games, skateboards, thread, etc., made from discarded fishing nets, are being incorporated into the supply chains of industry-leading businesses such as Patagonia, and in the 'Untangled Collection' of Costa sunglasses. In doing so, over 185,000kg of Netplus materials have been collected across participating Chilean coastal communities since 2013. Recycling of waste plastic fishing nets to make value-added products

2.9 Overview of Plastic Recycling in Bangladesh

In Bangladesh, about 80% of plastic products are presently manufactured from virgin plastic resins. In 2017, about 1.3 million MT of virgin resins were used to produce various types of plastic products. Nearly 100 percent of waste from the plastic production process and also post-use plastic waste are being used as a source of raw materials for many plastic industries in Bangladesh (BPGMEA, 2019). A plastic sub-sector has gradually been developing mainly in Dhaka City which supplies about 20% of the required raw materials for plastic industries in Bangladesh in recent times although 70% of the post-use plastic waste was recycled in 2017 and the rest 50% of post-use plastic waste was used to produce various low- graded products (BPGMEA 2 019). Despite having advanced plastic recycling technology, recycling-infrastructure, and strict rules, developed countries have recycling rates of around 30% only (Woldemar d'Ambrieres, 2019).

On the contrary, in Bangladesh, plastic waste recycling rates are around 70% (BPGMEA, 2019) which is more than double of global average rate but could not add any value as those recycled plastic wastes were used to yield substandard products.

Henceforth, if Bangladesh can develop a practicable plastics recycling industry, more plastic waste can be diverted from incineration/landfills, and instead, produce numerous value-added new products as well as replace more virgin plastic raw materials for production. Because of inferior feedstock quality and with lack of modern recycling technology and waste infrastructure, the plastic recycling industry in Bangladesh is exceedingly contaminating its prevailing stand and thus throws away the opportunities to extract ultimate benefits.

A report published by McKinsey in 2018 projects that around 60% of plastic claims across the world could be covered by production based on formerly used plastic by 2050 (McKinsey, 2019). On the contrary, estimates of the growth of the recycled plastics industry range from 5-7%, compared to below 4% for the overall plastics industry, based on various market reports (WEF, 2017).

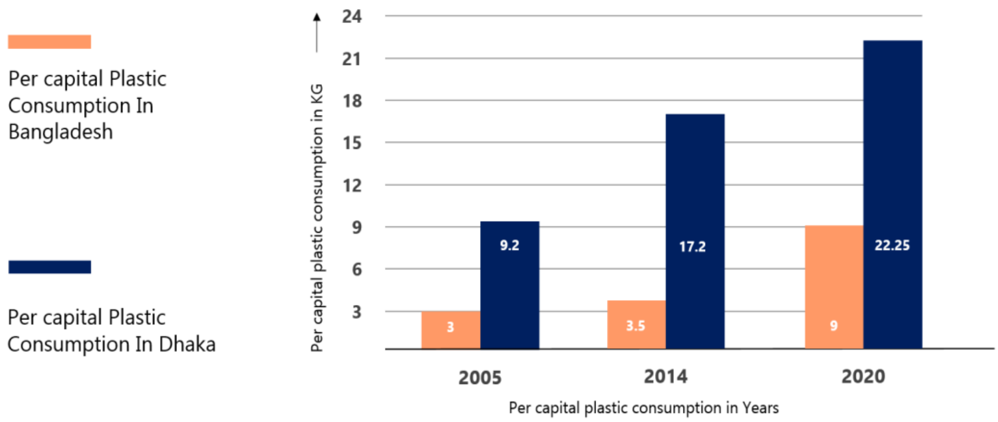
At the same time, a study in Bangladesh projects that the plastic recycled industry will raise by more than 10%/year in 2018-2019 (BPGMEA, 2019) which is higher than the global percentage (World Bank, 2018) and the existing production capacity of plastics resins only furnishes up to 20% of overall plastic raw materials demand; with the remaining 80% imported from various countries (BPGMEA, 2020, Delta Membranes, 2020).

Therefore, acceptance of the bright prospect of recycled plastics in Bangladesh would put this potential sector in a solid stage to achieve economic gain and environmental sustainability.

2.9.1 Per Capita Plastic Consumption in Bangladesh

Rapid urbanization and development have led to increasing per capita consumption of plastic goods and plastic waste generation. Per capita consumption of plastic was 3.0 Kg/year of the whole country in 2005 and in Dhaka city, it was 9.2 Kg/year (Enayetullah et al.,2005) and increased to 3.5 Kg/year in 2014, and in Dhaka, it was 17.2 Kg/year (Waste Concern, 2015). On the other hand, the annual per capita plastic consumption in Dhaka in 2020 was 22.50 Kg and in Bangladesh, it was 9.0 Kg (World Bank, 2020).

Figure 2.4: Per Capita Plastic Consumption, 2005, 2015 & 2020

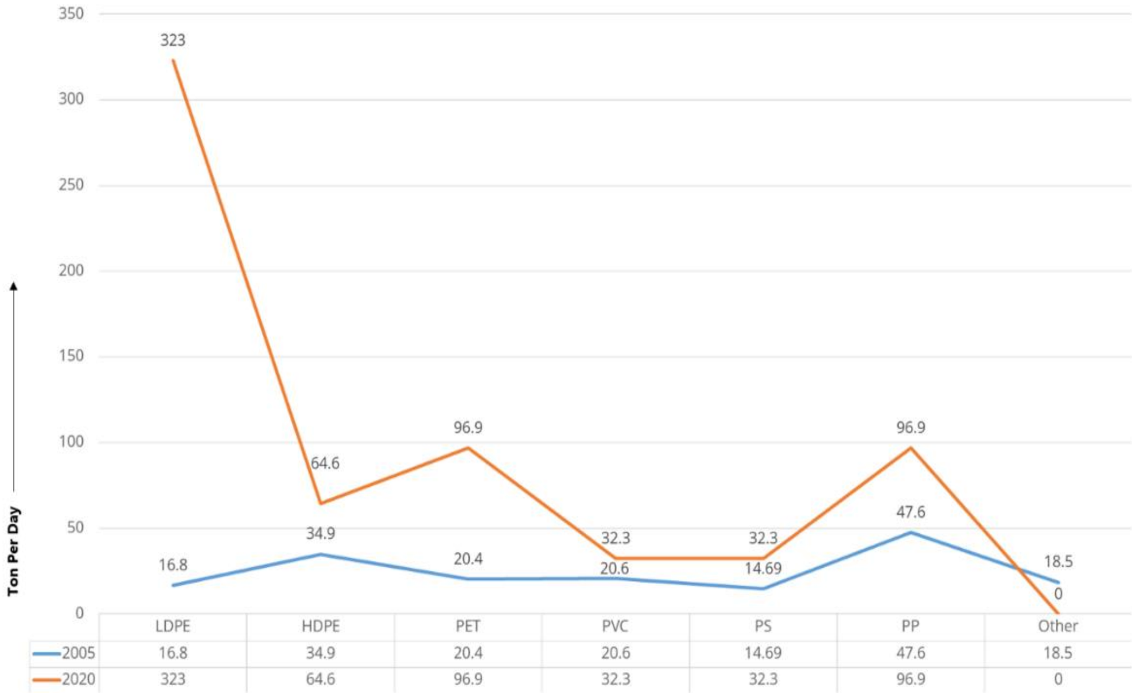


Source: Enayetullah et al.,2005, Waste Concern, 2015 and World Bank,2021.

2.9.2 Household Plastic Waste Composition

Households generated almost nine times as much LDPE in 2020 (323 MT/day) as they had in 2005 (16.8 MT/day. With the increase of fivefold in 2020, the amount of PET waste generated was 20.4 MT/day. Analysis from the field survey of the World Bank in 2020 also revealed that LDPE packaging materials accounted for 10 percent of plastic waste in 2005 which has increased to 50% by 2020. The amount of PP increased from 27% in 2005 to 15% in 2020. Finally, the proportion of HDPE increased in 2020 because of the increase in the use of various types of consumer products such as bottles, tubes, boxes for food and non-food items, toys, etc. that required HDPE bottles for packaging.

Figure 2.5: Household Plastic Consumption



	LDPE	HDPE	PET	PVC	PS	PP	Other
2005	16.8	34.9	20.4	20.6	14.69	47.6	18.5
2020	323	64.6	96.9	32.3	32.3	96.9	0

Source: Waste Concern, 2005 and World Bank, 2021

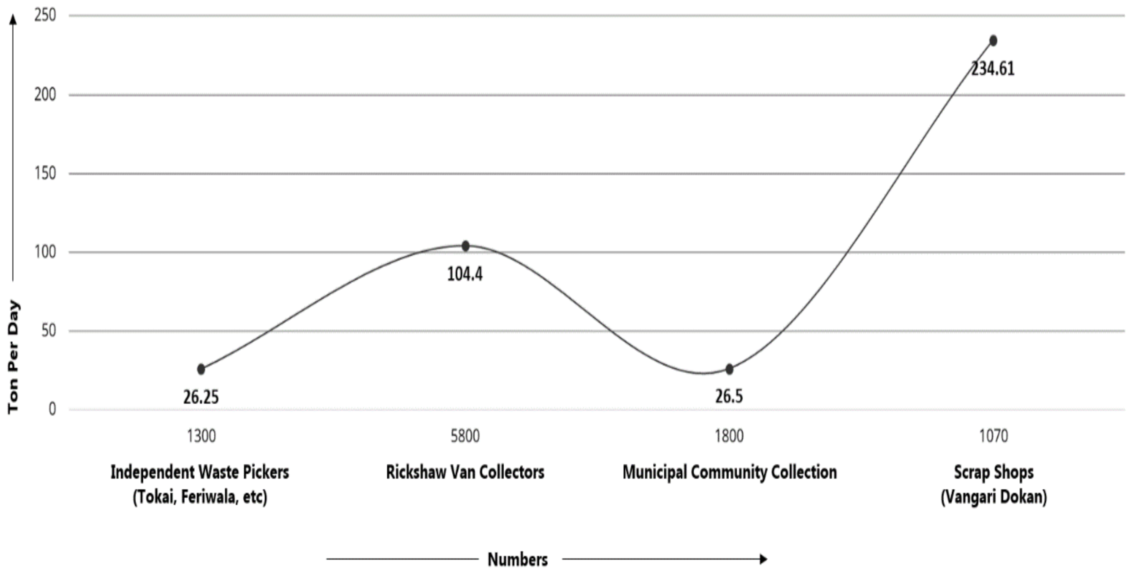
2.9.3 Collection of plastic waste by different actors

Independent collectors (popularly known as TOKAI), rickshaw and van waste collectors, and Municipal crews collect semi-soiled and soiled plastic waste. Feriwallas mainly collect unsoiled plastic waste. Scrap Shops (Vangari dokans) purchase clean, semi-soiled, and soiled plastic waste. There are some 1300 feriwallas working in Dhaka who buy 26.5 MT/day of clean waste from households. There are around 1,800 DCC crews who collect 26.5 MT/day.

Approximately 5,800 rickshaw and van collectors in both city corporations collect 104.4 MT/day of semi-soiled waste from houses. DCC crews and waste pickers in dump sites recover plastic and sell it to junk shops.

There are 1,070 Scrap Shops (popularly known as vangari dokans) in Dhaka that purchase 234.61 MT/day of plastic waste from feriwallas, rickshaw, and van collectors, DCC crews, tokais, and sell it to wholesalers, who resell it to re-processors. There are 737 wholesalers in Dhaka.

Figure 2.6: Collection of plastic waste by different actors

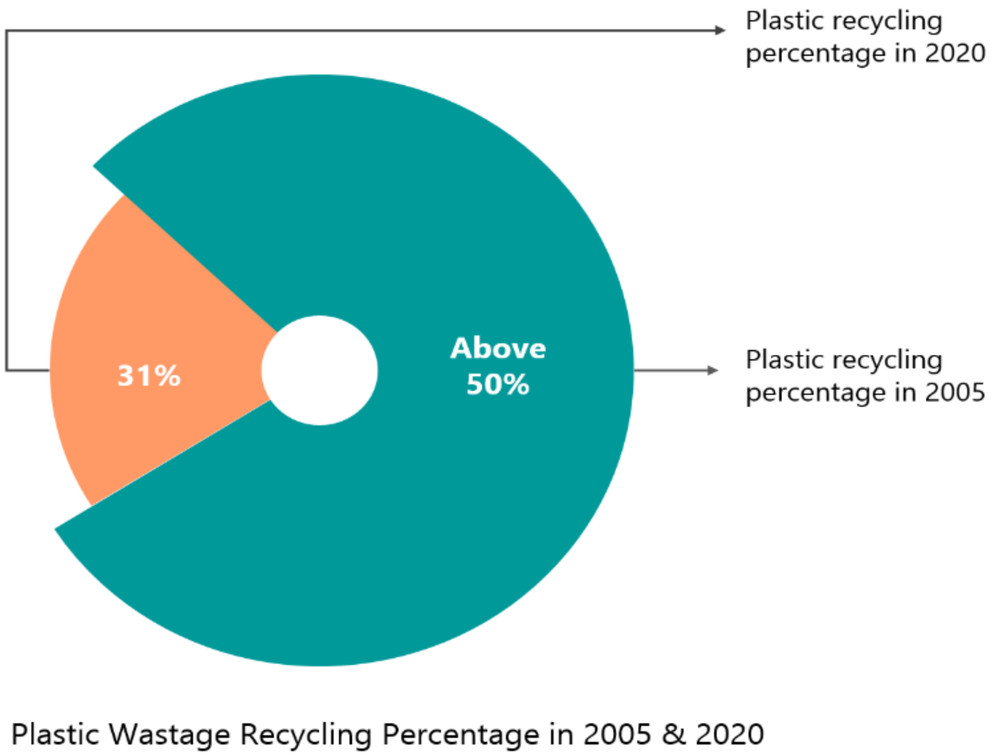


Source: World Bank, 2021

2.9.4 Waste Recycling Percentage in 2005 and 2020

In Bangladesh, the overall recycling percentage was more than 50% (Waste Concern, 2005), and with the passing of time, the trend has been declining at a faster pace which was 31% in 2020 (World Bank, 2020) though still, it is higher than the global average (more than 9%).

Figure 2.7: Plastic waste recycling percentage in 2005 & 2020



Source: Waste Concern, 2005 & World Bank, 2021

2.9.5 Why is Plastic Circularity needed in Bangladesh?

Plastics are indispensable components of the circular economy because of their durability, resource and energy efficiency, and recyclability which ease the circularity of products and climate neutral society. Plastics are also playing an important role in the journey towards a sustainable and climate-neutral future, e.g., in electric cars, wind power stations, and energy-efficient homes. The circular and climate-neutral plastics economy is defined as a system in which plastics are produced, converted, used, and managed sustainably. This means fostering the use of circular feedstocks, creating eco-designed products to increase recycled content, facilitating reuse and repair, and managing plastic waste to convert it into new resources to reduce fossil-based feedstock (PlasticsEurope. (2019).

The shift towards a circular and climate-neutral plastics economy for plastics has already started. Countries around the world are striving to enable a circular and climate-neutral economy for plastics and prevent plastics waste from ending up in the environment. To accomplish this cooperative determination, collection, sorting, and recycling technologies need to be enhanced to obtain higher quality and quantities of recycled plastics, which will facilitate a circular economy for plastics (Calleja, D.,2019). Thus, the plastic industry is leading the way in this transition, from improved product designs that enable reuse and recycling, to innovation in new technologies. Emerging technologies also create the prospect of recycling mixed and contaminated plastic waste streams that cannot be processed before by mechanical recycling, opening up new possibilities for the plastic circular economy.

Likewise, global trend, the plastic sector is developing rapidly in Bangladesh and it has become one of the remarkable sectors in Bangladesh. Bangladesh consumed approximately 1.5 million tons of plastic polymer in 2017 and the consumption has been rapidly increasing. This ever-rising trend in plastic consumption in Bangladesh leads to plastic waste that needs proper reprocessing to achieve economic gain and environmental sustainability (Ijaz, 2019).

Over the last few decades, the increased use of plastics has accompanied Bangladesh's fast economic growth. With increasing industrialization, urbanization, and a rising middle class, the demand for plastic products has grown rapidly in consumer packaging, construction, household goods, and industries because of their convenience, durability, and versatility. The contribution of plastic to the total GDP of the country is 1.0% and per capita plastic consumption in the financial year, 2016/17 is 6 KG (Serajul & Mahmudul, 2019). Considering the impacts of the Plastic Sector on Bangladesh's GDP growth, this sector should initiate to rethink of the sustainable plastic business. Applying the circular economy principles, the initiative brings together key stakeholders to rethink and redesign the prospect and future possibilities of plastics with a clear vision (Serajul & Mahmudul, 2018).

As stated earlier, renowned consumer product manufacturers, garments buyers, brand owners, and chemical companies across the world are incessantly doing research and development from their respective ends to improve prevailing plastic recycling activities aiming to transform into a plastic circular economy which eventually helps achieve potential market growth. They have set ambitious targets for incorporating recycled plastic into their packages. Garments renowned buyers of renowned brands are pushing suppliers to add recycling content into their packages. Since Bangladesh is an integral part of the global village and its major export earnings generated from garments cannot ignore it. The prevailing recycling infrastructure cannot provide quality recyclates to meet the ultimate requirements of buyers since it produces substandard recyclates and finished products though the recycling aggregate percentage (31%, according to the World Bank, 2020) of Bangladesh is higher than the global average (9%).

To continue building on this potential, current challenges around plastic product design, collection, sorting, and end-of-life management (recycling, energy recovery, landfilling), must be addressed. A lack of appropriate waste management infrastructure, policy incentives, and business models means that the full value of plastic waste is currently not being captured. Plastic waste that is not disposed of correctly most often ends up in the environment, with unacceptable consequences. Plastic waste sent to landfill for energy recovery must be kept as a resource in the circular economy.

The circular and climate-neutral plastics economy redefines existing production and consumption patterns that support positive economic, social, and environmental benefits throughout supply chains, business models, and life cycles, from the choice of raw materials and technology, design of products/services, to recycling and end-of-life (Robertson, D. 2019). Therefore, effective resource management in a circular economy could create jobs and private investors could save money as a result of the lowered costs of raw materials and the promotion of employment and innovation. This presents an opportunity to rebuild using more sustainable models, create green and resilient livelihoods, and advance technology innovation. Technology innovation can help businesses, governments, and communities transition to an inclusive circular economy faster and more efficiently.

Chapter Summary

This chapter started with the basic concept and terminologies of plastic and plastic waste recycling and presented the exciting growth potential of plastic waste recycling on a circular economy notion. This chapter has exemplified that renowned Consumer Product Manufacturers and Chemical Companies across the world are incessantly doing research and development for the development of the plastic recycling industry. This perspective helps to emerge innovative recycling companies in the world and some names of such innovative companies have been mentioned in this chapter. Finally, an overview of plastic waste recycling in Bangladesh has been incorporated into this chapter.

CHAPTER 3: LITERATURE REVIEW

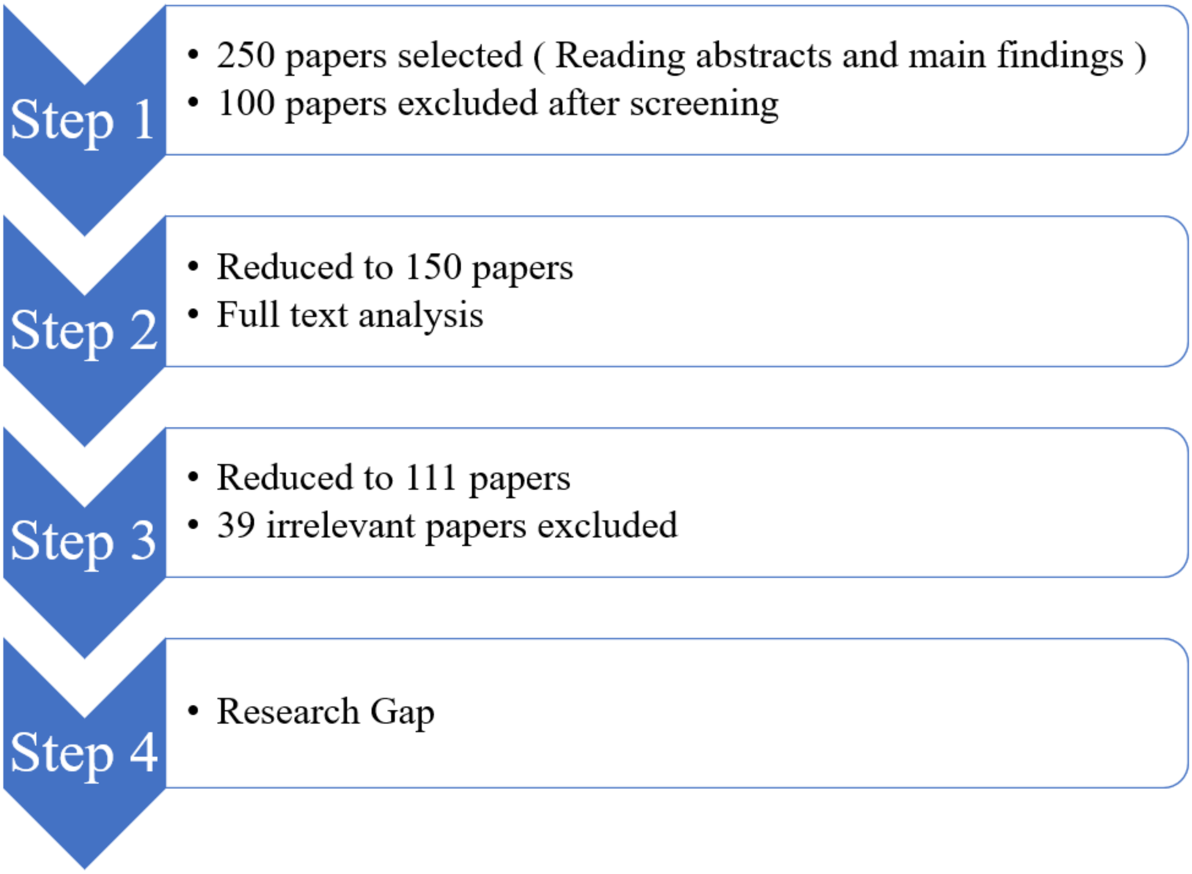
CHAPTER CONTENTS

This chapter provides a comprehensive review of available literature related to the study topic to find out research gap and to form conceptual framework

CHAPTER 3: LITERATURE REVIEW

This chapter provides a comprehensive review of available literature related to the study topic where studies related to plastic and plastic waste recycling have been reviewed meticulously and have been incorporated in this study as a major source of qualitative data. In any field of research, the literature review is basically a stock-taking of available literature. While conducting the study, previously available studies haven't been ignored as those would help to check up on the changes, alterations, modifications, or replication in the present study. Thus, one can find what studies have been conducted, what can be replicated, what can be modified, and what remains to go. The study has considered a review of previous studies in a similar field of study. In this consideration, 250 papers have initially been identified from various sources depicted in the below Figure (3.1).

Figure 3.1: Overview of Literature Review



Adapted from Johansen et al. (2022)

The papers were then screened for duplicates and irrelevance. The relevance of the papers was judged based on the following inclusion criteria: 1) plastic recycling value chain; 2) primarily post-consumer and post-industrial plastic or plastic in general; 3) plastic in the circular economy 4) plastic recycling technology. These papers were further screened meticulously for relevance to the study topic reading abstracts and main findings, which reduced the number of relevant studies to 150. Subsequently, all these 150 relevant studies have been analyzed through full-text readings that further decreased the numbers to 111 relevant studies. The papers have been excluded from the analysis since the papers did not meet the overall inclusion criteria described above.

It is noteworthy mentionable that the study has mostly reviewed literature from different countries rather than Bangladesh as there are a few studies carried out in the same field according to this study and other countries' references will contribute significantly to the study as those studies are contemporary considering the circular economy.

3.1 Studies on Global Perspective

3.1.1 Growth Estimations of Plastics and Recycled Plastics Market in Global Context

According to a recent study conducted by Grand View Research (2022), the demand for plastic is increasing at a faster pace and the global market for plastics was valued at USD 593.00 billion in 2021 and the market size is anticipated to reach USD 811.57 billion by 2030; the market is projected to advance at a CAGR of 3.7% between 2022 and 2030.

A study conducted by PEMRG in 2020 that plastic production and consumption are mounting year by year. In 2019, global plastics production almost reached 370 million MTs and, plastics production almost reached 58 million MTs in Europe.

BCC Research explored that the global market for recycled plastics is projected to grow from $28.7 billion in 2022 to $37.3 billion by 2027 with a compound annual growth rate (CAGR) of 5.3% for the period 2022 to 2027. Newest information on major market dynamics, technology advancements, industry structure, government regulations, and other macroeconomic factors affecting the overall plastics industry. Trends and opportunities of emerging technology, and gaps estimating current and future demand for recycled plastics (BCC Research,2022).

A recent study conducted by Research & Market (2022) has revealed that the global recycled plastics market is expected to grow from $ 27.9 billion in 2021 to $ 43.5 billion by 2026, at a Compound Annual Growth rate (CAGR) of 9.3 percent from 2021 to 2026. Favorable initiatives to promote the use of recycled plastics in developed countries, growing acceptance of recycled plastics consumption in developing countries, and cost-effective, sophisticated recycling technologies are the key factors that drive the global recycled plastics market more than ever before.

“Recycled plastics for the market are expected to grow by $ 14.74 billion from 2020 to 2024. The market growth rate will accelerate at a Compound Annual Growth rate (CAGR) of almost 7 percent. The year-over-year growth rate for 2020 is estimated at 5.7 percent 2020. 56 percent of growth will originate from APAC” (Technavio,2020).

“It expects the recycled plastics market to grow globally at a compound annual rate of 6.8 percent, reaching a value of $66.73 billion by 2025 where most recycled plastic materials come from Post-industrial waste and post-consumer waste sources” (Clare Goldsberry, 2020).

In line with the economic growth of plastics, Europe processes approximately 50 MT/year with an annual growth rate of 2 % between 2012 and 2016, and the demand for recycled plastic grew significantly faster over the same period by 17 percent (KPMG 2019).

The share of successfully recycled plastic waste is projected to rise to 17% in 2060 from 9% in 2019 globally while landfilling incineration will continue to account for around 50% and 20% of plastic waste respectively. The share of plastic waste ending up instead in uncontrolled dumpsites, incineration or leaking into soil or water bodies is projected fall to 15% from 22%. (OECD, 2022)

3.1.2 The Plastic Value Chain from a Circular Economy Perspective

The circular plastic economy is a feasible substitute to the prevailing linear economy, wherein the plastic is manufactured, used, and disposed of, targeting to growth of plastic that is reused or recycled, and inject into the system (Calleja, 2019; European Commission, 2020).

Though the principle of circular economy is gaining attention globally, only 30% of plastic waste is collected for recycling in Europe, and most of the waste is downcycled and yielded a lower value than materials that are attributed to the original product. The transformation percent toward attaining a circular economy is slower than expected (Calleja, 2019).

According to Dijkstra et al. (2020), the linear flow of plastic through the value chain is one of the primary sources of CO_2 emissions and environmental pollution. A notable percentage of plastic is used only once in products and packaging, with only a limited amount being reused or recycled.

The transition toward a circular economy from the prevailing linear economy cannot be attained exclusively through changes within the waste-handling system but through a full combination of changes in the other parts of the whole value chain including the design, the production, and the use phases. The whole value chain of plastics must be studied to examine how to design, produce, use, and recycle waste plastic within the circular economy. Tending to focus on the 'end-of-life' phase, aimed at improving recycling and recovery of plastic waste (Nielsen et al., 2020).

The Plastic Circular Economy is gaining momentum at all levels across the world. Learning from the negative consequences of the prevailing linear plastic value chain and "throw-away" culture, the plastic circular economy is gaining attention to the world. Governments, policymakers, businesses, academics, organizations, and international associations across the world are incessantly formulating strategies for a desired transition to the circular economy, aiming amplified reuse and recycling of plastic waste (Ellen MacArthur Foundation, 2020; European Commission, 2020).

The down-cycling of plastic in the economy is caused by contamination with organic and inorganic substances. Because of the contamination with organic and inorganic substances, and product designs that combine various multi-layered polymer types and thereby inhibit and complicate technical and economically feasible pathways for plastic waste recycling (Dahlbo et al., 2018, M. T. Brouwer et al., 2018).

Post-consumer plastic waste characteristically contains a diverse mix of various polymer types and additives. Single-use plastic packaging materials are the major challenge for recycling because these often generate from short-lifespan products (e.g., Gasde et al., 2021; Kranzinger et al., 2018, Meys et al., 2020).

The cause of multi-layered mixed polymers in plastic recycling is not only sorting and recycling processes but also the initial design of plastic products and packaging. Since post-consumer plastics are often designed with various polymers making recycling functions problematic from a technical perspective as well as an economic perspective (M. T. Brouwer et al.,2018).

The plastic circular economy will not be attained, not only through recycling but also through design, use, and legislation. To ensure and optimize recycling owing to the homogeneity of plastic waste, it is not only crucial to have the right recycling facility but also to design, produce, use, and dispose of the materials so that closed-loop recycling will be ensured. Without proper design, use, and legislation circular plastic economy are impossible (Bucknall, 2020, Eriksen et al., 2020, Nielsen et al., 2020).

3.1.3 Phases of the Plastic Recycling Value Chain

A solid foundation for better business decisions and policymaking can be done through a detailed overview of material flow, and environmental, economic, and social impact. (Reinales et al., 2020; Vingwe et al., 2020). According to Milios et al. (2018), implication opportunities of plastic recycling can be established through better communication between value-chain phases and stakeholders. According to Eriksen et al. (2020), changes in plastic design, demand, and collection have a significant impact on the possibilities of end-of-life for plastic to recycle plastic into new products. This indicates that a holistic value-chain approach is necessary to ensure an effective transformation of the current linear plastic value chain.

3.1.3.1 Design Phase

Design is the primary value-chain phase of plastic waste recycling. In this phase, the role and qualities of the product are decided such as color, recyclability, polymer mix etc. Careful attention must be given to the design phase of the value chain. (Iacovidou et al., 2019).

It is hard to use recycled plastic granules in making new products due to the contamination of polymer types, that may affect characteristics such as durability, toxicity, and weight. Contamination within the plastics must be reduced to get hassle-free recycling functions (Civancik-Uslu et al., 2019; Foschi et al., 2020; Gall et al., 2020 and Iacovidou et al., 2019; Masmoudi et al., 2020).

Most of the challenges in plastic waste recycling can be overcome by incorporating the whole value chain of plastics into the design of new products and thus production, consumption, and recyclability of plastic waste will be ensured. (Civancik-Uslu et al., 2019, chi et al., 2020).

During designing out plastic waste, a number of principles need to be followed to ensure the recyclability of products that include:

- reducing resource loops by designing & making long-life goods and product-life extension
- closing resource loops through recycling
- design for sustainable sourcing
- design for optimized resource use
- design for environmentally sound with safe product use
- design for extended product use
- design for recycling (Bocken et al., 2016; le Blevennec et al., 2018 and Johansen et al.2022).

3.1.3.2 Production Phase

The production phase covers multiple production steps that usually include the sorting, melting and moulding process of primary plastics at high temperatures to produce plastic polymer into diverse plastic products (Getor et al., 2020).

Plastic products can typically be manufactured through extrusion, moulding, or blowing using an input virgin material made from crude oil or secondary raw materials recovered from plastic waste where the input is usually in the form of pellets, flakes, or profiles depending on the type of product produced and generally involves shaping the plastic intermediates (Vieitez et al.,2011).

Plastic waste is mostly composed of different polymer types and is contaminated with non-plastic materials, such as additives cause a range of complications such as lumps of undispersed crystalline plastic, which reduce the value of the final product. Classifying polymer type and other adulterations is also a major challenge and there is no solution to this dilemma currently available, which implies that solutions must be found in other phases of the value chain. If plastic products are designed with mixed and/or contaminated polymers in the waste collection and sorting yielding the waste stream becomes contaminated, and the properties of the recycled plastic will be affected (Curtzwiler et al., 2019 and Getor et al., 2020).

The circular production of plastic goods is not only concerned with recycled plastic but also examines the possibility of using Nano-composites in the plastic mixture to accommodate the transition to circular; however, due to a lack of research in the field, it is not yet possible to conclude whether the introduction of Nano-composites will make recycling easier (Sarfraz et al. 2021).

3.1.3.3 Use Phase

The third phase of the value chain is consumption, addressing the demand, use, and disposal of plastic products that address purchase and demand (Boesen et al., 2019).

Consumers must be informed appropriately about the environmental issues of the products. It is also true that 69% of consumers worry about the impact of plastic on the natural environment, illustrating a general awareness of plastic pollution. When purchasing products, consumers are influenced by knowledge, habits, beliefs, and social norms. These impact consumer demand for plastic products taking a more holistic approach to the use phase of the plastic recycling value chain. Therefore, the users are the highest priority when it comes to designing new products and increasing recycling rates. Due to the consumer’s role in both creating demand

for and sorting the plastic after use, the behavioral transition is crucial to the success of the circular economy (Núnez-Cacho et al. and Clark et al. 2020).
Due to the customers’ role in both creating demand for recycling and sorting plastic waste after use, the behavioral transition is crucial to the success of the circular economy. Consumers play a key role in establishing a circular economy (Sarfraz et al. 2021, Getor et al., 2020 and Curtzwileret al. 2019).

3.1.3.3 End-of-life Phase

The last and the most important phase of plastic recycling value chain is End-of-life Phase. It comprises the following categories:

- collection and sorting
- recycling technologies (mechanical, chemical, biological)
- lifecycle assessment (LCA) and mass flow analysis (MFA) (of the end-of-life phase);
- Policy and regulation (Bucknall, 2020, Eriksen et al., 2019).

3.1.3.4 Collection and Sorting

“One-bin-to-rule-them-all” system could increase the rate of collection, and reduce the post-use leakage of plastic waste into the environment. However, the system would require infrastructure that supports the transition to circular with the incorporation of mechanical, and chemical recycling technologies; recyclable product design; and sorting systems to attain desired efficiency. (Burgess et al. 2021)
An inclusive approach is highly suggested to plastic design and waste management for improving plastic waste collection where a separate waste-collection system would allow improved communication with the consumer, eventually making it easier to manage plastic waste (Kranzinger et al. 2017. Tallentire and Steubing 2020).
It is easier to sort plastic waste according to polymer types by applying a tracer-based sorting system and, therefore would yield less contamination with the combination of marking into the design and production process (Gasde et al., 2021).
The capacity to execute manual sorting is highly dependent on the actual objective (positive/negative sorting) and the sorting accuracy as well as the type of material being separated. For example, by sorting plastic beverage bottles one person is able to sort out approx. 50 kg/hour and sorting heavier plastic containers one person might separate as much as 200 kg/hour (IUT, 2012).
In many cases, manual control of the quality of mechanical/optically sorted recyclable materials is, however, still widely used to ensure sufficient purity than NIR infrared separation

equipment and other types of sensor-based separation equipment, e.g., between 96 and 99% requirement in different countries – purity depending on material type. Sometimes manual sorting yields better purity than NIR infrared or other sensor-based separation (ARA system, 2022).

3.1.3.5 Recycling Technologies

"A combination of mechanical and chemical recycling is a part of the transition to a circular economy from the prevailing linear economy provided mechanical recycling is the main recycling technology. Mechanical recycling is the preferred option" (Schyns and Shaver, 2021).

In mechanical recycling, both problems and opportunities are identified. Packaging and municipal plastic waste are good sources of plastic for recycling, but mechanical recycling is hindered by contaminated waste streams, which, in turn, can affect the properties of recycled plastic. Multiple strategies to overcome these challenges, including wet mechanical recycling and upstream washing processes, using recycled plastic in the production of new products and packaging are either mixing the recycled plastic with virgin plastic or, as to mix nano-additives. The challenges in mechanical recycling can be overcome by applying multiple strategies such as upstream washing, mixing with virgin plastic, etc. (Avolio et al., 2019; Dahlbo et al., 2018; Eriksen et al., 2019; Mollnitz ¨ et al., 2021, Kranzinger et al., 2018, Lopez ´ de Dicastillo et al.2020 and Schyns and Shaver 2021).

Chemical recycling is preferred when mechanical recycling does not yield the desired level, especially in cases of multilayer packaging and composite plastics. Chemical recycling technology is capable to increase overall recycling rates, despite a series of identified technical difficulties associated with the technology. For multilayer packaging and composite waste chemical recycling is the best option to be adopted (Dunkle et al., 2021; Qureshi et al., 2020, Mumladze et al., 2018).

In chemical recycling contamination and the mixture of several polymers may have a negative impact on the recycled plastic where sorting and cleaning are seen as an important part of most recycling processes. Depending on the type of polymer and the respective chemical process, the recycled material may retain its properties; chemical recycling is, therefore, recommended by some experts as the best solution concerning plastic-waste mismanagement (Mark et al., 2020, Vollmer et al., 2020, Mumladze et al., 2018; Santagata et al., 2020 and Tournier et al., 2020).

To enhance the performance of subsequent equipment installed size separation equipment is widely used in sorting facilities. Waste plastics normally appear in the middle size and oversize fractions. Middle size normally sorts further in a ballistic separator and maybe also an air classifier and the oversize fraction normally continues into a manual sorting cabin for handpicking of the large plastic (Alstrup, Thomas 2012).

Separation and removal of impurities from different plastic materials can be achieved by gravity/density sorting with the following range of different technologies: **Float sink method:** Density sorting of different plastic materials can be separated from each other through a fluid medium resulting in a purity of up to 98 % for mixed plastics and this technology can also be applied to separate plastic from heavier materials. **Hydro-cyclones:** Density sorting based on the centripetal force to fluid resistance by feeding waste into the hydro cyclones in a suspension. Lighter fractions transport upwards, whereas more dense particles will end in the bottom of the cyclone. Reduction of size is normally done before treatment in hydro cyclones (COWI, 2013).

The optic sensor equipment separates various types of materials like paper, cardboard, wood, glass, electric scrap, minerals as well as individual plastic polymers (as PE (LLDPE, MLLDPE, LDPE, HDPE), PP, PVC, PET, EPS, and ABS) and colors. Because of non-reflection characteristics, black items can normally not be separated (Bilitewski, B. 2011).

Biological recycling has prospects and opportunities but must be further developed to make a viable contribution considering the circular economy principle (Papadopoulou et al. 2019).

3.1.3.6 Lifecycle Assessment (LCA) and Mass Flow Analysis (MFA)

Considering the LCA of different recycling technologies and the environmental impact, mechanical recycling has the lowest environmental and financial impact but, if most plastic is to be recycled, and a mix of mechanical and chemical recycling are necessary where mechanical recycling of plastic can contribute to the reduction of GHG emissions. However, both mechanical and chemical recycling is necessary for LCA (Faraca and Astrup 2019 and Van Eygen et al. 2018).

The quality and performance of recycling technologies depend on polymer type and mix. Polymers of poor-quality and mixed plastics are managed properly with chemical recycling technologies, whereas closed-loop mechanical recycling, sorting, and collection must also be improved. Inferior and mixed plastic wastes are better managed by chemical recycling (Horodytska et al., 2020 and Schwarz et al., 2021).

It is necessary to improve both collections and sorting to ensure the availability of larger amounts of plastic waste for recycling in order to increase the recycling rates as well as the quality of the recycled plastics (M. T. Brouwer et al., 2018; Hahladakis and Iacovidou, 2018; Horodytska et al., 2020 and van Eygen et al., 2018a).

Most of the waste plastic collected for recycling is colored plastic especially the packaging originating from products with a short lifespan which affects recyclability. Color plastic waste affects recyclability (Faraca and Astrup 2019).

3.1.3.7 Regulation & Legislation

In relation to the end-of-life phase of the plastic recycling value chain, regulation and legislation are the fourth and last categories. Due to different rates of economic growth and waste generation rates variations in managing waste management also varies among countries across the world hence investing in recycling technologies. Government policies must facilitate investment in the transition to a circular economy from the prevailing linear economy and economically encourage and support private investors where pragmatic policy and investment support will be an important part of ensuring that hazardous chemicals in plastic are designed out of new plastic products (Robaina et al. 2020 Wagner and Schlummer, 2020).

Regulation and legislation in relation to sorting, collection, and recycling must be imposed at government levels as a solution to overcome the challenges of plastic waste recycling. Strong regulation and legislation yield desired level of output (Bishop et al., 2020; Horodytska et al., 2020).

The then US Plastic Society introduced a system of Resin Identification Codes (RIC) in 1988 and commoners across the world are being familiar with the symbols, although not essentially identify the meanings behind them. It has been administered by the American Society for Testing and Materials (ASTM) since 2008. However, the symbols were changed in 2013, from cycling clockwise arrows (called as Mobius loop) to equilateral triangles, although many countries are still using Mobius loops (Oulton. M ,2021).

Extended Producer Responsibility (EPR) for plastic packaging is a policy approach that directs to shift the waste management cost from local value chain actors to the manufacturers of those products. Extended Production Responsibility Schemes can vary from country to country considering commitment either unpaid or compulsory, its series of instruments, product coverage, and charges. (OECD, 2001).

EPR benefits can be shortened in the four main advantages:

- Through the EPR scheme, producers change favorable product design and thus lead to increase recyclability and/or less packaging use.
- EPR provides supplementary funds for recycling plans that yield higher recycling rates.
- EPR scheme helps improve recycling program efficacy that leads to reduced cost and provides significant benefit to society.

A rational waste management system can be developed by EPR through which individual consumers pay the cost of their own consumption, rather than general taxpayers (Marc,2014, OECD, 2001).

According to Kleme and Fan (2021), the focus should not only be on how to change consumer habits but also to regulate the manufacturer, so that more recyclable and reusable plastic.

3.2 Studies on Bangladesh Perspective

Over the last 15 years, Bangladesh's annual per capita plastic consumption in urban areas tripled to 0.0 kg in 2020 from 3.0 Kg in 2005. In contrast, the capital Dhaka's annual per capita, plastic consumption is more than three times the national average urban area and stands at 22.25 kg (World Bank, 2021).

The annual percentage of plastic waste recycling in Bangladesh is higher than the global aggregate percentage. Against the aggregate consumption of 977,000 tons of plastic in 2020, only 31 percent were recycled in Bangladesh, and in Dhaka, about 646 tons of plastic waste is collected daily whose 37.2% is recycled. (Waste Concern, 2020) which is higher than the global average of about 9% (Waste Concern, 2020, Geyer et al. (2017).

BPGMEA registered 5110 companies in the plastic business present in Bangladesh with an additional non-member of around 500 where over 1.5 million people work. Against 13,469.7 MT/Year (11.76 MS$) imported virgin resin, Bangladesh uses 1, 05045.73 MT/year (MUS$95.91). The contribution of plastic to the total GDP of the country is 1.0% and per capita plastic consumption in the financial year, 2016/17 is 6 KG (Serajul & Mahmudul, 2019).

Recycling as a concept is inherent in the Bangladesh culture where a vibrant eco-system exists today. Building a practicable eco-system that enables circularity rests on leveraging & strengthening the existing collection, sorting & segregation system; use of appropriate technology to upgrade processes & infrastructure. In order to improve present practice and future possibilities a spirit of collaboration across the stake holders is highly required (M. Hanif and A Momen, 2020).

Considering the impacts of the Plastic Sector on Bangladesh's GDP growth, this sector should initiate to rethink of the sustainable plastic business. Applying the circular economy principles, the initiative brings together key stakeholders to rethink and redesign the prospect and future possibilities of plastics with a clear vision (Serajul & Mahmudul, 2018).

A very few plastic industries have basic recycling machinery like shredders or extruders rather than using crude technology where cleaning and sorting are done manually. Because of the cheap labor cost, most factory owners like to do these works manually (Mosaddeque Hossain, 2018).

Likewise, global trend, the plastic sector is developing rapidly in Bangladesh and it has become one of the remarkable sectors in Bangladesh. Bangladesh consumed approximately 1.5 million tons of plastic polymer in 2017 and the consumption has been rapidly increasing. This ever-rising trend in plastic consumption in Bangladesh leads to plastic waste that needs proper reprocessing to achieve economic gain and environmental sustainability. At present, 50-60% of plastic waste is used to recycle (Ijaz, 2019).

In Bangladesh, 60% of the post-use plastic waste was recycled in 2010 resulting in a saving of $600 million on the import of virgin materials. As almost all factories used the recycled from rejected machines yielded poor quality raw materials for production only 3% use directly recycled plastic waste raw materials. Where 37% are for no virgin materials, 40% for virgin materials, and 16% for virgin and no virgin materials (Serajul & Mahmudul, 2016).

As recycling waste plastic is an increasing concern for everyone proper training for the disposal and recycling of plastic products is needed & environment for getting economic and environmental benefits (Serajul & Mahmudul, 2014).

Among all types of plastic waste, post-consumer PET bottle is widely collected and reprocessed in the world. The collection of post-consumer PET bottle waste and its recycling procedures is a mandate for any country, especially in a developing country such as Bangladesh, as PET bottles are designed to have a short lifespan but may last centuries. In Bangladesh, post-consumer PET Bottle recycling has not proved economical yet due to collection, separation, sorting, washing and processing difficulties as well as advanced technological shortfalls. Amongst all other Plastic Litter, mainly post-consumer PET Bottle is collected for further processing through informal sector presently in Bangladesh while most of the other plastic litter is mainly dumped in the landfill sites along with various types of organic and inorganic waste. Despite huge potentials, the collection and recycling of post-consumer PET Bottle in Bangladesh has not played any significant role on economic growth and environment sustainability as compared to neighboring countries. (M. Hanif and A Momen, 2020).

An integrated supply chain is required for plastic waste recycling. The private sector usually plays a key role in the case of plastic waste recycling and the scope of activities of the private sector needs to be expanded. An integrated supply chain should be incorporated for the collection, processing, and recycling of the waste with the proper mechanism for handling all types of plastic waste for recycling (Moazzem K.G, 2016).

Bangladesh could emerge as a global player in the plastic industry by hiking its annual turnover to US$ 2 billion by 2015 and US$ 4 billion by 2020. At present, plastic-based goods represent a sizeable sub-sector of the country's chemical industry. The present market size is around US$ 1 billion, with US$ 714 million affecting the domestic and the rest to the global market. Meanwhile, plastic recycling has developed into a sizeable component of this particular sector, where major recycling centers operate in and on the capital city, Dhaka. Around 300 small facilities are recycling some 138 MT/day of plastic wastes; the availability of river water and low transportation costs have made them economically attractive (Recycling International, 2012).

Because of cheap labor, the plastic recycling sector could be quite prospecting and rewarding to start in Bangladesh as the production, consumption, and waste generation is increasing at a faster pace (Sultana., 2019).

Approximately 55% of available plastic wastes are recycled every year in Bangladesh and thus recycling would reduce the number of plastic wastes in the environment which can protect against environmental pollution. Since many people are looking for jobs to survive and recycling plastic wastes can bring foreign currency to the economy of Bangladesh, and job opportunities can be a great plus point for the country (Shimo, 2014).

There is a significant demand for recycled plastic wastes in Bangladesh. Even though the plastic recycling sector is not able to improve their activities producing clean recyclables of higher value. Source sorting and modern recycling technology are completely missing in the existing recycling practices. Despite these, there is enormous scope for expansion at micro-level which will exploit the value of recyclables. Source sorting and inclusion of appropriate processing technology will certainly improve the quality of recyclables, and thus increases their value (M. Hanif and A. Momen, 2017).

From 1990 to 2020, the consumption of Plastics in Bangladesh has increased by 50 times; i.e. 15000 tons to 750000. As plastic production and consumption are increasing waste generation is also increasing. So, it is mandatory to promote the recycling of plastic waste and to reach a 100% recycling rate leaving no amount of plastic waste to be landfilled and incineration to achieve economic and environmental benefits (Hossain, 2016).

Plastic waste can be transformed into a good source of export income for the country through coordinated efforts of the government, consumers, recycling industries, and plastic products manufacturers which could create a positive atmosphere for recycled plastic products and companies. In this way, plastic waste management would emerge as a major productive industry in Bangladesh (Mehnaz,2020).

In Bangladesh, recycling activities have been carried out informally and the plastic recycling industry is labor-intensive. The reverse logistics channel for plastic recycling challenges and must overcome many issues such as loan facilities to recyclers with the minimum interest rate, technological up-gradations, reduction of handling inefficiency, etc. to improve the overall efficiency and marketability of recycled products through strategic planning (Akter, Hossain, 2016).

Waste generators, waste collectors, scrap shops and dealers are usually considered to be the **Upstream Actors.** They are responsible for collecting and storing recyclables. On the other hand, big scrap dealers, traders, recycling, and producers are considered to be the **Downstream actors**. They process recyclables until they are re-manufactured. The whole recycling value chain of Bangladesh is in a vulnerable condition currently since this segment is deprived of getting banking opportunities and remains incapable of shifting the present status which makes them helpless to unstable market prices and vertical power relations with other downstream stakeholders of the value chain. Apart from this, the absence of pragmatic guidelines & strategies to uphold sorting at source of recyclables, and support a suitable collection system yields in substandard supply. There is a common awareness problem among mass people regarding the economic and environmental benefits of recycling. Moreover, the value chain actors are commonly made social outcasts and suffer poor working conditions. As a consequence, these factors reduce the earnings of those involved in the recycling process. In addition, they used to compromise the investment capacity and technological advancement, which then hinders the perfection of product quality, standards, and general working environments (UNDP, 2019).

Tokai (itinerant waste pickers, usually children) is popularly known in Bangladesh. They collect recyclables from households, streets, markets, parks, public gathering hubs, and landfills. Feriwallas are the waste collectors who buy waste from door-to-door on tricycles or by foot. Both Tokai and Feriwala belong to the bottom layers of society. Feriwala usually buys recyclables from households and markets. They are usually paid by waste dealers, who give them 300 takas per day to collect recyclables. Tokai typically collects waste from the streets, parks, landfills, and other public gathering hubs (. Kabir M.H, M. Ismail, and M. Jashimuddin, 2015).

In Bangladesh, the waste generation rate is 0, 41 Kg per capita a day (WC, 2006) and is expected to reach 0.68 Kg per capita a day by 2025. Plastic waste ending up in landfill has gone up by +2.60% from 4.75% to 7.35% between 2005 and 2014. The amount of plastic waste has increased by +3.30% from 5.15% to 8.45% over the same time period. Pourashavas have also experienced an increase in quantities of plastic waste, with a change of +3.73% from 3.58% to 7.31%. There is a seasonal variation regarding waste generation and collection. For example, waste is weightier during the rainy season since it contains higher moisture content than in the dry season. The volume of post-consumer PET bottle waste generation increases since drink consumption during the dry season increases exponentially. Apart from this, waste generation per capita is powerfully connected to regional wealth, with rural areas generating fewer waste than richer urban areas (Waste DB, 2014).

Plastic waste recycling related research stated above has attracted substantial attention across the world in recent years which is evident from the below table (3.1):

Table 3.1: Literature on plastic waste recycling

Focus	Authors	Name of the Journal/Publication	Year
Global market size of plastic	Grand View Research	Grand View Research Publication, California, USA	2022
Plastic production and Consumption	Plastics Europe Market Research Group	PEMRG Publication	2020
Trends and opportunities of recycled plastics	BCC Research	BCC Publishing	2022
Market Size of recycled plastics	Research and Markets	Technavio Research	2022
Projected growth of recycled plastics	Clare Goldsberry	Plastics Today	2020
Projection of global plastic waste recycling percentage	OECD	OECD Publication	2022
Plastic recycling opportunity	Tom Hesselink	KPMG	2019
Circular economy action plan	European Commission	EU Publication	2020
The transformation from linear to circular economy is lower than expected	Calleja	The journal of field actions	2019
Review of plastic value chain	Johansen et al.	Journal of Environmental Management	2022
Global commitment towards new plastic economy	a. Zhongming et al. b. EU	a. Progress b. EU publication	2020
Recycling potential of post-consumer plastic packaging waste	Brouwer, M. T et al. Dahlbo et al	Waste management	2018
Challenges of potential tracer-based recycling technology	Gasde et al	Sustainability	2021
Problems associated with mixed plastic wastes to process	Brouwer, M. T et al.	Waste management	2018

Plastics as a materials system in a circular economy	Bucknall Eriksen et al., Nielsen et al.	Philosophical Transactions of the Royal Society	2020
Important of product designing	Iacovidou et al	Science of the total environment	2019
Design and characterization of food packaging by recycled plastics blend	a. Foschi et al.; b. Iacovidou et al c. Masmoudi et al. d. Gall et al	a. Sustainability b. Science of the total environment c. Polymer Engineering & Science d. Sustainability	2020 2020 2020 2020
Improving the production chain with LCA and eco-design	Civancik-Uslu et al., Chi et al.	A. Conservation and Recycling	2019
Product designs and business model strategies	a. Bocken et al., b. le Blevennec et al. c. Johansen et. al	a. Journal of Industrial and Production Engineering b. OKOPOL c. Journal of Industrial and Production Engineering	2016 2018 2022
The role of innovative technology	Getor et al	Conservation and Recycling	2020
Production process of plastics	Vieitez et al.	JRC Publications (EU)	2011
Mixed post-consumer recycled plastics as a property tuning substantial for virgin plastics	a. Curtzwiler et al., b. Getor et al.	c. Science Direct d. Conservation and Recycling	2019 2020
Nano composites of plastics in food packaging	a. Sarfraz et al. b. Getor et al. c. Curtzwiler et al.,	a. Nanomaterials b. Conservation and Recycling	2021 2020 2019
Sustainable consumption and production of plastic products for food and beverage packaging	Boesen et al., 2019	Journal of cleaner production	2019
Importance of sustainable purchase decisions	Núnez-Cacho et al. and Clark et al.	Plos One	2020
End-of-life phases of plastics	Bucknall and Eriksen et al.	a. Philosophical Transactions of	2020 2019

		the Royal Society A b. Waste management	
The future of plastic recycling	Burgess et al.	Conservation and Recycling	2021
Importance of holistic approach to improve waste collection	a. Kranzinger et al. b. Tallentire and Steubing	a. Waste Management & Research b. Waste Management	2017 2020
Usefulness of tracer-based sorting	Gasde et al	Sustainability	2021
Importance of NIR infrared separation equipment	ARA System	ARA System	2022
Mechanical Recycling of Plastics	Schyns and Shaver	Macromolecular rapid communications	2021
Challenges and opportunities of mechanical recycling	a. Avolio et al. b. Dahlbo et al. c. Eriksen et al. d. Kranzinger et al. e. Lopez ´ de Dicastillo et al. f. Schyns and Shaver	a. Polymers b. Waste Management c. Waste Management d. Waste Management e. Comprehensive Reviews in Food Science and Food Safety f. Macromolecular rapid communications	2019 2018 2019 2018 2020 2021
Opportunities and challenges of pyrolysis of plastic wastes	a. Dunkle et al. b. Qureshi et al. c. Mumladze et al.	a. Journal of Chromatography A b. Journal of Analytical and Applied Pyrolysis **c.** Green Chemistry	2021 2020 2018
Options for chemical recycling	a. Mark et al., b. Vollmer et al.,	a. ChemSusChem b. Angewandte Chemie c. Journal of Analytical and	2020 2020 2020 2020

	c. Mumladze et al., d. Santagata et al. e. Tournier et al.,	Applied Pyrolysis d. Journal of cleaner production e. Nature	
Sorting of Plastic Wastes by types	Alstrup, Thomas	EU Publication	2012
Recycling Technology	COWI	Aalborg University	2013
Applications of Optic Sensor in Plastic Recycling	Bilitewski, B	Blackwell Publishing	2011
Biological Recycling	Papadopoulou et al.	Chimia	2019
Role of Mechanical and Chemical Recycling in LCA	a. Faraca and Astrup b. Van Eygen et al.	c. Waste Management d. Waste Management	2019 2018
Preferable options for chemical recycling	a. Horodytska et al., b. Schwarz et al.,	a. Chemosphere	2020 2021
Efficiency analysis of circular economy in plastic waste	a. Robaina et al. Wagner b. Wagner and Schlummer,	a. Science of the total environment b. Conservation and Recycling	2020 2020
Regulation and legislation in relation to sorting, collection, and recycling	a. Bishop et al. b. Horodytska et al.	a. Environment International b. Chemosphere	2020 2020
Confusion Around Recycling	Oulton. M	Czapp	2021
Extended Producer Responsibility	OECD	OECD Publication	2001
Action Plan for Sustainable Plastic Management in Bangladesh	World Bank	The World Bank Group	2021
Production, use, and fate of all plastics	a. Geyer et al. b. Waste Concern	Waste Concern Science advances	2020 2017
Refurnishing the usability of plastics	Serajul & Mahmudul	BPGMEA	2019
Review of Plastic Scrap Dealers & Recyclers in Dhaka City	M. Hanif & A Momen	International Conference on Management of	2020

		Innovation and Sustainability: Vision 2041. IBA, DU	
Rethinking the future of plastics for enhancing the plastic economy	Serajul & Mahmudul	BPGMEA	2018
Salient Feature of Recycling Plastic	Mosaddeque Hossain	BPGMEA	2018
International Experience and Strategies to Improve Plastic Recycling in Bangladesh.	Ijaz	BPGMEA	2019
Need Assessment to set up plastic training institute	Serajul & Mahmudul	BPGMEA	2014
Post-consumer PET Bottle Collection and Recycling Practice in Bangladesh	M. Hanif & A Momen	International Conference on Business, Economics, Education and Social Sciences (ICBEESS, 2018), East West University	2018
Effective framework for plastic waste management	Moazzem	BPGMEA	2016
Growth of plastic recycling industry in Bangladesh	Recycling International	Recycling International	2012
Plastic recycling in Bangladesh	Sultana	Adv Envi Was Mana Rec	2019
Theoretical framework of Plastic Recycling in Bangladesh	Shimo	ARCADA	2014
Insights into plastic litter collection and recycling practices in Bangladesh	M. Hanif & A. Momen	ICBM, BRAC University	2017
The Prospects and Challenges of Plastic Industries in Bangladesh	Hossain	BPGMEA	2016
Export Potential of Recycled Plastic in Bangladesh.	Mehnaz	Asian Social Science	2020
Investigating Plastic recycling supply chain in Bangladesh	Akter, Hossain	Du journal of marketing	2016
Recycling Value Chain Analysis in Teknaf and Ukhia in Bangladesh	UNDP	UNDP Publication	2019
Solid Waste Recycling Status at Sholokbahar in Chittagong	Kabir M.H, M. Ismail, and M. Jashimuddin, 2015	Journal of Environmental Science and Natural Resources	2015
Waste generation and consumption statistics in Bangladesh	Waste Concern	Waste Database	2014

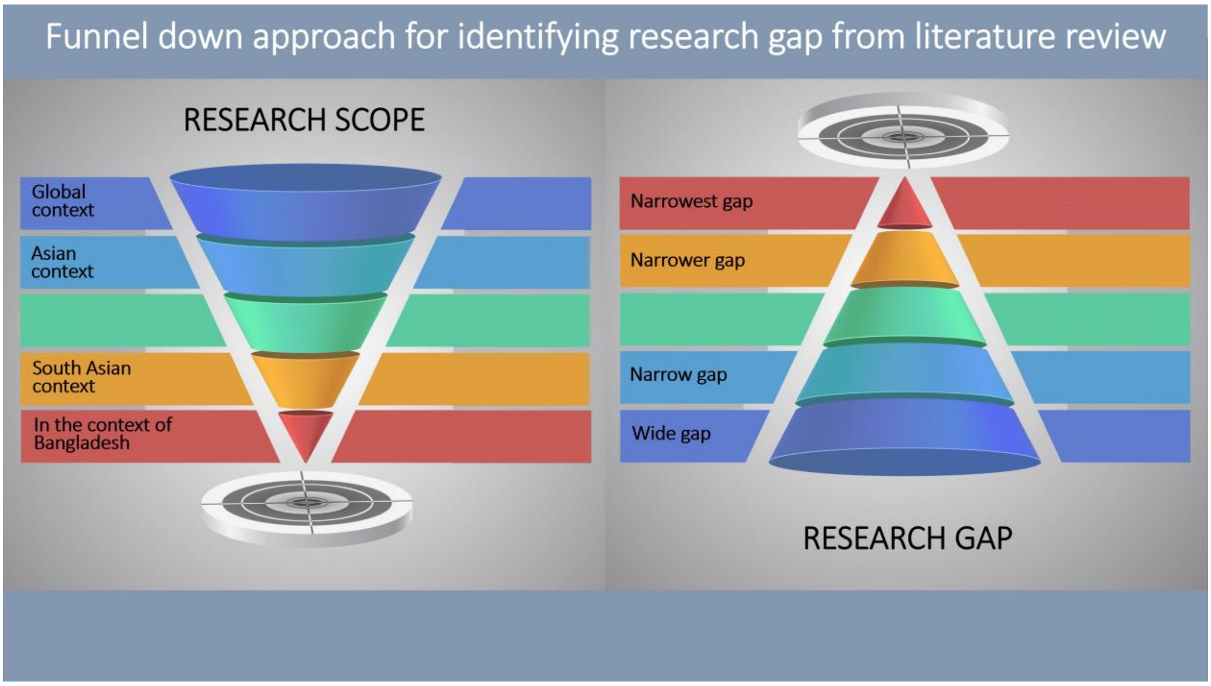
3.3 Research Gap

It is well accepted that the research gap helps researchers in every step of any research work from the grounding stage to the end of the study such as title selection, objective setting, work out of methodology, data collection as well as analysis, and suitable implication. In another way, it can be furnished that the research gap permits the researcher to come up with unique research findings and their suitable implication in the study from beginning to end. Thus, research gap identification is the most indispensable step for designing the research work holistically. Research gaps are mainly categorized as explicit and implicit/implied as mentioned below:

Explicit research gap: Already published and from this article's future studies

Implicit/ implied research gap: After a rigorous literature review, the researcher may discover implicit gaps. In the case of this study, research gap is implicit in nature because the researcher studied literature review extensively through Funnel Down approach for identifying research gap.

Figure 3.2: Relationship between Research Scope and Research Gap



The review of the literature suggests that the transition from the prevailing linear to the circular economy must include more than new recycling technologies; it must also incorporate reconsidering the process of design, production, and use of plastic products (Iacovidou et al., 2019). This method is highlighted in most of the studies but is not reflected in the number of studies covering each value chain stage. According to Milios et al. (2018), one of the flashpoints found in the value chain is a lack of communication and coordination, which results in a lack of traceability. This indicates that the lack of coordination and required knowledge of the remaining phases within the value chain affects the whole system. As described above, most of the studies concentrating on the whole value chain accomplish that existing policy and research focus primarily on end-of-life (Hahladakis and Iacovidou, 2018; Nielsen et al., 2020), overlooking the other important stages and how these may influence end-of-life possibilities for reuse, recycling, and reprocessing of plastics. Moreover, the literature review reveals that there is a knowledge gap in the design, production, and use phase that may hinder both the transition to a circular and the operation of waste-management procedures with limited attention given to opportunities for the prevention of plastic waste, redesign, new product development despite the fact that these aspects are often regarded as the most desirable on the circular-economy notion. According to Nielsen et al. (2020), most of the legislation issues are about regulating the end-of-life phase (i.e., waste-management legislation), paying little attention to the remaining stages of the plastic recycling value chain. There is another problem concerning the circular business model in the current research, where the majority of the research focuses on the recycling of plastic, leaving out other aspects of the circular plastic economy. Another challenge mentioned is that the existing literature focuses on recycling and reducing the amount of plastic consumed, ignoring the strategy formulation of making sustainable products from recycled plastic.

There are also research gaps to integrate design for recycling; including recycled materials in the production process; increasing the demand for recyclable materials; new product development strategy from recycled plastics, and raising required investment in the development of recycling technologies (and technology systems that integrate or combine mechanical and chemical recycling technologies).

The literature on the Recycling of Plastic Waste and its Sustainable Product Strategy for Bangladesh is insufficient in the context of Bangladesh. Besides this, the contemporary studies gave conflicting or inconclusive results. Hence, reaching a valid conclusion remains an imperative goal to attain the circular and climate-neutral plastic economy.

3.4 Conceptual Framework

A conceptual framework has developed to represent this study originating from the literature review. Jabareen (2009) suggested that a conceptual framework is defined as a network of linked concepts that comprise theorization techniques considering the grounded theory method and the data consists of several disciplines. According to Mishler (1990: p.431), the ultimate aim of qualitative study is to describe and explain the relationship pattern which can only be achieved with a set of abstractly detailed categories. Nonetheless, theory or theoretical framework representing a multifaceted phenomenon will always be lively and will be reviewed rendering several issues such as new understandings, observations, literature, and so on, and theory should be taken into consideration for those disciplines and expand their potentiality on theoretical viewpoint on the specific phenomenon in question (Jabareen, 2009: P.55).

From reviewing available literature about the plastic waste recycling value chain, it has been identified that the structure is almost similar across different countries, though not exactly the same, and considering this a conceptual framework has been developed.

Since the research design of this study is constructed on a "systems-thinking" method (OECD, 2017) that emphasizes the cohesive investigation of the issues considering compound connections among elements within the process. Due to the interconnectedness, the system thinking method apparently contemplates feedback loops from any modification in one part of a system that crops alteration across the whole system. As a consequence, the system-thinking method differs from a linear, and fundamental theory of change (Olivier et.al, 2011). Therefore, system thinking, emphases establishing 'leverage points' (Metabolic 2020), where a nominal change in one element of a system can produce a significant net influence across the entire system.

It has been observed that there is a cohesive relationship between the plastic recycling value chain and the conceptual framework of this study. In this consideration, the value chain is premiered and the conceptual framework is designed afterward.

Traditionally, the plastic recycling value chain splits into four phases in Bangladesh: 1) plastic waste generation, 2) plastic waste collection, 3) processing and 4) offtake. The below figures abridge the stakeholders and constraints within each phase of the loop.

Figure 3.3: Plastic Recycling Value Chain Stages

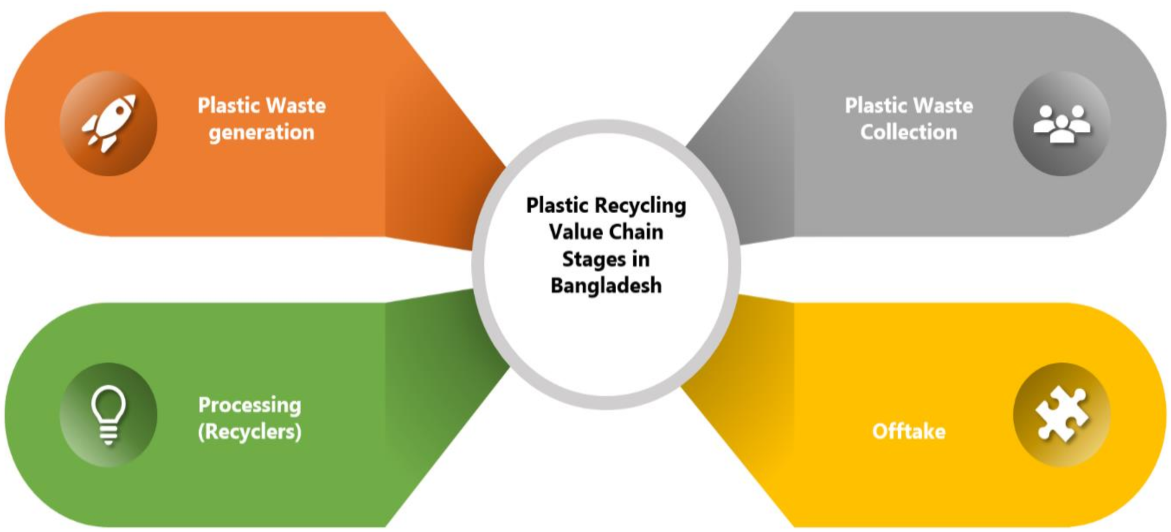
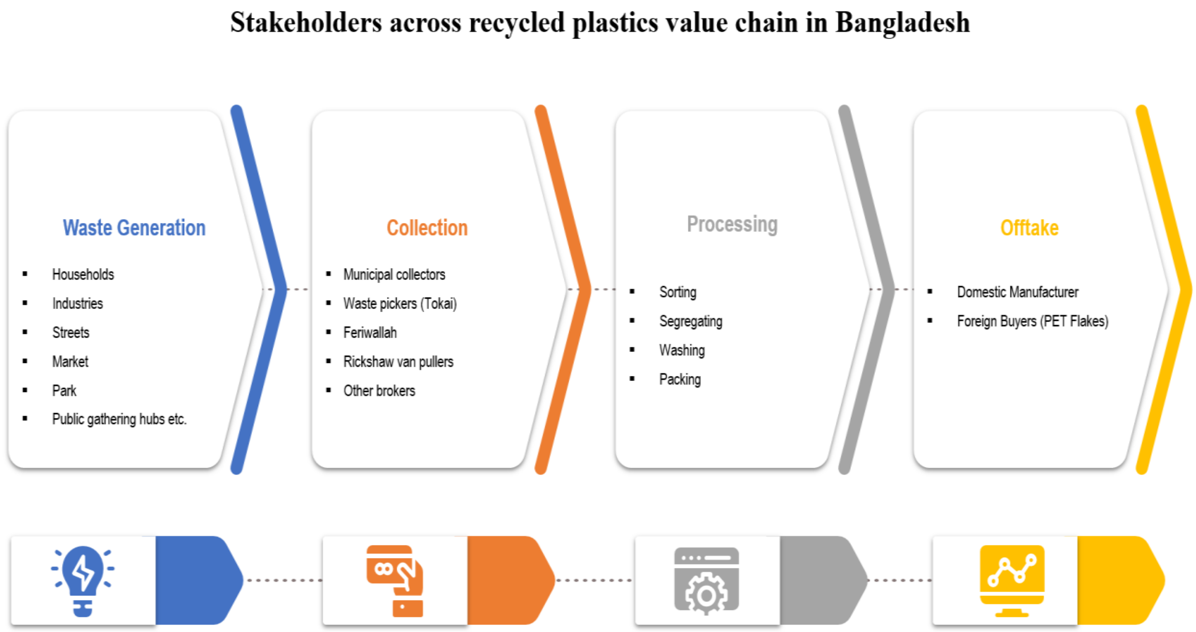
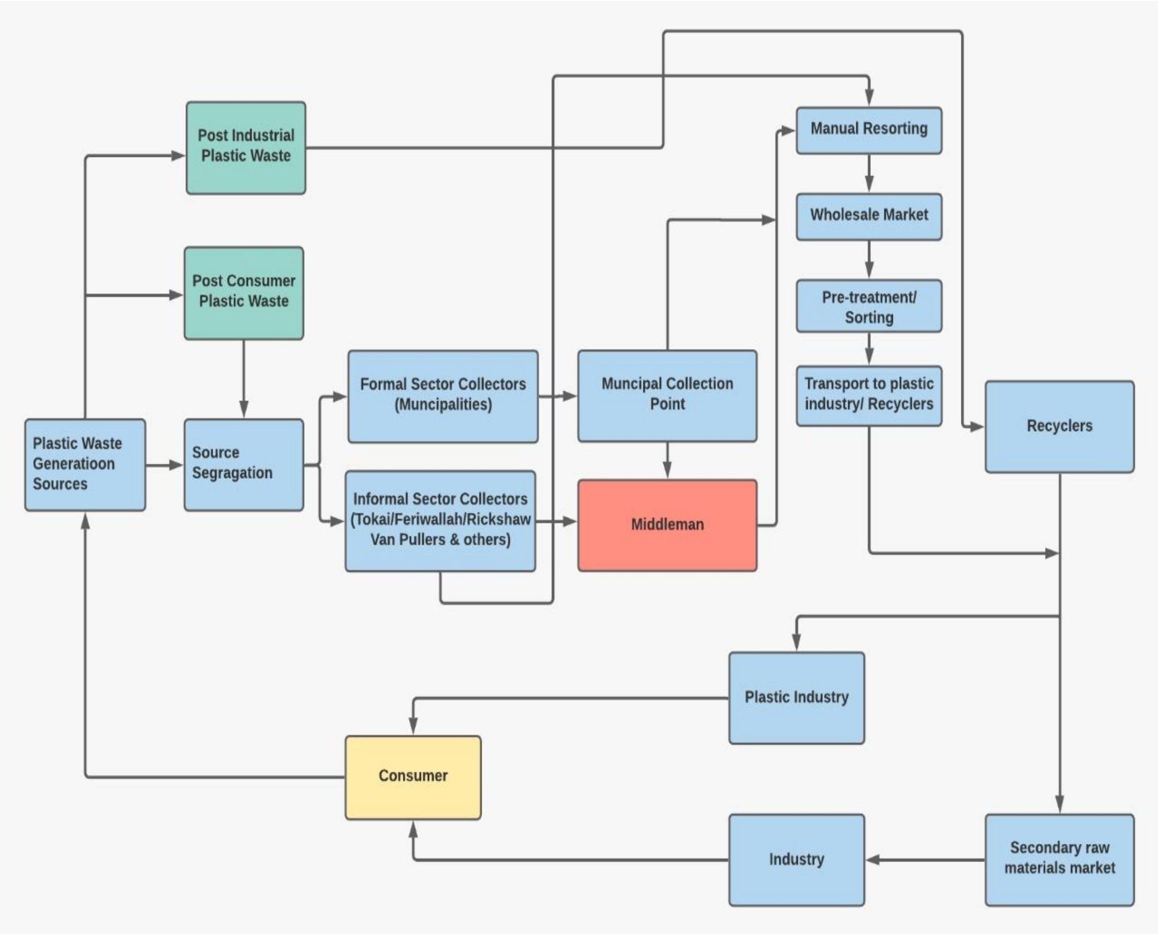


Figure 3.4: Stakeholders across the recycled plastics value chain in Bangladesh



The plastic recycling value chain involves a multitude of actors from the collection, transport, dismantling, sorting, and finally to recycling& product manufacturing from a circular economy perspective. All value chain actors are interconnected with each other and one small change within an actor can create a significant impact across the whole value chain. Taking into this consideration, the conceptual framework has been developed coping with a ‘system-thinking approach’ from a circular economy perspective as illustrated below:

Figure 3.5: Conceptual Framework



Chapter Summary

This chapter started by reviewing some studies from a global perspective considering the growth and development of the plastic recycling sector, the plastic recycling value chain and its phases. The chapter also has exemplified some studies on Bangladesh's perspective. The study has found an unequal distribution of research across the different value chain stages where a significant number of published and unpublished articles focus on the waste-management phase, and comparatively fewer studies deal with product design, production, and use phases. This is an important knowledge gap, as most research has been focused on the end-of-life phase, despite the increased political, economic, and scientific prominence on the circular economy perspective that, ideally, would include recycling as just one aspect.

CHAPTER 4: METHODOLOGY

CHAPTER CONTENTS

This chapter explains the methodology that is used in this thesis. The types of methods, research philosophy, literature, journal articles, open-field interviews, case studies, document studies, expert interviews, and websites are discussed. In addition, it reviews the quality of this thesis by discussing its validity and reliability.

CHAPTER 4: METHODOLOGY

This chapter explains the methodology that is used in this thesis. The types of methods, research philosophy, literature, journal articles, open-field interviews, case studies, document studies, expert interviews, and online sources are studied. In addition, it reviews the quality of this thesis by discussing its validity and reliability.

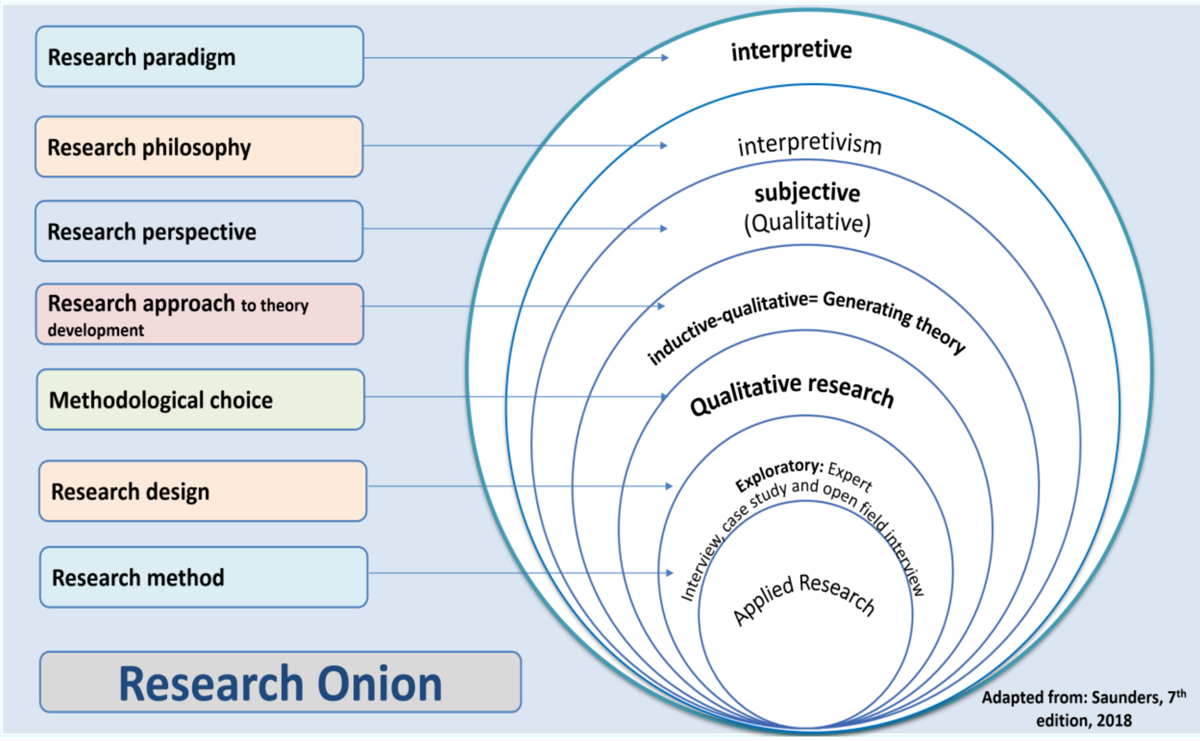
The researcher hopes to provide a sincere and rich description of the methodology used in this thesis. The overall research design of this study is based on a 'systems-thinking' approach (OECD, 2017) that emphasizes the cohesive investigation of the problems seeing multifaceted connections between elements within the system. Thus, the system-thinking approach is distinct from a linear, and causal theory of change, as it clearly reflects feedback loops from any change in one part of a system, which produces change across the system due to its interconnection (Olivier et.al, 2011). Therefore, system thinking approach emphasizes on establishing "leverage points" (Metabolic 2020), where one minor modification can create a major net effect across the system.

Since plastic waste recycling loops equipped with multifaceted connections between actors within the whole system the study adopted the "System Thinking Approach" where any change in one element produces change across the whole system.

4.1 Research Design

Saunders, et al. (2019) defined research design as a general plan to answer a research question and it is a framework that includes methods and procedures to collect, analyze, and interpret data. Thus, the research design describes the blueprint to accomplish objectives and to answer the question(s) as well as to describe how the researcher will explore the central problem of the research and part of the research proposal.

Figure 4.1: Research Onion



4.1.1 Research Philosophy

"Research philosophy is defined as a system of beliefs and assumptions about the development of knowledge" (Saunders, et al. (2019). Among the five research philosophies, Interpretivism developed from a subjectivist perspective and it emphasizes that human beings are different from physical phenomena because they create meanings. Interpretivism studies meanings to create new and richer understandings of realities. Empirically, interpretivism focuses on individuals' lived experiences and seeks to include their participants as well as their interpretations in their research (Saunders, et al. 2019). This research considers the interpretivism philosophy as the purpose of research is to create new and deeper understandings of plastic waste recycling and its utmost benefit in the context of Bangladesh allowing people to see the worldviews in new ways.

4.1.1.1 Philosophical Assumptions

Epistemology refers to assumptions about knowledge, what constitutes acceptable, valid, and legitimate knowledge, and how we can communicate knowledge to others (Burrell and Morgan 2016). Epistemology in its simplest sense is a simplistic approach to theories and concepts to focus on narratives, stories, perceptions, and interpretations for new understanding and worldviews as a contribution to a problem and has associations with qualitative research (Saunders, et al. 2019). Thus, epistemological assumptions consider- What is possible to know? How can we generate meaningful knowledge? Therefore, this research is underpinned by an epistemological position.

Ontology refers to assumptions about the nature of reality (Thomas and Hardy 2011). This research has an ontological assumption considering multiple meanings, interpretations, and realities where the flux of processes, experiences, and practices co-exist.

Axiology denotes the role of values and ethics (Heron, 1996). As the researcher is part of what is researched, the researcher maintained a subjective stance. For that reason, it is value-bound research.

Like social research, this research has an ontological position, a combination of both interpretivism and subjectivism and reflexivity adopted in this research where researcher interpretations are the key to contribution.

4.1.2 Research Method

To analyze the different mechanisms of plastic waste recycling and create a sustainable product strategy in the Bangladesh context, a qualitative approach appears most suitable since it can capture subtleties and causal relationships that a quantitative approach could not capture. However, this is complemented by some descriptive quantitative elements. While quantitative methods are concerned with specific aspects or phenomena seeking to abstract from particular instances to a general description, qualitative methods can provide a more comprehensive explanation of an event or unit (King, Keohane, and Verba, 1994).

Qualitative research comprises a range of interpretive techniques that seek to define, infer, interpret, and then come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world (Fred N. Kerlinger, 1986).

Strauss, et al. (1990) state that qualitative research is used for a deeper understanding of any unknown subject area.

The commonly used qualitative methods are observations, focus groups, expert interviews, questionnaire surveys, open-field interviews, document studies, case studies, and others (Frechtling et al. 1998). In this thesis, the research questions involve the collection of information regarding plastic waste recycling from various kinds of literature and journals as well as the collection of information regarding the current state of plastic recycling and reprocessing from various stakeholders in Bangladesh. Hence, document studies, open-field interviews, and expert interviews are selected as the qualitative methods used for this thesis adopting reflexivity. According to Edge, J. B. (2017), reflexivity is the process of reflecting upon the bidirectional relationship between the researcher and the research which can be divided into two types: prospective and retrospective. Prospective reflexivity refers to the effects of the researcher on the study and on the other hand, and retrospective reflexivity refers to the effects of the study on the researcher. Accepting the bidirectional relationship between the researcher and the research is one of the important concepts in qualitative methodology.

Exploration is predominantly advantageous when researchers lack a rich knowledge of the problems they will meet during the study. Through extensive exploration, researchers develop concepts more clearly, establish priorities, develop operational definitions, and improve the final research design (Cooper, D. R., & Schindler, P. S. (2014)

Exploratory research is mostly directed toward describing equivocal circumstances or discovering untapped business opportunities. Therefore, this type of research is not proposed to provide conclusive evidence from which to determine a particular course of action (Zikmund et al, 2010: p.54).

Since information regarding the current plastic waste recycling and practices are mostly unknown and there is limited research on plastic waste recycling in Bangladesh, the researchers have opted for exploratory-qualitative research methodology as a major tool. Researchers practiced reflexivity in the overall research in a way, such as keeping journals, and maintaining open dialogues, discussions, interviews, observations, and surveys with open-ended questionnaires on the research process.

A predominantly qualitative approach is most suitable for this study because with qualitative methods the external effects that did not result in the process of plastic waste recycling and sustainable product strategy issue can be analyzed to find out more about the obstacles to the process of external effects. It would be difficult in exclusively quantitative studies. For quantitative studies, comparable data is required, which is often gathered in closed questions. However, for capturing the complexities and the broad range of different aspects that could have played a role in the blocking of the transmission of external effects, open-ended questions are deemed better suited.

Based on the qualitative research methods explained above, the research design for this the study can be divided into four phases such as 1) Theoretical studies (Literature Review) and pre-planning, 2) Open Field Interviews & Observations 3) Expert Interviews 4) Case Studies.

Table 4.1: Research outline

Research Philosophy	Philosophical Assumptions	Research Approach	Research Method	Research Design	Data Collection Method	Sample Group	Sampling Techniques
Interpretivism	**Epistemology:** Opinions, Narratives, perceptions & Interpretations **Ontology:** Relativism **Axiology:** Researcher Reflexive	**Data to Theory (Inductive)**	**Qualitative**	**Exploratory**	Reviewing Literature Open-field interviews Observations In-depth expert Interviews Case Studies	**Heterogeneous**	**Purposive & Convenience Sampling**

Table 4.2: Data Collection Methods Considering Specific Objectives

Specific objectives	Sources/ data collection methods
To evaluate the current state of the plastic waste recycling value chain.	Open-field interviews, Observations, Literature Reviews, Expert interviews
To study the existing plastic waste recycling industry for replication and scalability of the business model on the circular economy principles	Case studies
To formulate a sustainable product strategy from recycled plastic waste in Bangladesh	Literature review, Expert interviews Case studies

4.2.1 Open-ended Field Interview

According to De Vaus (2002) and Bailey (2008), a questionnaire includes methods where each respondent is asked to respond to an identical set of questions in a predetermined order at a certain point in time. Diamantopoulos and Schlegelmilch (1996) stated that it is the most widely applied method for the collection of primary data. “Questionnaires are mostly completed at the convenience of respondents, they can be used to get a significant amount of data or information using diverse question types” (Evansand Mathur, 2005; Bryman, 1992).

The purposes of using questionnaires can be either descriptive or explanatory: an explanatory questionnaire gathers data to test a hypothesis or theory, and a descriptive questionnaire seeks to describe the characteristics of a population (Gill and Johnson,2010). According to Oppenheim (1992), descriptive questionnaires aim “to count” to find out the proportions of the population that have a certain characteristic without studying causality or offering explanations. On the contrary, explanatory questionnaires involve a more analytical perspective where there is interest in investigating the relationship between variables. Therefore, they require a prearrangement of variables that would be examined before the questionnaire is designed and such variables are typically identified in the preceding stages of the research and typically include qualitative primary or secondary data (Ghauri and Grønhaug, 2005).

The type of variable is important because it guides the selection of question types, whether open-ended or closed-ended. Open-ended questions are similar to interview questions as they allow respondents to reply freely in words (Fink, 2002). Because open-ended questions are qualitative and require additional analysis, their use is not recommended in the questionnaires (Saunders et al., 2009). On the contrary, closed-ended questions restrict the respondents to several answers to choose from (Foddy and Foddy, 1994).

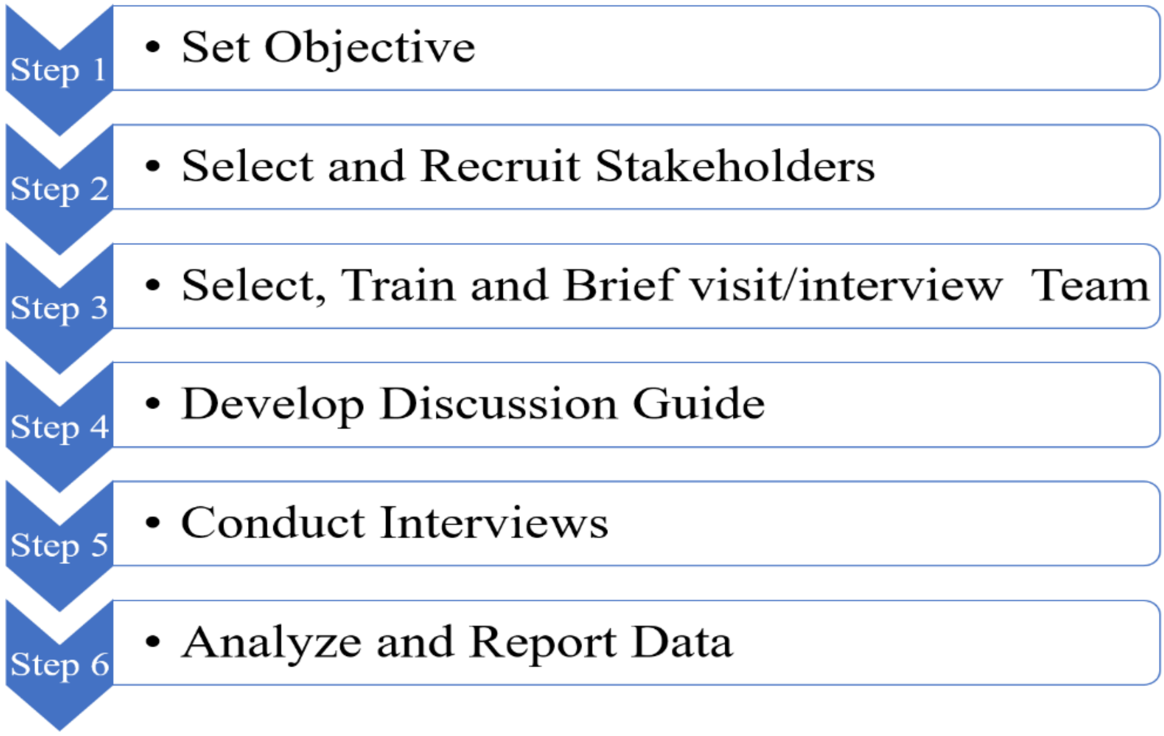
Considering the above, the research has adopted an open-ended explanatory questionnaire, and the following actors of the waste plastic recycling value chain have been considered as respondents to collect primary data:

Table 4.3: Actors, Sampling techniques & sample sizes for open field interviews

Sampling Units/Respondents	Sampling Techniques	Sample Sizes
Waste Pickers	Non-probability Convenience Sampling	50
Middle Dealers	Non-probability Convenience Sampling	25
Wholesale Dealers	Non-probability Purposive Sampling	25
Recyclers	Non-probability Purposive sampling	10

In this qualitative study, the open-field interview method has been adopted by deploying the modified version of the customer visit program as suggested by McQuarrie (1991), in which the qualitative interview has been used to identify the factors that describe the existing plastic recycling value chain in Bangladesh. In addition to the visual information collection, the customer visit program allows researchers to gather information through an interview. According to MacQuarrie (1991), the application of a customer visit program contains six-step procedure which is: setting objectives, selecting and recruiting information providers, training and briefing the visit team, developing a discussion guide, conducting interviews, and analyzing & report data (Figure:4.3). In this study, one of the specific objectives is 'to evaluate the current state of the plastic waste recycling value chain'. Considering this specific objective, the study adopted the modified version of the customer visit program. Thus, the first step of the visitation program is to set research objectives for the study that has already been set. The second step is to select and recruit the stakeholders to be interviewed. In this study, stakeholders were determined through reviewing literature and are grouped into four categories: waste pickers, middle dealers, wholesalers and re-processors/ recyclers. The fieldwork and data collection involved in this study was conducted in Dhaka City. The third step was to select, train and brief the visiting team. This step focused on the type of required information and how the interview should be conducted to get the desired information. In the fourth step, the discussion was developed with a formal set of open-ended questionnaires for conducting the interview. The fifth step was to conduct the actual interview. After completing the interview, the sixth and final step of the visit program was to conduct an examination session that includes the detailed discussion and analysis of all relevant interview notes and recording of findings.

Figure 4.3: Six-steps procedure for applying for a visitation program



Justification

Dhaka is the capital and the most densely populated city of Bangladesh. Dhaka Metropolitan City offers more employment opportunities and higher income levels, which leads to the migration of the population from different parts of the country to it. As mentioned in the research method part that the fieldwork and data collection involved in this study were conducted in Dhaka City as it generates the largest plastic waste in Bangladesh. Furthermore, almost all types of plastic waste travel to this single destination. On the contrary, more than ninety percent of recycling facilities exist within or in the periphery of this megacity. For this reason, Dhaka metropolitan city has been selected as the study area for an open-field interview that eventually portrays the whole country. The field interview findings will help identify the gaps in the existing value chain and analyze them with primary data to meet the research objective.

4.2.1.1 Observation

“Observation is a method of collecting data through observation rather than asking questions. The purpose is to take a separate view of the phenomena and be ‘invisible’, either in fact or in effect. Observation is a basic data-collecting activity for many branches of research, particularly the social and technical sciences. It is useful in the social sciences where people and their activities are studied. Observation can record how people respond to questions, and whether they act differently to what they communicate or intend. They can sometimes establish their understanding of a process better by their actions rather than by a verbal explanation of knowledge” (Nicholas, W. 2011).

According to Becker (2018), real-world observations can lead researchers to find more direct forms of research which could have been missed like focus groups and interviews.

This research has adopted the observation technique as one of the important methods of collecting primary data. Apart from field interviews, researchers have done extensive traveling by foot to cover as much area as possible within the study area to capture the real scenario of plastic waste collection, sorting, grading, and reprocessing activities to collect required information as well as to justify data that came into papers through field interviews.

Justification

This research has adopted the observation technique to avoid exaggerated, wrong, and hypothetical answers away from realities during the interview. Furthermore, the data which comes into the papers could be altered. Thus, observation has helped researchers to look into all such activities in front of their eyes. Therefore, this is one of the main data collection and justification techniques for this study, and researchers have allocated significant time to do this.

4.2.2 In-depth Interviews with Experts

In qualitative research, interviews are primarily done when researchers ask one or more participants general, open-ended questions and record their answers (Creswell, 2015). Interviews are particularly useful to uncover the story behind a participant’s experiences and pursuing in-depth information about a subject and it may be useful to follow up with individual respondents after questionnaires, e.g., to further examine their responses. (McNamara, 1999). In the case of qualitative research specifically, interviews are used to pursue the meanings of central themes in the world of their subjects. Understanding the meaning of what the interviewees say is the main task in interviewing (McNamara, 2009). Generally, open-ended questions are asked during interviews to get neutral answers, while closed-ended questions may force participants to answer in a specific way (Creswell, 2015; McNamara, 1999). An open-ended question gives participants more options to respond, while a closed-ended question provides a preset response (Cresswell, 2015).

Thus, the study adopted expert interviews where views and opinions of key informants from different backgrounds related to this field like recycling experts, industry experts, scavengers, and owners of waste recycling centers were kept in this thesis work as subject matter.

Justification

The interview is popular and one of the most important oral methods of collecting primary data. It is an important process of social interaction with the respondents. By this method, we can know the opinion and views of individual people and society as well. The opinions of people from home and abroad about waste management, recycling, and solution methods were collected by having face-to-face conversations with them. Identifying key informants and taking information from them made this research more effective. It is important to conduct qualitative research to understand the issues associated with plastic waste recycling by interviewing and detailed discussions with the practitioners as well as the experts in the field of waste recycling.

Important documents, archival data, and related issues about the study topic have been collected during the interview to deliver triangulation of support material for the thematic study. The list of interviewees has been conducted considering the name of the organization/company, the name of the interviewees and the country belong to, the goal/purpose of the interview, and the list attached in the appendix section.

4.2.3 Methods for Case Studies

According to Yin (2009), the case study method allows investigators to retain real-life events' holistic and meaningful characteristics and provides an in-depth understanding of a real-life event or process within its contextual conditions.

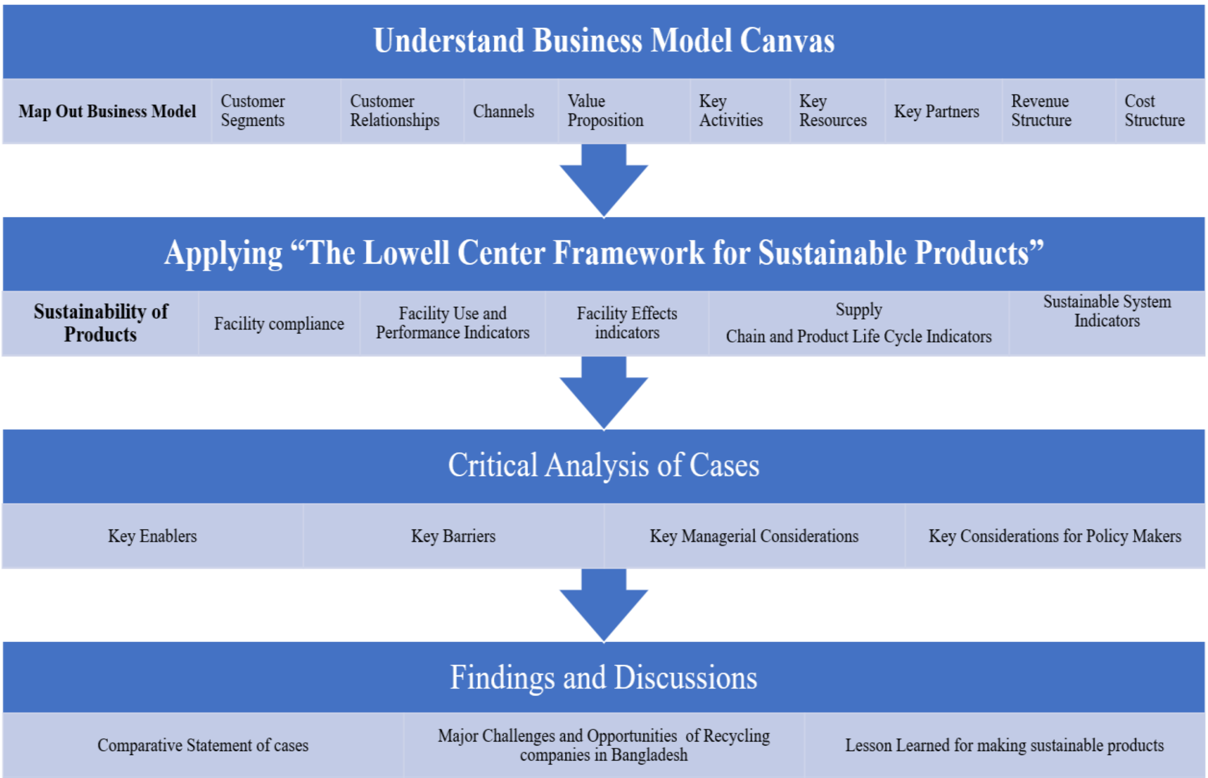
“Due to the amalgamation of quantitative and qualitative data collection and analysis methods and triangulation of information from multiple sources, case studies are extensively used in business research because they offer rich and reliable results (Robson, 2002). Case studies serve numerous research purposes such as providing descriptive accounts, theory development, and theory testing” (Yin, 2011). Eisenhardt (1989) stated that case studies adopt an exploratory and inductive approach to develop theory in numerous situations that involve limited prior theoretical knowledge aiming to generate theory from close observation of the phenomenon within the context of its own.

In case study research, the selection of a case is a challenging yet crucial task. Although unbiased, random sampling could yield cases that are unrepresentative of the population, and hence non-probability purposeful sampling is often recommended to obtain a representative case (Seawright and Gerring, 2008). To this end, the study has adopted the “Maximum Variation Cases Method” adapted from Flyvbjerg (2006), Seawright, and Gerring (2008) using purposefully selected multiple heterogeneous cases to obtain data under varied circumstances with the exploratory and inductive approach.

Considering the above, this research adopted an exploratory and inductive approach. Case studies are a reflection on the stream of matters where plastic waste becomes a valuable resource, and success stories of people who are a part of the process of transformation are central to it.

The case study has been carried out between January 2018 and March 2020. The case study method is organized into four steps, with an iterative approach at the end of each step. The first step (based on the business model canvas as suggested by Alexander Osterwalder and Pigneur, 2010) aims at producing an overview of the company, the context, and its (circular) business model, to capture how the company creates and delivers value. The second step involves a products sustainability assessment of the company (based on the Lowell Center Framework as suggested by Sally Edward, 2010 and its activities in the value chain. The third step critical analysis of the company’s operational activities. The fourth and last step involves a wrap-up of the results and concludes with the case company’s strengths regarding circularity, an overview of the barriers and enablers for circularity, and opportunities for further enabling circularity. The final result is a case study description, covering the previously established information.

Figure 4.4: Overview of Case Study Process



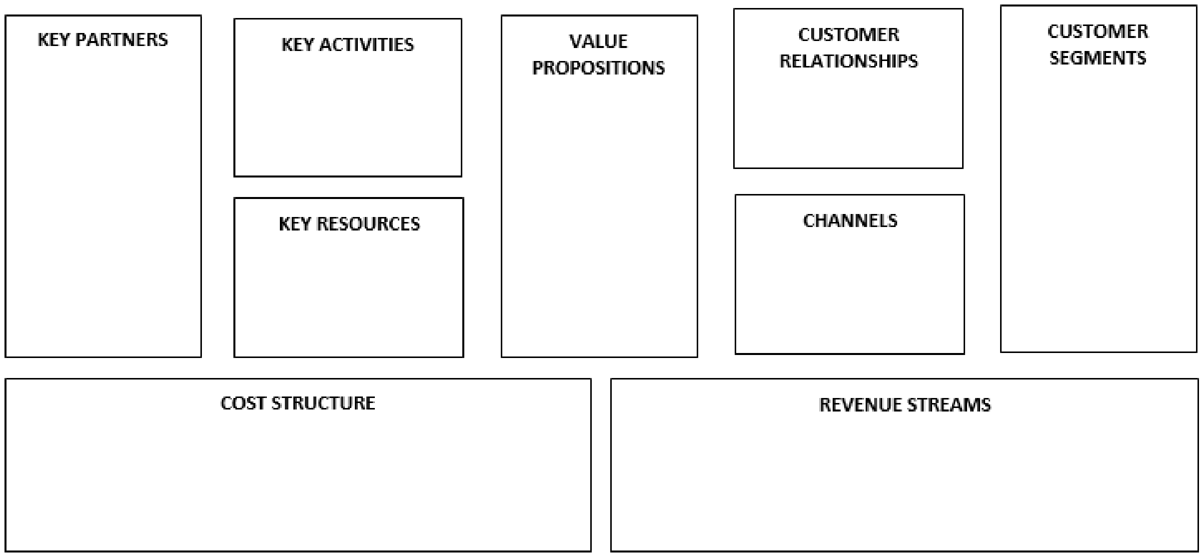
The study developed a 'big-picture perspective of the case study organization's business model, value chain, and business context. The study has been conducted, based on information that is publicly available and readily available within the Case Organization. The analysis has mainly involved desk research conducted by the researchers. This has been complemented by targeted interviews with the Case Organizations considering the elements (e.g., customer segments, value proposition, channel, customer relationship, revenue stream, key resources, key partners, cost structures, and environmental impact) of the business model canvas.

The study was conducted through a mix of interviews and data collection, then synthesized with findings from the business context analysis.

The analysis is structured using the Business Model Canvas (BMC) framework as developed by Alexander Osterwalder and Pigneur (2010) which allows the representation of a business model in a visible single-page format. These are tested tools for business model design and innovation, used by leading organizations around the world. This has been done jointly with Case organization stakeholders through interviews and data gathering. Interview questions (appendix 7) for the case organizations have been designed by following the Circular Economy Business Model Case Studies developed by the R2Pi project of the European Union in 2017.

Osterwalder et al (2010) developed a widely accepted business model canvas (Figure- 4.5) followed by millions of organizations around the world.

Figure 4.5: Traditional Business Model Canvas



Template produced by the researcher (Adapted from original source Osterwalder, 2010)

The above blocks intend to collect by asking the following core questions;

Customer segments: Who are the key customers?

Customer relationships: how to satisfy the requirements?

Channels: How is the customer to be approached?

Value proposition: What value is to be generated?

Key activities: How can the value be created?

Key resources: What is needed to generate?

Key partners: Who will help to achieve this?

Revenue structure: How to generate money?

Cost structure: What are the major cost drivers?

The canvas considers nine key blocks to evaluate the business strategy that is globally practiced. The model consists of nine blocks that include key partners, key resources, key activities, value proposition, customer segments, customer relationships, channels, revenue streams, and cost structure.

Apart from Business Model Canvas, the case study has also adopted the Lowell Center Framework for Sustainable Products, where "sustainable product minimizes environmental and social costs during the product lifecycle and maximizes environmental and social benefits to communities while remaining economically viable." The Lowell Framework works with three basic assumptions as mentioned below:

1) Developing a sustainable production system with a continuous, evolutionary process of setting goals and measuring performance.
2) Different companies/industries start at different places in the evolution process.
3) Developing truly sustainable production systems that cannot be achieved by companies or industries without holistic cooperation and coordination among companies, communities, and government at different levels such as local, regional, national and international.

And thus, from the sustainability perspective companies can evaluate whether their products are sustainable by asking the following five core questions and examining the measures that define each component (Sally Edward, 2010) (see appendix 8).:

Is the product economically viable?

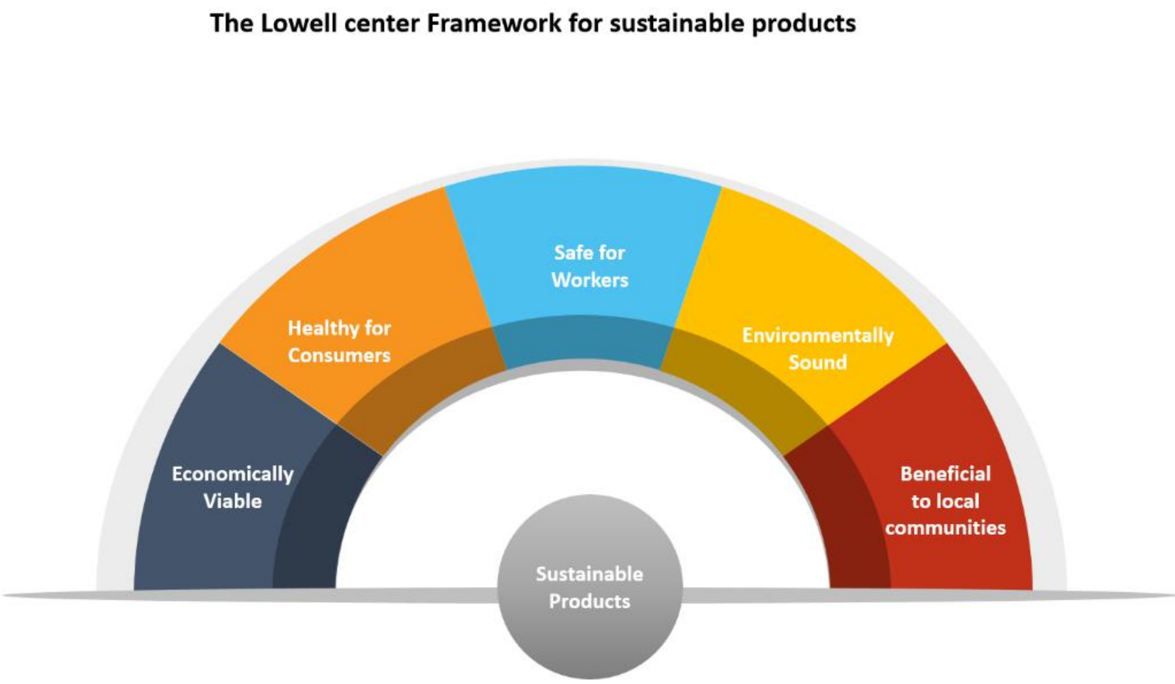
Is the product healthy for consumers?

Is the production process safe for workers?

Is the product environmentally sound?

Does production benefit local communities?

Figure 4.6: The Lowell Center Framework for Sustainable Products



Source: The Lowell Center Framework for Sustainable Products, 2010

The Lowell Framework consists of the following five levels:

Level One: Facility Compliance/Conformance Indicators

Level Two: Facility Material Use and Performance Indicators

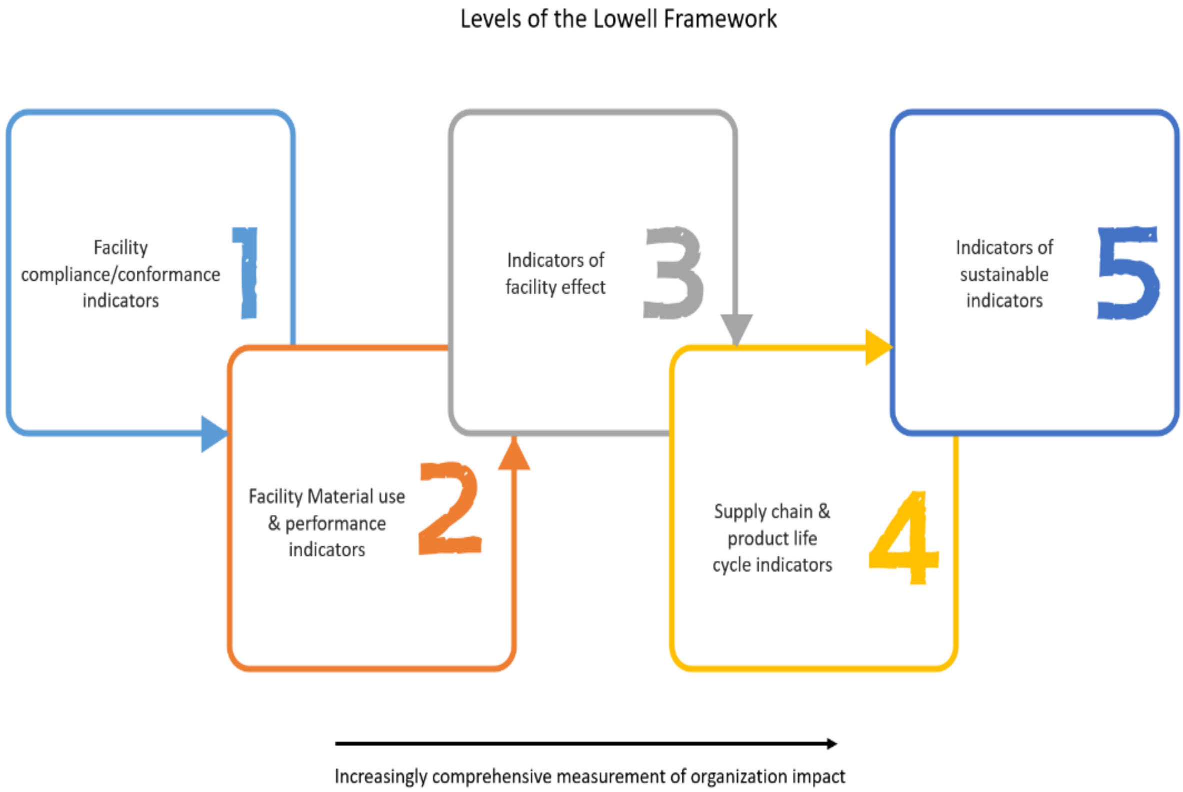
Level Three: Facility Effects Indicators

Level Four: Supply Chain and Product Life-Cycle Indicators

Level Five: Sustainable Systems Indicators

The case studies of varied plastic waste recycling companies apply this broad framework to demonstrate the use and value of this tool. Therefore, the Lowell Center Framework for Sustainable Products can be helpful in evaluating whether a holistic approach is being implemented in developing greener, safer, and healthier products. The case studies also demonstrates that a company can meet many of these criteria and be successful economically.

Figure 4.7: Levels of Lowell Framework



With sustainability in mind, innovative companies that design and make products are part of a new business trend that is representative of a "restorative economy," where industry plays a noteworthy role in supporting community sustainability by reducing its impact on the environment simultaneously and providing benefits to the community (Hawken, P, 2010).

Considering this the following plastic waste recycling companies from different part of the world have been considered for this study.

Table 4.5: Selected cases of Plastic Waste Recycling Companies Across the World

Sl#	Company Name	Country	Types of Plastic waste handling	Person interviewed	Interview Site
1	TERRACYCLE	USA	Post-consumer waste	Tom Szaky CEO	Taipeiplas 2018, Taiwan
2	BYFUSION	USA	Post –Consumer waste	Heidi Kujawa CEO	Taipeiplas 2018, Taiwan
3	INTEGRICO	USA	Post-consumer & Post-Industrial waste	Ken Webber GM	Taipeiplas 2018, Taiwan
4	GEMINI	Belgium	Post-Consumer & Post-Industrial waste	Piyush Jain Sales & Marketing Manager	TaipeiPlas 2018, Taiwan
5	DAISAKU	Japan	Post-Industrial Waste	Shunsuke Kobayashi Sales Head	International Conference on Plastic 2019, Dhaka
6	Shin Hua	Taiwan	Post-consumer & Post-Industrial Waste	Robin Yang Consultant	Shunhua factory, Taipei, Taiwan
7	Union J Plus	Thailand	Post Industrial	Nattaporn Tha Head of Sales	Union J Factory Samutsakorn, Thailand
8	GANESHA	India	Post-consumer PET Bottle	B.P Sultania Joint President	Ganesha Office Delhi, India
9	BPCL	Bangladesh	Post-Consumer PET Bottle	Khadem Mahmud Yusuf MD&CEO	BPCL Office, Dhaka
10	Royal Poly ware	Bangladesh	Post-consumer & Post-Industrial waste	Md. Shafiullah Chairman	RPL Office Dhaka

Justification

Cases from different parts of the world have been chosen purposively to find the critical success factors and the possible replication option from Bangladesh's perspective. Literature review revealed that there are various types and grades of plastic products available in the world that waste generation. Considering this, a few large-scale recycling companies have emerged across different parts of the world. The study has considered eight successful recycling companies from a global perspective along with two domestic recycling companies as stated above (Table 12). Mostly stable, large and prominent plastic waste recycling companies have been selected in this study. In Bangladesh, quite a few small-scale recycling companies have been operating their respective businesses over the years. But in terms of business value and volume till today there is no world standard company in Bangladesh except Bangladesh Petrochemical Company. Ten cases of different successful plastic waste recycling companies across the world including Bangladesh Petrochemical Company have been selected for this study.

4.2.4 Secondary Research

There are some exceptional publications on resource recovery devoted to the field of plastic and plastic waste field. In this connection, secondary and tertiary data were collected from published and published materials papers, journals, magazines, online articles, association bodies, company websites and news articles, and grey document reviews. Grey document review has been considered one of the most important techniques of this research. The term grey literature means the information produced by external traditional publishing and distribution channels and can include reports, policy literature, working papers, newsletters, government documents, speeches, white papers, urban plans, and so on (Janis McKenzie, 2020).

Though complex, grey literature is an extensive source of information. The Luxembourg definition of grey literature is a widely accepted description across the world as being produced on all levels of government, policymakers, academics, business, and industry in print and electronic formats which are not controlled by commercial publishers whereas publishing is not the primary activity of the producing body (Farace & Schopfel, 2010). These documents are not formally published in academics such as books & journals and include reports, theses, conference proceedings, newspapers, fact sheets, websites, policy documents, etc. Furthermore, unpublished research and data may be considered forms of grey literature in many cases (Higgins et.al, 2011). The Internet is often considered a central platform for publishing grey literature by a wide range of organizations, such as government and non-government organizations, business entities, research centers, profit, and nonprofit organizations, contributing to a proliferation of this source of data (Benzies et al, 2006). Thus, grey literature documents can serve as valuable resources for researchers, practitioners, and decision-makers across all disciplines, since these documents often contain policy and research-relevant information from authoritative sources and tend to be widely accessible.

The online publication is sourced from Plastic Europe, Recyclers Europe, British Plastic Federation (BPF), American Chemistry Council, Bangladesh Plastic Goods Exporters and Manufacturers Association (BPGMEA) Harvard Business Review (HBR), Google Scholar, Research Gate, and so on. Books on plastic and plastic waste have been reviewed based on the publication by top publishers like Macmillan, McGraw Hill Education, Sage Publications, Routledge, Oxford University Press, Cambridge University Press, The Guilford Press, and Pearson Education.

The data on selected renowned plastic waste recycling companies of developed countries and developing countries are mostly based on secondary data which played a significant role in this research. While collecting secondary and tertiary data four points principles of Scott (1990) 1) establish the authenticity of the evidence, 2) evaluate the credibility of the evidence 3) ensure the evidence is representative 4) Evidence is a clear and comprehensible guide to ensure the quality. These four points were carefully considered during the whole research work where data authenticity, the credibility of information, evidence with supporting data, and clear messages were taken as vital sources of information.

The literature in this study has been managed by searching for a structured database using pre-selected search words, while the papers from these searching have been screened for duplicates and irrelevance. Based on five inclusion criteria, the relevance of the papers has been assessed: 1) the value chain of plastic as the main area of interest; 2) primarily post-consumer/post-industrial plastic or plastic in general 3) the growth & development of plastic recycling 4) regulations & legislation and 5) plastic in the circular economy. Finally, a decision has been made to include only research relevant to the Bangladesh context. To provide an in-depth, systematic overview and discussion of the literature, the results have been presented and discussed.

4.3 Sample Design

4.3.1 Sample Groups

To understand plastic waste recycling and hence to devise a sustainable product strategy from plastic waste, it is important to understand the value chain of mainstream plastic waste. The plastic waste recycling value chain involves multiple actors. Thus, the research has followed a combination of judgmental and convenience sampling approaches. Sample groups consist of 1) Community collectors 2) Middle Dealers 3) Wholesalers 4) Industry Experts 5) Recyclers and 6) Cases of other countries and Bangladesh as chosen heterogeneously.

4.3.2 Sampling Techniques

A researcher selects respondents/sampling units to draw a purposive sample because they have characteristics that the researcher desires. Keeping specific characteristics in mind, a researcher wishes to examine and then seek out research participants who cover that full range of characteristics (Neuman, W. L 2014).

Convenience sampling is a nonprobability sampling strategy that is employed to draw a convenience sample, a researcher simply collects data from people or other relevant elements that they can access conveniently and is the most useful in exploratory research (Mason, M. 2010). To this end, the study adopted the following method of sampling:

Table 4.6: Sample Types

Sample Type	Description
Purposive	The researcher seeks out respondents/sampling units with specific characteristics
Convenience	The researcher collects data from whatever cases happen to be convenient

Adopted from DeCarlo, M. (2018). Scientific inquiry in social work.

The research considered a convenient approach to conduct the open-field interviews with the waste pickers and middle dealers; while the purposive sampling technique considered conducting open-field interviews with wholesalers and recyclers. In-depth interviews and case methods are considered purposive sampling. A large number of waste plastic recycling industries are operating all across Bangladesh. The goal is to analyze the business models of recycling companies. For this research case study purpose, some successful and large plastic waste recycling companies in developed and developing countries have been considered.

Table 4.7: Sampling Techniques & Justification

Sampling Units/Respondents	Sampling Techniques	Justification
Waste Pickers	Convenience	Waste pickers are usually found in clusters. Therefore, they are being chosen conveniently.
Middle Dealers	Convenience	Middle dealers are found in every ward of Dhaka City. They used to do the same task. Thus, the convenience sampling technique has been applied to choosing middle dealers as respondents.
Wholesale Dealers	Purposive	Wholesale market is mainly located at Nimtali of old Dhaka. Thus, respondents are selected on the basis of a purposive approach.
Recyclers	Purposive	Almost all plastic recycling facilities locate in Old-town (Islam Bag & Kalam Bag). Thus, respondents are selected on the basis of a purposive approach.
Industry Experts	Purposive	Respondents were purposefully chosen from international exhibitions such as Taipeiplas 2018, Plastindia 2019 and IPF 2019 because of their respective presence at those events.
Case Studies	Purposive	Representatives of case organizations were present in Taipeiplas 2018, Plastindia 2019 and IPF 2019. Therefore, cases are purposefully selected for the study.

The sample considered here has a wide representation in the country.

4.3.3 Sample Sizes

The open-ended field interview was conducted among waste pickers, middle dealers, wholesale dealers, and recyclers in Dhaka metropolitan city of Bangladesh the following respondents were in Dhaka City of Bangladesh.

Table 4.8: Sample size and Justification

Sampling Units/Respondents	Sample Size	Justification
Waste Pickers	50	For the case of qualitative study, we took a reasonable sample size to get a favorable outcome and stay far from data saturation. Because after taking these sample sizes, if here the study incorporates more samples, then the scope of getting new information is limited and most of the cases close to zero. So, from the perspective of data saturation, here sample size is not increased further for this qualitative study.
Middle Dealers	25	
Wholesale Dealers	25	
Recyclers	10	
Industry Experts	32	
Case Studies	10	

Waste collectors are used to roam across the city from morning to afternoon and fifty (25 from Dhaka south city corporation and 25 from Dhaka north city corporation) were interviewed as a convenient approach because of their mobility. On the other hand, in every ward of both city corporations there exist numbers of middle dealers who used to sell various types of waste to the wholesale market located in Namtali at Old Town. 25 Middle dealers were interviewed as a conventional approach.

Almost all plastic recycling facilities exist in Old-town (Islam Bag & Kalam Bag) at the periphery of the Buringanga River. 25 wholesalers and 10 recyclers were selected purposively for the open-field interviews.

Compared with global standards there is no large-scale plastic waste recycling company in Bangladesh till today though significant numbers of small-scale plastic waste recycling companies existed. However, according to an industry expert, one medium-range company is doing well over the years. Thus, among many small plastic waste recycling companies in Bangladesh, this research only purposively considered a medium-range company and a small-scale recycling company in Bangladesh to understand, evaluate and replicate the business models.

A similar approach is taken for the selection of recycling companies in different countries. A purposive approach has been taken to stress the place for studying business models. Locations are widely spread across different parts of the world. This is mainly to study possible replication and scalable options in the case of Bangladesh as well as a good representation of the sample.

4.4 Data Collection Techniques

It is well regarded by all that successful data collection technique plays an important role in making the research successful. As stated earlier, the research has conducted qualitative methods and focused on primary, secondary, and tertiary data. For getting primary data researchers conducted in-depth interviews with Key Informants and industry experts, open-ended field interviews with waste pickers, scrap dealers & traders, recyclers, and on-site observation of the collection, sorting, segregation, recycling, and new product making, institutional functions, and capacity. The questionnaire was conducted with the help of six interviewers under the strict supervision of the researchers. The questionnaires were field-tested before finalization, and four several questionnaires were made for collecting data from waste pickers, middle dealers, wholesalers, and recyclers respectively. Questionnaires were administered by the field interviewers after adequate training. Secondary and tertiary data sources include published materials papers, journals, and news articles, grey document reviews, and have been documented with proper referencing. The necessary data for this research were collected by using the following techniques.

Table 4.9: Data collection techniques

<table>
<tr><th rowspan="2">Research Design</th><th rowspan="2">Primary Data Collection</th><th colspan="4">Sample Design</th></tr>
<tr><th>Respondents</th><th>Sampling Techniques</th><th>Sample Sizes</th><th>The rationale for the small sample sizes</th></tr>
<tr><td rowspan="11">Exploratory</td><td>Open-field interview & Observation</td><td>Waste Pickers</td><td>Convenience</td><td>50</td><td rowspan="2">Since it is a qualitative study, small sample size taken into consideration for getting better outcome and staying away from data saturation.</td></tr>
<tr><td>Open-field interview & Observation</td><td>Middle Dealers</td><td>Convenience</td><td>25</td></tr>
<tr><td>Open-field interview & Observation</td><td>Wholesale Dealers</td><td>Purposive</td><td colspan="2">25</td></tr>
<tr><td>Open-field interview</td><td>Recyclers</td><td>Purposive</td><td colspan="2">10</td></tr>
<tr><td colspan="5">Duration of Open-field Interviews: January 2019 to February 2020</td></tr>
<tr><td>In-depth expert interview</td><td>Industry Experts</td><td>Purposive</td><td colspan="2">32 (Domestic: 13 & Foreign: 19)</td></tr>
<tr><td>Literature Review</td><td>Various Sources</td><td>Purposive</td><td colspan="2">250 Papers</td></tr>
<tr><td rowspan="2">Case Method</td><td rowspan="2">Foreign & Domestic</td><td rowspan="2">Purposive</td><td colspan="2">8 Foreign</td></tr>
<tr><td colspan="2">2 Domestic</td></tr>
<tr><td colspan="5">Duration of Case studies: January 2018 to March 2020</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Analysis</td><td colspan="5">Findings have been supplemented by relevant qualitative analysis</td></tr>
</table>

4.4.1 Data Collection, Processing, and Analysis

The success of any research depends upon the effective presentation and analysis of collected data (Cooper et al, 2014). The collected qualitative data were classified according to their nature as primary, secondary, and tertiary data. They were further organized, analyzed, and finally presented in a suitable form and format following interview questions.

The primary data have been collected through open-field interviews. For an in-depth discussion, interviews have been conducted among industry experts in the plastic sector from home and abroad. Each session was from half an hour to an hour. However, for the open-field interviews, data were collected through open-ended questionnaires (see appendix). Apart from that, the respondent demographic information also helped to identify their views under diverse scenarios like age, education, length of business/service, position, location, and involvement with the current waste collection, sorting, recycling, and reprocessing activities. The following points were considered carefully while developing questionnaires:

- Introductory Part: Names & Contact details of the respondents
- Demographic part: Age, education, profession, and income level of the respondents
- Questions on the present activities of plastic waste collection, sorting, recycling, selling, reprocessing - type, nature, social contribution, addressing social & environmental issues, etc.
- In Dhaka city, a pilot test was conducted among 50 respondents (20 waste pickers, 15 middle dealers, 10 wholesalers, and 5 recyclers).
- Questionnaire has been translated from English to Bengali for open-field interviews.

While making the questionnaire, it was taken into consideration that different questions shall provide different types of qualitative data, starting from demographic/ personal information to service/business. Through the pilot, test questionnaires have been reevaluated to structure and identify if there is any inconsistency or irrelevancy in data collection.

After completing the pilot test, the study conducted an open-field interviews targeting the value chain actors of plastic waste recycling, and in-depth expert interviews to gather primary data, and then the main analysis began.

This research follows a matrix to compare business models as a methodical tool to consolidate and evaluate business models. The matrix method stimulates pattern matching and effective classification of data (Miles & Huberman, 1994). Finally, this research aims to explore the feasibility of a sustainable plastic waste recycling industry in Bangladesh and develop a business model for Plastic waste recycling. This will help business persons associated with the plastic sector to take decisions on their business. The business model canvas and its components were used to compare the real case analysis. On the other hand, the Lowell Center Framework for Sustainable Products helps companies to evaluate whether their products are sustainable and hence assess the prospect and opportunities for replication and scalability of the business model on the circular economy notion.

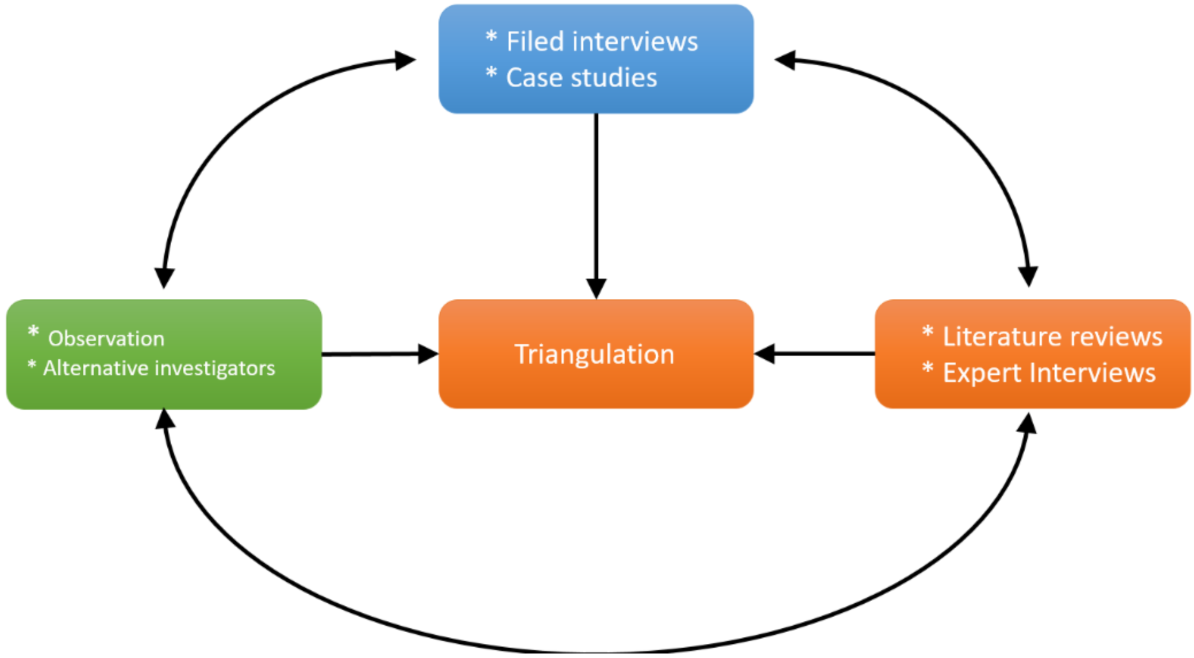
As this is qualitative research, no statistical analysis has been used.

4.5 Validity

Validity means different things to different observers and there is more than one type of validity that has been suggested as particularly appropriate to the logic of qualitative research Triangulation, meaning comparing different kinds of data quantitative and qualitative, and different kinds of methods such as observation and interview, case studies, etc., (Silverman, 2003). Validity means truthful' referring to the bridge between the construct and the data (Lawrence Neuman, 2003) where validity is done with the association between data and conclusion (Lamnek, 1988). According to Lamnek (1988) that qualitative studies attain higher validity than quantitative studies since in qualitative research, the data are closer to the research field, and a successive data expansion is possible.

Therefore, validity in qualitative research concerns the relationship between data and construct, findings and conclusion, reality and representation; in other words. In qualitative research, the possibility of validity rises with the effort to reduce the gap between a social reality that has been researched and the representation that the research produces. The study adopted a triangulation method for establishing validity that includes data triangulation, investigator triangulation, and methodological triangulation. Data triangulation involves the use of different sources of data/information categorized into different groups related to the study topic. Considering investigator triangulation, the researcher has used several different investigators/evaluators for the study for evaluating the findings until arriving at the same/approximate conclusion for establishing validity. Finally, methodological triangulation has been applied by applying field interviews, secondary research, case studies, and expert interviews to this study to reach the same/approximate conclusion from each method.

Figure 4.8: Triangulation: Establishing the Validity



Experts suggest taking meaningful action for the production, consumption, waste generation, and waste re-processing of plastic to attain economic, environmental, and societal benefits since the different pathways are often distinct, challenging to determine the right actions for the collection, sorting, and reprocessing of different types of plastic wastes, or to understand the synergies between different solutions. Therefore, the study attempts to fill those gaps by investigating the existing plastic recycling value chain, extensive reviewing of secondary research, conducting cases studies (foreign & domestic), and interviewing both global & local experts focusing on the best-case scenario to transform the existing system in Bangladesh into a standard system practiced across the globe that will certainly reduce the gap between the existing scenario of plastic waste recycling sector and representation originating from the research. Considering the above, the study has made an attempt to prove that the research is properly valid.

4.6 Reliability

Reliability is commonly used in relation to the question of whether the ‘measures that are devised for concepts in the social sciences are consistent’ (Bryman, 2008). According to Hammersley, reliability refers to “the degree of consistency with which instances are given to the same category by different observes or by the same observers on different categories” (Hammersley, 1992). Similarly, Lawrence Neuman, argues that ‘reliability means dependability of consistency’ where the qualitative researchers ‘use a variety of techniques such as interviews, participation, documents, and case studies to record their observations consistently’ (Lawrence Neuman, 2003). On the other hand, according to Silverman, reliability can be addressed by using standardized methods to write filed notes and proper transcripts in the case of interviews and document studies, and a method by which the reliability of a qualitative method can enhance, asserting that “reliability can be improved by comparing the analysis of the same data by several observers” (Silverman, 2003). Therefore, a qualitative study can be gauged or regarded reliable as to check whether, how and to what extent consistent methods and measures are used. For example, with proper tabulated participant observation, literature reviews, qualitative interviews, field surveys, focus groups, and conversation analysis research, tapes and transcripts are open to supplementary examination by both researchers and readers; this would allow both to verbalize their ideas about the position of the people who have been studied. It is compulsory for qualitative researchers to document their procedures and to reveal that categories have been used consistently for the reliability of the study.

There is no” silver bullet” solution to significantly lessen plastic waste generation and disposal rather deploying upstream and downstream solutions together while engaging plastic value chain actors, policymakers, experts, researchers, and organizations that are in this field for attaining the most effective output (SYSTEMIQ, 2022). To this end, the study has been conducted to collect data maintaining utmost consistency from value chain actors through field interviews, secondary research, case studies, and expert interviews as all these have a key role to play in the days ahead of the future plastics system in Bangladesh, and none can be left out, but none are sufficient on their own. Thus, the study has confirmed and argued that the tabulated data of findings from field interviews, secondary research, case studies, and expert interviews have been documented properly and showed that the categories have been used consistently. In addition, the study has confirmed the possibility to achieve properly reliable qualitative research and argued that the degree of reliability can be improved with properly tabulated data of findings that are open to supplementary examination by both researchers and readers to enable them to articulate their views about the position of the researched, in relation to the study topic and the researcher. Considering the above, the researcher persuasively argued that the research is properly reliable.

Chapter Summary

This chapter started by describing the research philosophy and philosophical assumptions for this study. The chapter also has exemplified detailed methodology and an overview of Business Model Canvas and The Lowell Center Framework for Sustainable Products through which case studies have been conducted.

CHAPTER 5: EVALUATION OF THE CURRENT PLASTIC WASTE RECYCLING VALUE CHAIN

Outcomes of the specific objective 1

To evaluate the current state of the plastic waste recycling value chain

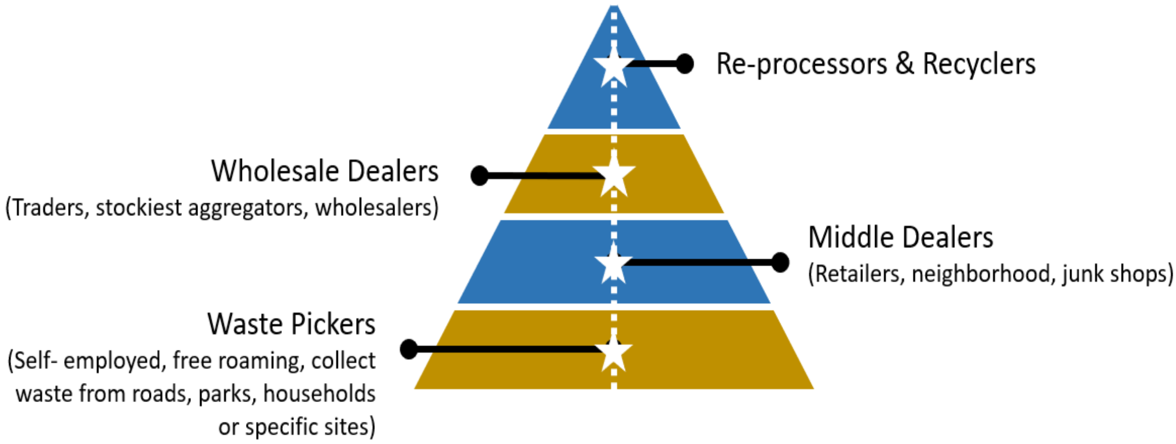
CHAPTER CONTENTS

This chapter provides a total overview of findings from field interviews with plastic recycling value chain actors such as waste pickers, middle dealers, wholesale dealers and recyclers, and expert interviews related to the prevailing plastic recycling value chain in Bangladesh, and the future growth and development of the plastic recycling sector, aligning with the global practices. This chapter also summarizes prevailing legislative groundwork of Bangladesh

CHAPTER 5: EVALUATION OF THE CURRENT PLASTIC WASTE RECYCLING VALUE CHAIN

This chapter of the study documented the outcome of open field interviews with fifty waste pickers, twenty-five middle dealers, twenty-five wholesale dealers, and ten recyclers in both city corporations. Apart from this, expert interviews were undertaken along with the analysis of prevailing legislative groundwork of the plastic recycling value chain to document the economics of waste retrieval by studying how waste is regained and chart its journey towards the recovery and recycling markets in terms of value addition. The literature review revealed that against the aggregate consumption of 977,000 tons of plastic in 2020, only 31 percent were recycled in Bangladesh, and in Dhaka, about 646 tons of plastic waste is collected daily which 37.2% is recycled. (Waste Concern, 2020) which is higher than the global average of about 9% (Geyer et al. (2017). Even though the annual percentage of plastic waste recycling is higher than the global average, Bangladesh's annual plastic waste recycling percentage is declining gradually over the last 10 years, it was more than 50% (Waste Concern, JICA, BPGMEA 2014). The literature review also revealed that plastic recycling has been proven difficult and uneconomical in Bangladesh despite the aggregate recycling percentage being higher than the global average where plastic waste recycling is mainly done by the informal sector. Aiming to extract the ultimate benefit from this potential sector, the study has evaluated the current state of the plastic recycling value chain through open-field interviews with the value chain actors such as waste pickers, middle dealers, wholesale dealers, and re-processors. Similarly, the study also considered expert interviews for knowing the same and incorporated them into this report. Thus, this chapter provides a total overview of findings from open field interviews, existing legislative groundwork, and expert interviews related to the prevailing plastic recycling value chain in Bangladesh, and the future growth and development of the plastic recycling sector, aligning with the global practices for the same that enables to meet the first objective. Value Chain Actors of the Plastic Waste Recycling Pyramid are depicted in Figure 5.1.

Figure 5.1: Plastic Waste Recycling Pyramid: Value Chain Actors



Plastic Waste Recycling Pyramid: Value Chain Actors

5.1 Findings and Discussions

5.1.1 Waste Pickers

Waste pickers, scavengers, Tokai, Vangariwala, Feriwalla... all are names for those people who make a living on waste in an informal way in Bangladesh and they have no contract, no regular income, rather a simple kit to work with, no formal recognition and high vulnerability. Municipal solid waste is mainly recovered by informal sector collectors though there exist no exact figures of authentic waste generated or the waste composition. According to World Bank (2020), there are 1300 Feriwallas, 1800 DCC crews, and 5,800 Vangariwallas collectors in both city corporations who collect waste and sell it to middle dealers or wholesale dealers across different wards of Dhaka Metropolitan City. Among these collectors, 50 were considered conveniently and interviewed through an open-ended questionnaire. Since the same response and answers were generated from these open-field interviews, the study had not considered more respondents. The study discovered there are mainly two types of waste pickers- Municipal Collectors and Independent collectors (Tokai, Feriwalla, Vangariwala) and all of whom informally collect various types of waste and sell to middle dealers or wholesalers or preprocessors. Of the 50 waste pickers, 80 % (40) were city corporation waste pickers and the rest 20 % (10) were independent waste pickers (popularly known as TOKAI, Vangariwalla, Feriwalla).

Waste-pickers operate purely while free roaming by picking various types of waste from the streets, parks, households, industries, offices, and other public gathering hubs. They collect small quantities and then, sell them to the local neighborhood middle dealers. A total of 50 waste pickers were interviewed (Table: 5.1) conveniently available from different wards of Dhaka City Corporations (North & South).

Table 5.1: Total numbers of Municipal Collectors & Waste Pickers Interviewed

Dhaka Metropolitan City	Total Numbers	Numbers of Wards
Dhaka North	25	54
Dhaka South	25	75

The questions were related to the type of waste, length of time in waste picking, sources of waste, average income, and other factors depicted below table.

Table 5.2: Waste Pickers' response about the questions

Question	**Theme**	**Participant Response**
Who do you sell the recyclables to?	Buyer	• Wholesale markets /Middleman /Recyclers • Other large single-material types of dealers • Directly to manufacturers
What is the average daily collection of plastic waste? (In kg)	Average Daily Collection	• Municipal collectors: 5-50 Kg/day • Itinerant waste pickers: 5-10 Kg/ day.
What is the price/kg of plastic waste of different types that you buy?	Buying Price	• 2-15 Taka/Kg depending on the quality • Usually, PET Bottle price is higher
What is the price/kg of plastic waste of different types that you sell?	Selling Price	• 5-25 Taka/Kg depending on the quality • Usually, PET Bottle price is higher
What are the methods used to collect plastic waste?	Collection Method	• Municipal collectors: By rickshaw Van • Itinerant waste pickers: Walking by Foot
What are the sources and methods used to clean the collected plastic waste?	Sources and cleaning methods	• Sources: Households, Municipal collection points, other traders • Cleaning methods: Traditional manual cleaning
What are the methods used to identify and sort collected plastic waste?	Sorting Method	• Manual sorting mainly
What challenges and problems do you face in the business?	Challenges and Problems	• no contract • no regular income • no formal recognition and • high vulnerability
What are the new trends you have observed in this type of business over the years?	New trends in the waste business	• Number of itinerant waste pickers is gradually declining

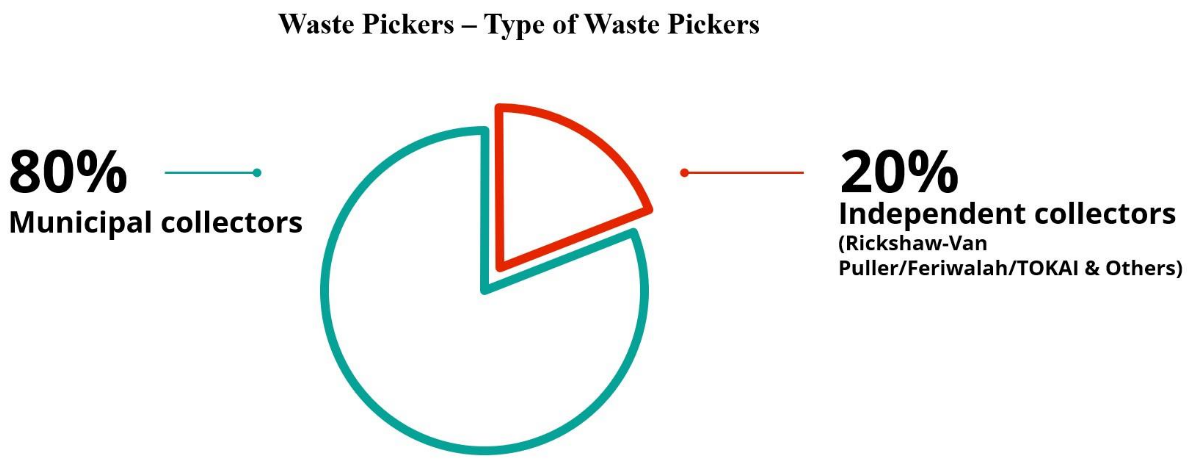
5.1.1 Summary of Major Findings (Waste Pickers)

The outcomes of the interviews have been analyzed applying some basic mathematical tools and techniques that are described in the following sections. Since it is a qualitative study no statistical formula and techniques has been used here.

5.1.1.1Type of Waste Pickers

There are different types of waste pickers roaming around the city. They are mainly typed as municipal collectors and independent collectors (popularly known as TOKAI). Of the 50 waste pickers interviewed, 80 % (40) were city corporation's waste pickers and rest 20 % (10) were independent waste pickers (mainly TOKAI). Rickshaw van puller, Feriwalah etc. can be also considered as independent collectors. The type of waste pickers is depicted at the following figure:

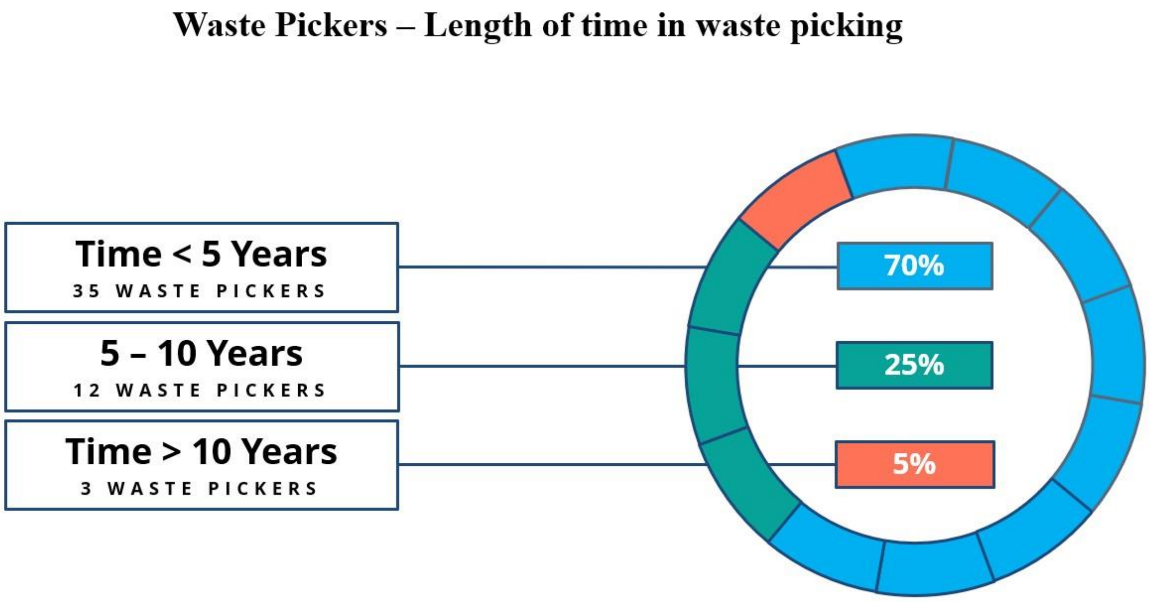
Figure 5.2: Waste Pickers Type



5.1.1.2 Length of Time in Waste Picking

It has been found from the field interviews with the waste pickers that approximately 70% (35) of waste pickers are below five years, 25 % (12) are five to ten years and 5 % (3) had more than ten years of waste picking and selling experience that has been depicted in the following figure:

Figure 5.3: Length of time in waste Picking



5.1.1.3 Sources of Recyclable Waste

Municipal and independent collectors equally get waste of different types from various sources. From those, a major portion of waste is obtained from households (75%) and Municipal Collection Points (15%), and the rest 10 % from other sources such as traders, factory caretakers, hotels, maids, office assistants, restaurants, and construction workers. The below figure depicts sources of recyclables:

Figure 5.4: Recyclables Sources

5.1.1.4 Types of Waste Handlings

Waste Pickers usually collect all types of recyclable solid waste upon availability such as bottles, drums, paper, cardboard, soap, tin, and iron. Regarding plastic waste, PET bottle waste is getting more popular to waste pickers than other plastic waste as it gets higher prices. Apart from this consumer goods like toothbrushes, empty toothpaste tubes, toys, helmets, shampoo bottles, lotion bottles, car dashboards, pipes, computers, telephones, food packaging, chairs, tables, frames, and other households' plastic items have also great demand to the waste pickers.

Table 5.3: Types of Waste handlings

Types of Waste Handling	Types of Plastic Waste Handling
• Plastic • Paper • Shipping Carton • Metal • Aluminum • Glass	• PET Bottle • PVC • Plastic Film & Sheet • Plastic Jar & Bottle • Other Plastic

5.1.1.5 The average income per day

The interview cited that most waste pickers were unwilling to give information about their daily earning. Largely, the analysis shows that municipal collectors earn more than itinerant waste pickers. Because municipal collectors use rickshaw vans that can carry volumetric waste and can cover wide areas for collecting waste. On the other hand, itinerant waste pickers are used to collect waste on foot while carrying simply one big bag. The analysis shows that municipal collectors can earn 100 to 500 taka per day while itinerant waste pickers hardly managed to sell 100-150 taka per day.

5.1.2 Middle Dealers

Middle dealers are the main source to get the recyclables for the wholesale market. In every ward of the city corporation of Dhaka, there exist four to five middle dealers that buy various types of waste from scavengers, households, and industries. After collecting various waste, they used to sort and segregate it manually by waste type and then send it to the wholesalers or the preprocessors. There are mainly three types of middle dealers -minor, small, and medium within the locality. Minor and small middle dealers connect with middle dealers to sell their respective wastes. On the other hand, medium and large-scale collectors, strategically located within the wholesale market or the reprocessing facilities, have bridges with wholesalers and re-processors. The majority of the material is sent to the informal waste groups for accumulation, exchange, processing, or product manufacturing for specific materials. These open-field interviews covering 129 wards across Dhaka North (54) and South (75) City Corporation were carried out with the help of 5 field staff. 40 shops were interviewed out of which 25 samples were considered for analysis and the rest 15 samples did not respond. The interview questions were related to the length of business, possession of shops, sources of waste, average income, connection with selling points, manpower, infrastructure, transportation facilities, frequency of sale, and other related factors. The questions also include the opportunities and threats that come from uncontrollable external factors depicted below.

Table 5.4: Middle Dealers' response about the questions

Question	Theme	Participant Response
Who do you sell the recyclables to?	Buyer	• Wholesale markets /Middleman /Recyclers • Other large single-material types of dealers • Directly to manufacturers
What is the average daily collection of plastic waste? (In kg)	Average Daily Collection	• 92 % (23) of dealers collect less than 300 Kg daily. • 8 % (2) dealers collect 300 to 1 ton daily.
What is the price/kg of plastic waste of different types that you buy?	Buying Price	• 5-15 Taka/Kg depending on quality • Usually, PET Bottle price is higher
What is the price/kg of plastic waste of different types that you sell?	Selling Price	• 10-30 Taka/Kg depending on quality • Usually, PET Bottle price is higher
What are the methods used to collect plastic waste?	Collection Method	• Traditionally practiced manual process
What are the sources and methods used to clean the collected plastic waste?	Sources and cleaning methods	• Sources: Households, waste pickers, and other traders • Cleaning methods: Traditional manual cleaning
What are the methods used to identify and sort collected plastic waste?	Sorting Method	• Manual sorting mainly
What are the sorted types of collected plastic waste?	Sorted types of plastic waste	• PET Bottle • Plastic Jar, container • Plastic films

		• Household plastics
Do you have any type of machinery to process the waste (baling, etc.)?	Waste processing machinery	• Middle dealers don't use waste processing machinery
Are there any seasonal variations in work and how does this reflect in the business in terms of number of employees, type of material in demand, etc.?	Seasonal Variation and its Impact	• During winter PET Bottle waste collection comes down • During the rainy season overall waste generation comes down. • Seasonal variations reflect the business in terms of employee numbers, material demand, and material quality, etc.
What challenges and problems do you face in the business?	Challenges and Problems	• Police harassments • Musclemen harassments • Volatile transportation cost • no formal recognition and • high vulnerability
What are the new trends you have observed in this type of business over the years?	New trends in the waste business	• Number of itinerant waste pickers is gradually declining • Wholesalers and re-processors directly buy from waste generation sources and waste pickers in many cases.

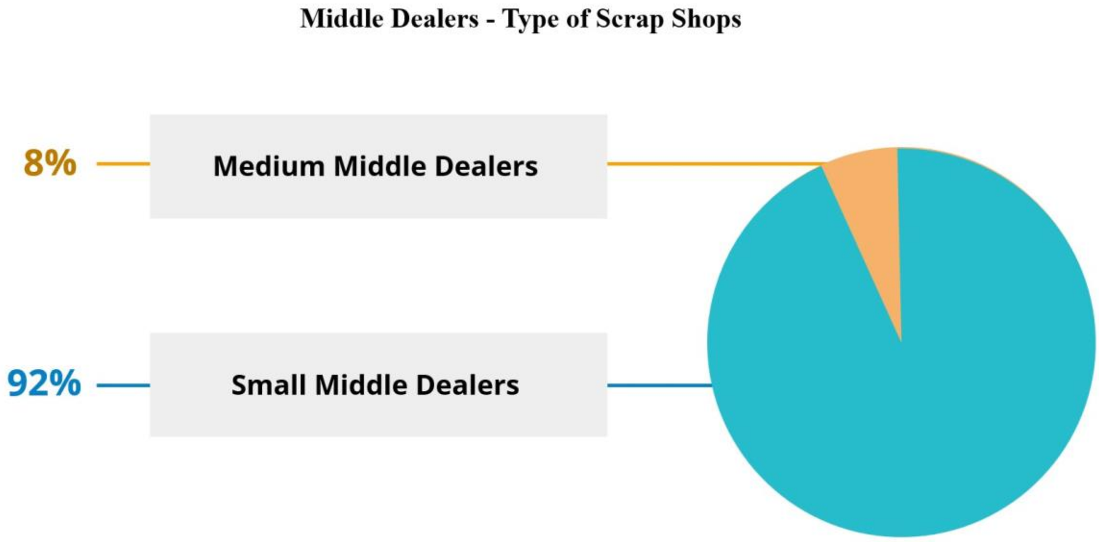
5.1.2.1 Summary of Major Findings (Middle Dealers)

The outcomes of the interviews have been analyzed applying some basic mathematical tools and techniques that are described in the following sections. Since it is a qualitative study no statistical formula and techniques has been used here.

5.1.2.1.1Type of Middle Dealers

Middle Dealers are mainly located in various wards of both Dhaka North and South City corporation as well as the periphery of the city. They used to buy various wastes including plastic waste from municipal collectors, independent collectors, households etc. There are mainly two types of middle dealers are seen such as small and medium. From the 25 small and medium middle dealers considering the quantities of waste handled per day, 92 % (23) were small middle dealers handle less than 300Kg daily and rest 8 % (2) were medium middle dealers handle 300 to 1 ton daily. The below figure displays scrap shops types of middle dealers:

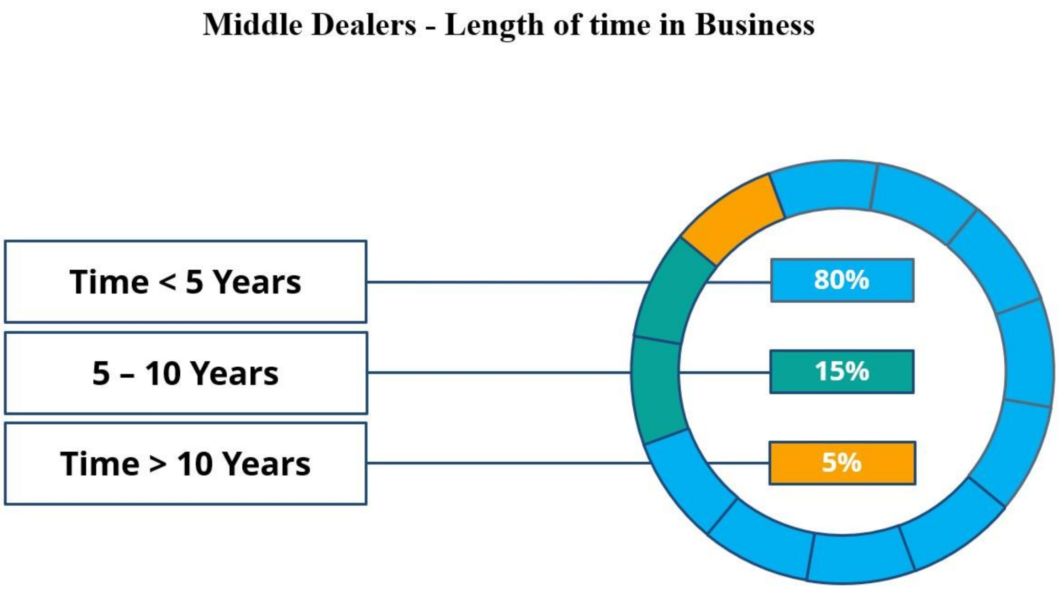
Figure 5.5: Type of Scrap Shops of middle dealers



5.1.2.1.2 Length of Business

It has been found from the field interview and observation that about 80% (20) of middle dealer are less than five years business experience, 15 % (4) are within the range of five to ten years' experience. On the contrary, only 5 % (1) had more than ten years of business experience in this trade. The study also discovered that the business of middle dealers is highly volatile and fragmented. The below figure depicts the length of business experience of middle dealers:

Figure 5.6: Length of time in Business (Middle Dealers)



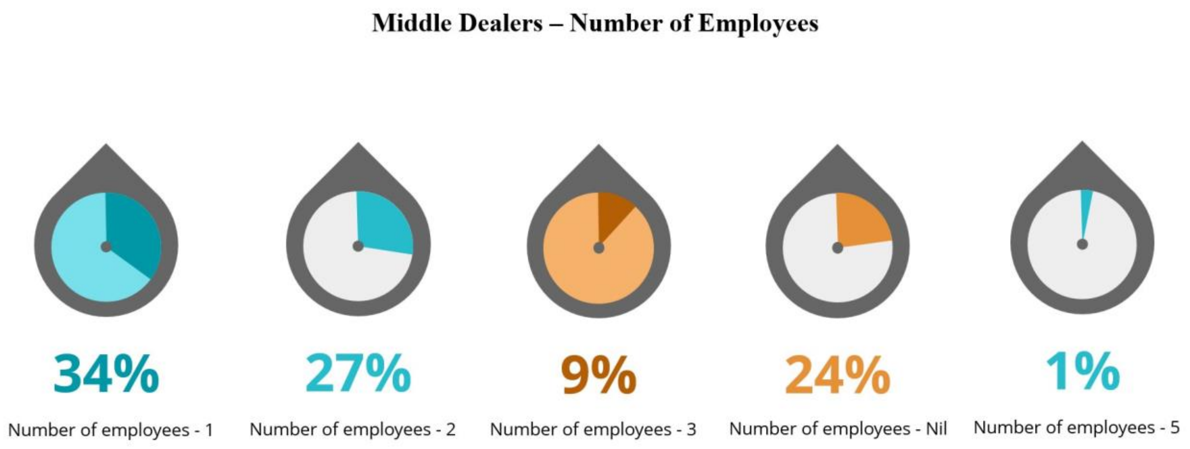
5.2.1.3 Possession of Shops

The study has found that about 97% (24) of shops are operating their respective business in rented spaces whereas only 3% (1) of shops are doing business on their own spaces. Most of the middle dealers are categorized as small shops. The study has found that almost all shops are placed in abandoned, unused, disputed land. Some of the shops are such space that is being left for building construction. Therefore, the business of the middle dealers is not stable and permanent.

5.1.2.1.4 Number of Workforces

It has been observed that 34% of middle dealers have one worker, 27% have two workers, 9% of have 3 workers and a noteworthy 24% of middle dealers do not have any workers in their shops. Those who don't employ any worker used to work by themselves, and family members assist in some exceptional cases. The study found only merely 1% has more than five workforces. The number of workforces are illustrated below:

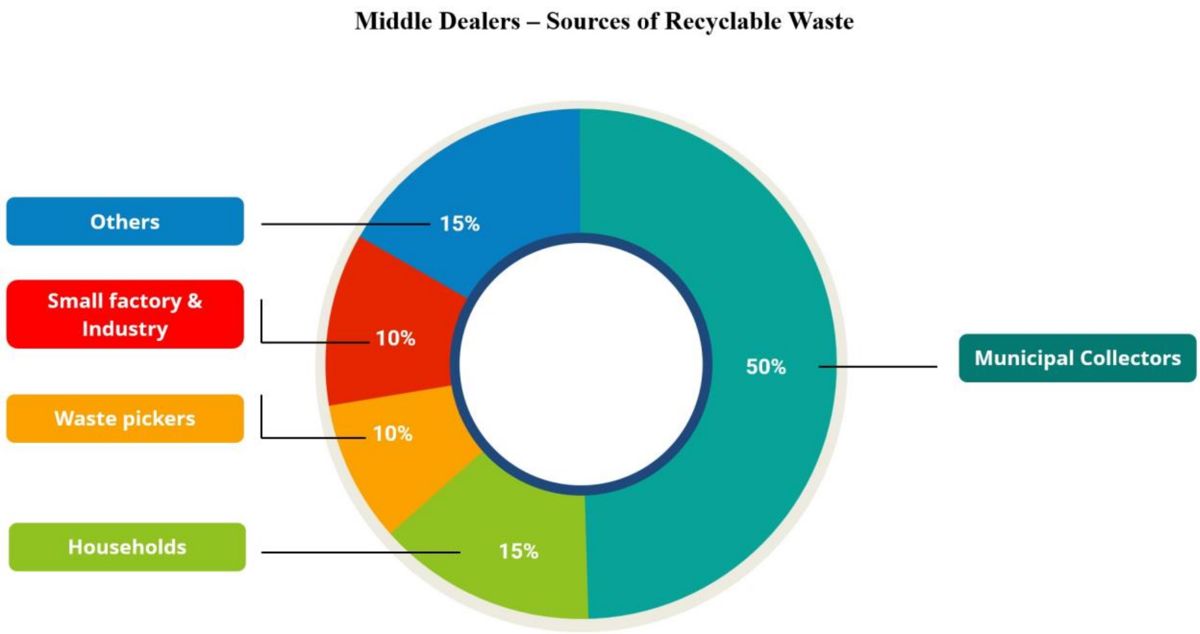
Figure 5.7: Number of Workforces of Middle Dealers



5.2.1.5 Sources of Recyclable Wastes

Regarding the collection of plastic waste, small and medium middle dealers equally buy from numerous sources. The majority of the waste is sourced from Municipal collectors (50%), households (15%), waste pickers (10%), small factories & Industry (10%), and the rest 15 % from other varied sources including factory workers, maid, market, park, caretakers, guard, hotels, office boys, community center, restaurants, and construction workers which are illustrated below:

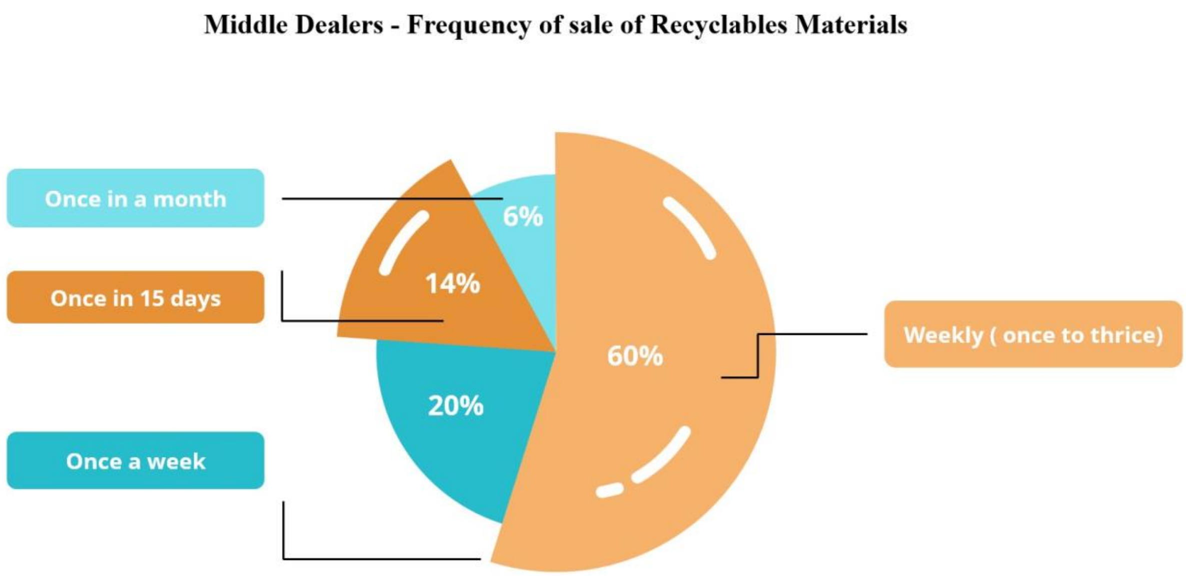
Figure 5.8: Recyclable waste sources by middle dealers



5.2.1.6 Frequency of Sale of Recyclable Waste

A remarkable 60% (60) of middle dealers sell their respective wastes daily and thrice on weekly basis due to space shortage and 20% (20) dealers sell once a week mainly owing to space limitations similarly. Likewise, 14% (14) of dealers sell different types of waste every fifteen days, and 5% (5) of middle dealers sell once in a month. The below figure displays the frequency of recyclable waste sale:

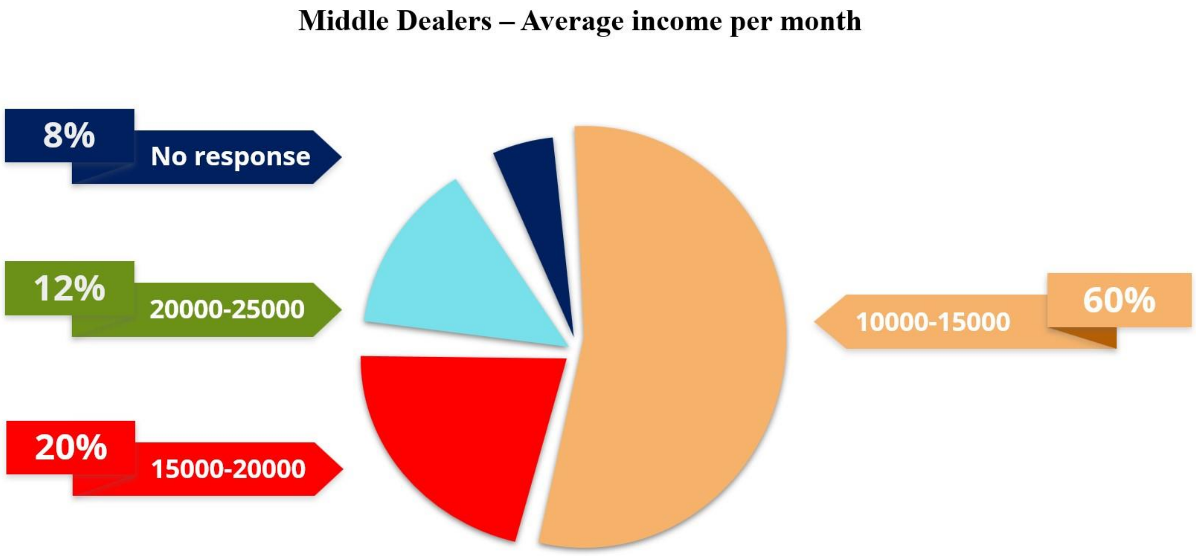
Figure 5.9: Frequency of sales of Recyclables by Middle Dealers



5.2.1.7 The Average Earning Per Month

Most of the middle dealers were decidedly unwilling to provide their average daily earnings. Even though the study discovered that 60% (60) of middle dealers earn in the range of TK 10000 to 15000 per month, 20% (20) of the middle dealers earn within the range of TK15000-20000, 12% (12) more than TK20000-25000 per month and 8% refused to reveal the details which have been illustrated in the below figure:

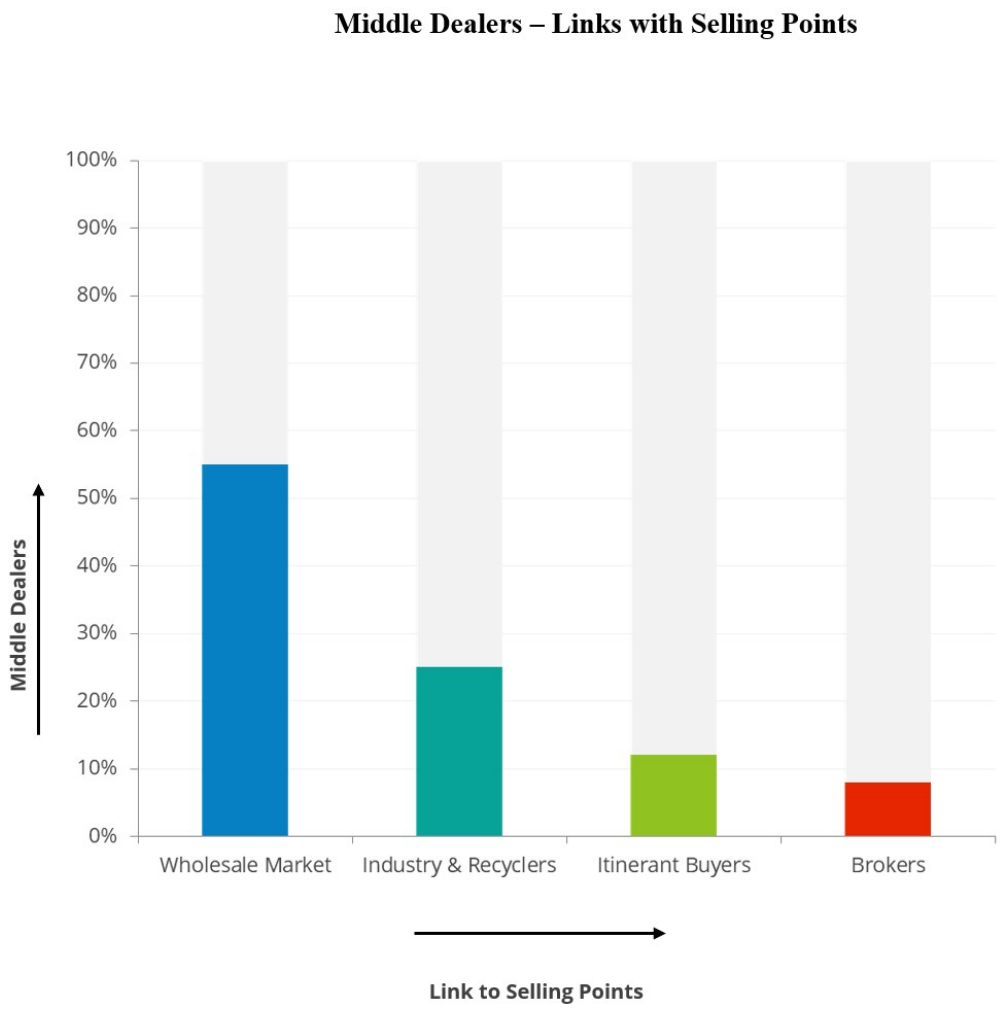
Figure 5.10: Average Earnings per month by Middle dealers



5.2.1.8 Connection with Selling Points

The study discovered that the main wholesale center of plastic waste recycling is located in Nimtali at Old Dhaka. Around 55% of the middle dealer sell the recyclables in Nimtali and 25% of middle dealers sell directly to industry and recyclers, 12% of middle dealers sell directly who come and pick the materials from their shop or sell it to nearby wholesale shops and 8% sell to brokers (Figure 5.11).

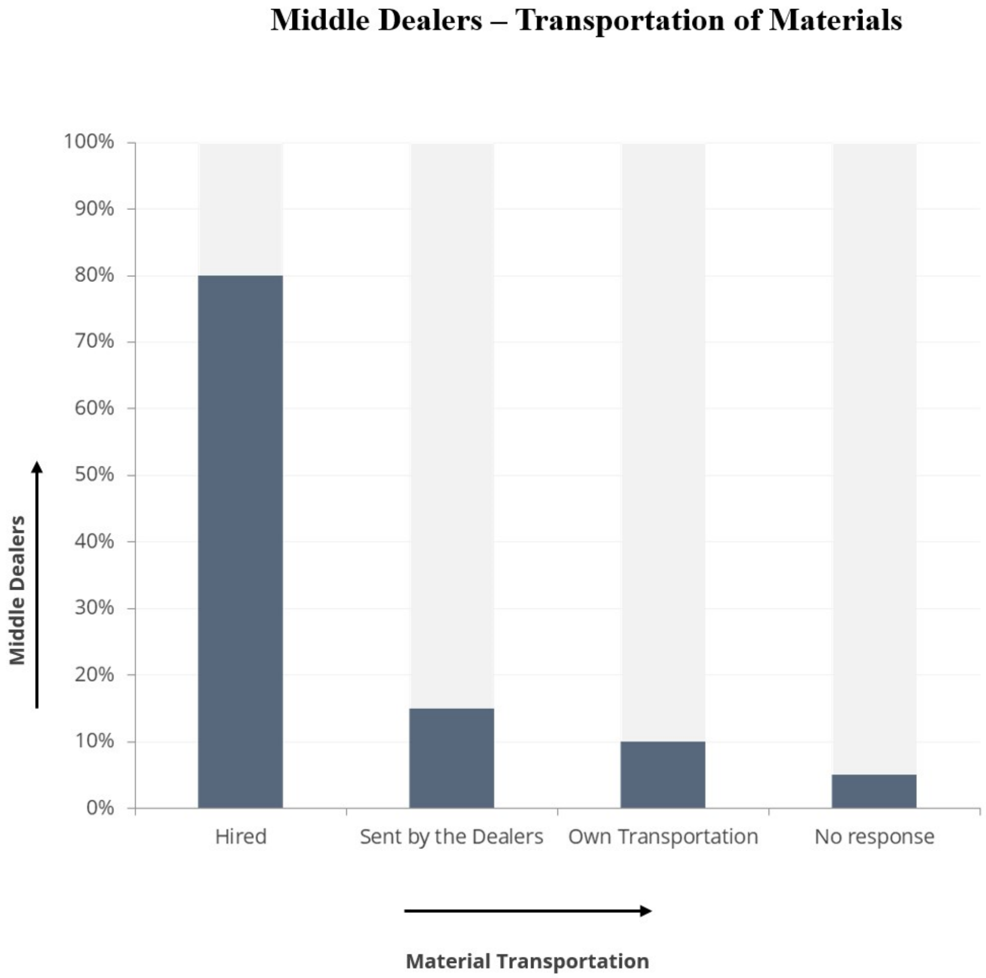
Figure 5.11: Middle dealer’s connection with selling points



5.2.1.9 Transportation of Recyclable Wastes

After investigation, it has been discovered that transportation is one of the major expenses to sell recyclables in the market and the middle dealers need to invest for the transportation of the recyclable wastes. The study found that 85% are hiring transports to carry recyclables whereas 15% middle dealers get vehicles from buyer, 10% of middle dealers have their own transportation and 5% refused to reveal details (Figure : 5.12).

Figure 5.12: Transportation (Middle Dealers)



5.2.1.10 Infrastructure Facilities

It has been observed that the capacity of waste handling is directly relational to the available space for the movement of transports, sorting, binding, storing and loading before transportation. The middle dealers handling 200 KG -800 KG daily performed out of an average space of 300 square feet. They do not use any kind of machines to sort the waste, instead everything is done manually.

5.2.1.11 Challenges and Problems Used to Encounter by Scrap Shop Holders

The study found that 70% of the middle dealers are facing frequent police harassment and they have to give bribes regularly since most of the middle dealer do not possess required trade license the business operation. While some of the middle dealers also encounter difficulties from the city dwellers. On top of that space-constraint is another noteworthy problem.

5.1.3 WHOLESALE DEALERS

Dhaka receives plastic waste from different areas of Bangladesh and the wholesale market located in Nimtali, Old Town, Dhaka. During the field study, 25 large scrap wholesalers (Table: 5.5:) were interviewed in the wholesale market located in Nimtali, old town, in Dhaka.

Table 5.5: List of interviewees

No.	Name	Place	Position of interviewees
1	Rafiq Traders	Nimtali	Proprietor
2	Sapan Enterprise	Nimtali	Proprietor
3	Asik Traders	Nimtali	Proprietor
4	Nahid Enterprise	Nimtali	Manager
5	Madina Traders	Nimtali	Manager
6	Fahim Enterprise	Nimtali	Proprietor
7	Mahmud	Nimtali	Proprietor
8	Jahid	Nimtali	Proprietor
9	Akota Enterprise	Nimtali	Proprietor
10	Bhai Bhai Enterprise	Nimtali	Proprietor
11	Srity Enterprise	Nimtali	Proprietor
12	Mokim Enterprise	Nimtali	Proprietor
13	Mamun Enterprise	Nimtali	Proprietor
14	Sunny Enterprise	Nimtali	Proprietor
15	Bismillah Enterprise	Nimtali	Proprietor
16	Harich Enterprise	Nimtali	Proprietor
17	Mobarak Enterprise	Nimtali	Proprietor
18	Al-amin Hossain	Nimtali	Proprietor
19	Sadhin Enterprise	Nimtali	Proprietor
20	Khaleda Pervin	Nimtali	Proprietor
21	Ruma Enterprise	Nimtali	Manager
22	Khorshed & Co.	Nimtali	Manager
23	Khaled Enterprise	Nimtali	Manager
24	Sunny Enterprise	Nimtali	Proprietor
25	Jashim	Nimtali	Proprietor

The interview questions were related to length of business, possession of shops, sources of wastes, average income, connection with selling points, manpower, infrastructure, transportation facilities, frequency of sale and other related factors. The questions also include the opportunities and threats come from the uncontrollable external factors depicted in the below table (Table: 5.6). Wholesalers buy various wastes such as metal scraps, PET Bottles, other types of plastic scrap, paper, shipping cartons, and aluminum cans to low-value glass. The challenge to attain at a projected volume proved difficult as most of the wholesalers were thoughtful in sharing about the waste flows into their daily dealing.

Table 5.6: Wholesale Dealers' response about the questions

Question	**Theme**	**Participant Response**
Who do you sell the recyclables to?	Buyer	• Recyclers • Directly to manufacturers
What is the average daily collection of plastic waste? (In kg)	Average Daily Collection	• 0.5-1 MT: 5 Wholesalers • 1-2 MT: 10 Wholesalers • 2-4 MT: 6 Wholesalers • 4 MT+: 4 Wholesalers
What is the price/kg of plastic waste of different types that you buy?	Buying Price	• 5-30Taka/Kg depending on the quality • Usually, PET Bottle price is higher
What is the price/kg of plastic waste of different types that you sell?	Selling Price	• 15-50 Taka/Kg depending on the quality • Usually, PET Bottle price is higher
What are the methods used to collect plastic waste?	Collection Method	• Traditionally practiced manual process
What are the sources and methods used to clean the collected plastic waste?	Sources and cleaning methods	• Sources: Households, waste pickers, middle dealers, and other traders • Cleaning methods: Traditional manual cleaning
What are the methods used to identify and sort collected plastic waste?	Sorting Method	• Manual sorting mainly
What are the sorted types of collected plastic waste?	Sorted type of plastic waste	• PET Bottle • Plastic Jar, container • Plastic films • Household plastics
Do you have any type of machinery to process the waste (baling, etc.)?	Waste processing machinery	• Middle dealers don't use and waste processing machinery

Continued…

Are there any seasonal variations in work and how does this reflect in the business in terms of number of employees, type of material in demand, etc.?	Seasonal Variation and its Impact	• During winter PET Bottle waste collection comes down • During the rainy season overall waste generation comes down. • Seasonal variations reflect the business in terms of employee numbers, material demand, material quality, etc.
Other details on the infrastructure available (vehicle, owned or rented space, etc.)	Available infrastructure	• Space: 500-2000 SFT • Out of 25 wholesale dealers only 2 have their own vehicles to transport wastes
What challenges and problems do you face in the business?	Challenges and Problems	• Police harassments • Musclemen harassments • Volatile transportation cost • Municipal wastes release a bad smell
What are the new trends you have observed in this type of business over the years?	New trends in the waste business	• Number of itinerant waste pickers is gradually declining • Wholesalers and re-processors directly buy from waste generation sources and waste pickers in many cases.

5.1.3.1 Summary of Major Findings (Wholesale Dealers)

The outcomes of the interviews have been analyzed applying some basic mathematical tools and techniques that are described in the following sections. Since it is a qualitative study no statistical formula and techniques has been used here.

5.1.3.1.1 Type of Wholesale Dealers

From the twenty-five wholesale dealers interviewed, six dealers deal only various types plastic wastes, five wholesalers deal only paper wastes, two deal only metal scarps, and one deal only wire scraps (metal and plastic). Eleven wholesale dealers deal all kinds of wastes.

Figure 5.13: Number of Wholesale Dealers by Waste Types

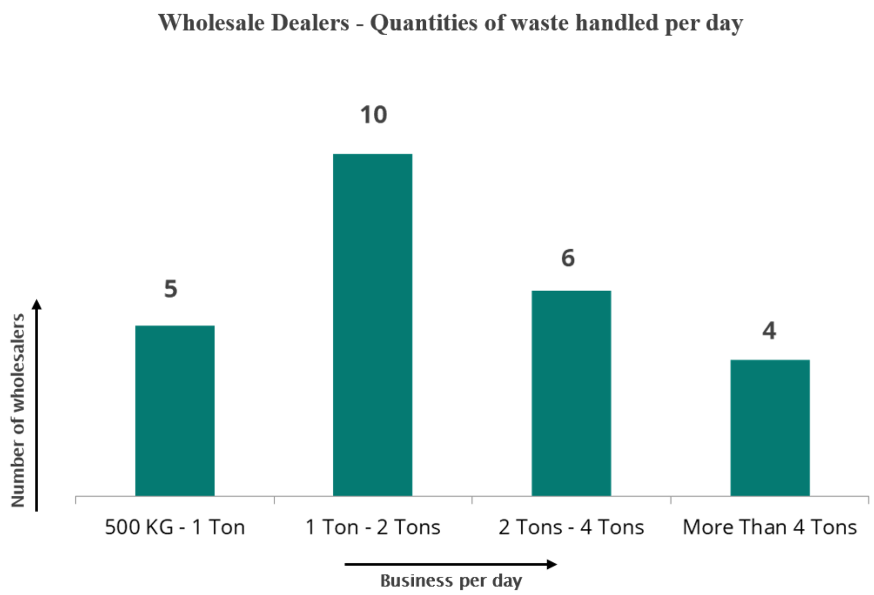
5.1.3.1.2 Length of Business

The study discovered that fifteen of the wholesalers have been doing business for more than ten years. Six wholesalers have been doing in this particular business for less than ten years; while four are the new entrants.

5.1.3.1.3 Daily Waste Handling Quantities

Based on the investigation, the wholesale dealers can be categorized on the basis of waste dealing between 0.5 MT to 1 MT daily (5 wholesalers), between 1 to 2 MT daily (10 Wholesalers), between 2 to 4 MT daily (6 wholesalers), and those dealing exceeding 4 MT daily (4 wholesalers).

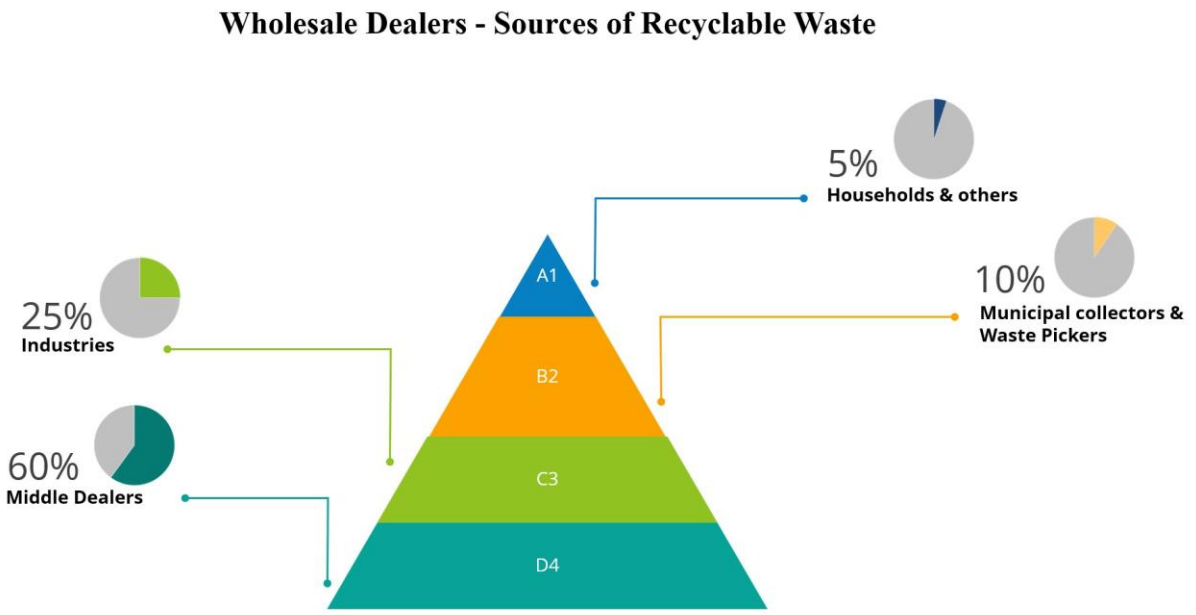
Figure 5.14: Quantities of Waste handled per day by wholesale dealers



5.1.3.1.4 Sources of Recyclable Wastes

It has been observed that wastes are being sourced mainly from different areas of Bangladesh and different waste dealers nearby as well as from different wards of Dhaka metropolitan city which is about 60% of scrap collected. 25% of scraps were sourced from various industries, 10% from municipal collectors and waste pickers, and 5% from households and other sources. Apart from this, some wholesalers employed waste pickers on daily wages to collect waste as well as to do the sorting, packing, and loading.

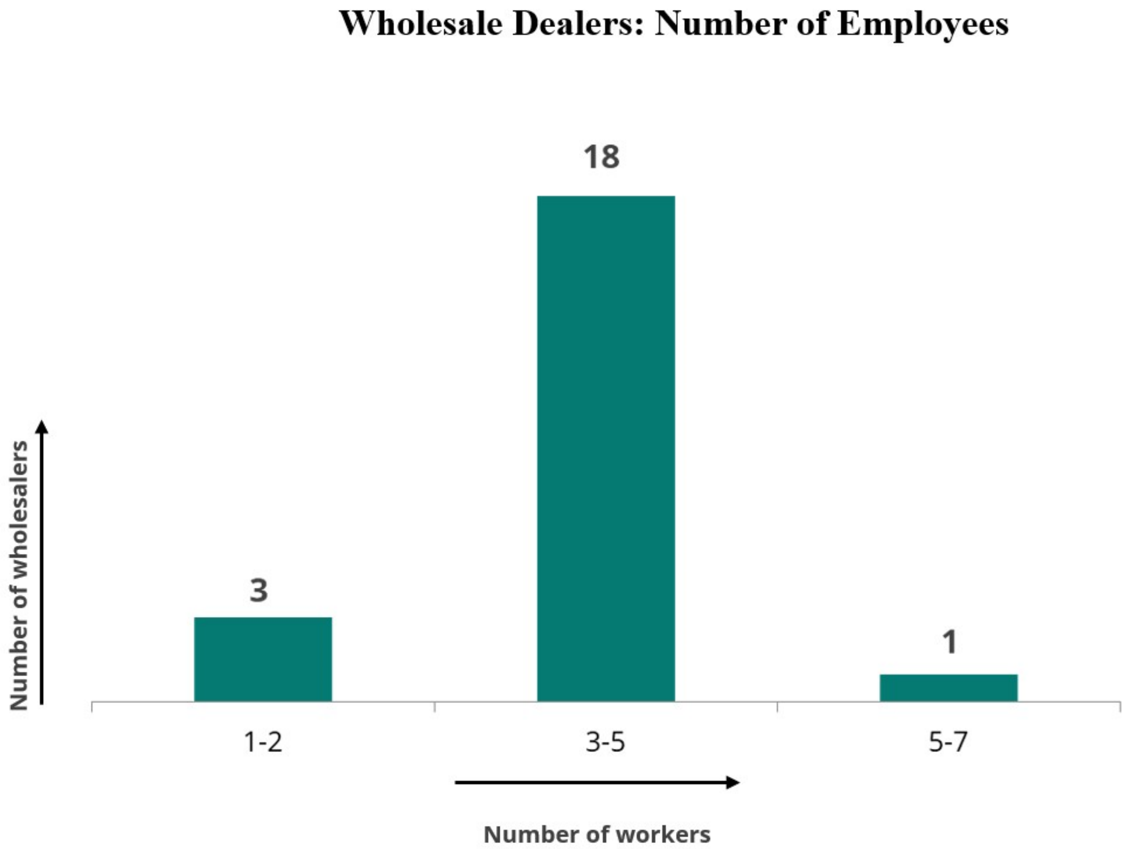
Figure 5.15: Sources of Recyclables by Wholesale dealers



5.1.3.1.5 Number of Workforces

Interview cited that the wholesalers mainly hired permanent manpower and casual workers on daily wage basis. Most of the wholesalers (15) interviewed had three to five workers. Two wholesalers hired two workers. One wholesaler hired seven workers and one wholesaler hired merely one worker. On the other hand, three wholesalers did not hire any workers taking support and assistance from members of the family. Wholesale Dealers usually run their daily operation getting assistance from permanent employees and casual labors on daily wages.

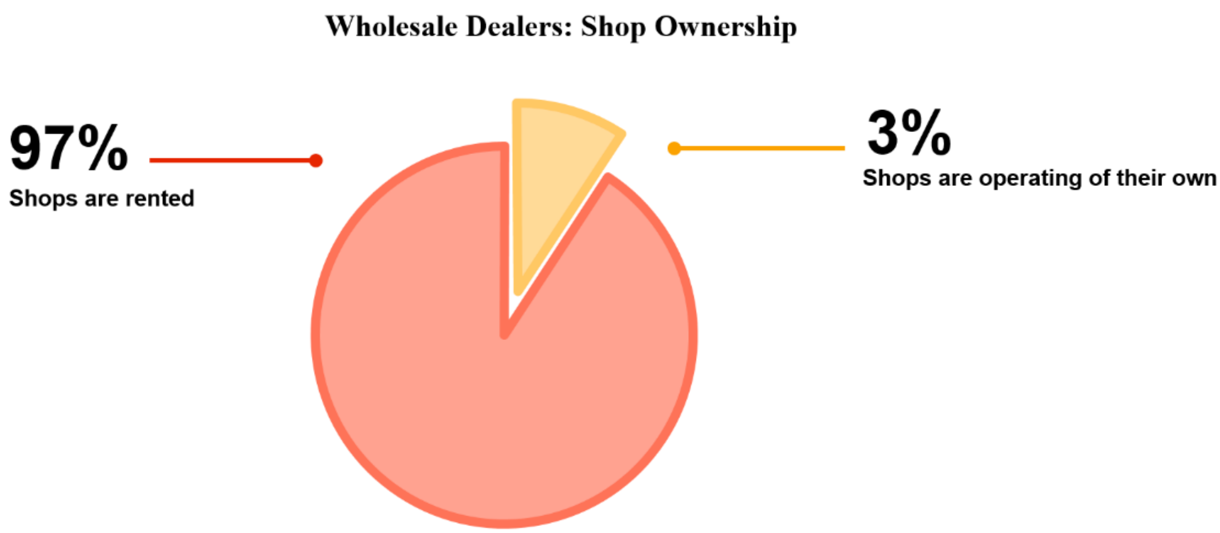
Figure 5.16: Number of Employees (Wholesale Dealers)



5.1.3.6 Possession of Shop

It has been observed that most of the wholesaler dealers operated their businesses in rented spaces (23), and no information found from two wholesalers on this issue.

Figure 5.17: Possession of Shop (Wholesale Dealers)



5.1.3.1.7 Infrastructure Facilities

It has been observed that the capacity of waste handling is directly relational to the available space for the movement of transports, sorting, binding, storing and loading before transportation. The wholesalers handling one to two tons daily operated an average space of 500 square feet. Wholesalers whose handling capacity exceed four tons daily have additional warehouses nearby gauging between 1000 and 2000 square feet. Like middle dealer, they also do not use any kind of machines to sort the waste, instead everything is done manually. The study found, two of the wholesale dealers have their own vehicles to transport wastes.

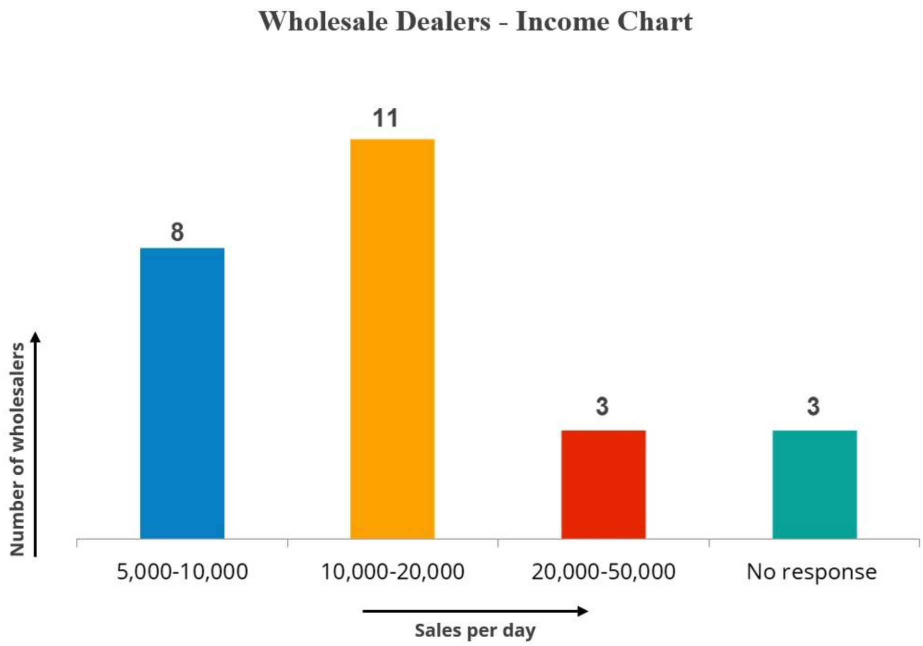
5.1.3.1.8 Frequency of Sale (Recyclables Materials)

The wholesalers used to handle wastes materials daily. The big wholesalers those trade above two tons packed the materials according to the types such as a single load of PET bottle waste or metal scrap or cardboard or paper scraps and many others.

5.1.3.1.9 Earnings Per Day (Sales)

It has been observed that seasonal variations during the rainy season causes decline of business since the wastes catch wet and get comparatively lower price. During the open-field interviews, the most of the wholesalers were extremely unwilling to reveal earnings and so that the data on their daily sales was collected. However, interviews revealed that eight wholesalers make sale ranging from five thousand to thousand taka daily; eleven wholesalers make sale between ten thousand to twenty thousand takas daily. Three wholesalers do sale between twenty thousand to fifty thousand takas daily. On the other hand. no information obtained from the three wholesalers interviewed.

Figure 5.18: Income chart of Wholesale Dealers



5.1.3.1.10 Challenges and Problems Used to Encounter

It has been discovered that undesirable police disturbance is the regular phenomena for the waste traders. Many dealers frequently face unexpected challenges such circumstances where police interrogate them that they purchase stolen objects, particularly metal scrap waste. Occasionally, workers of the dealers are accused of minor stealing which can literally be ignored and summoned to police stations for interrogation. Acquiring waste from municipal waste collection transports is problematic as the waste is assorted and releases bad smell. As a consequence, neighbors used to protest on several occasions. Some wholesalers also reported lingering health complications and imposed into their profession. Scrap Dealers are popularly known as BHANGARIR DOKAN and are privately owned by small businesses that are located in every ward of Dhaka City. They used to buy different types of scraps such as cardboard, paper, plastic, electric and electronic, metal, cans, glass, etc. Usually, the scrap dealers do not collect scraps from door to door rather they buy these from municipal collectors or else from others. Sometimes, city dwellers go to scrap dealers' shops to sell recyclable goods of different types. Almost all scrap dealer shops don't possess any trade license and are operated by the owner himself/herself. After collecting various types of scraps, they used to separate metal, cans, electric & electronic, plastic scraps, etc. from each other. And the second phase, the shop owners or employees clean the mixed recyclable plastic scraps and segregate these according to product types, color, size, and quality. As the scrap dealers used to sell all types of scrap from metal to plastic, their target buyers are from different sectors such as brokers, middle dealers, small businesses, wholesalers, industrial buyers, plastic waste preprocessors, etc. It was found from the study that no one solely depends on selling plastic scraps rather they sell all types of discarded items. Most of the dealers are disinclined to give data about their respective average monthly income. Broadly the analysis shows the scrap dealers used to earn 20000 to 25000 BDT/ month. While answering the interview almost all scrap dealers responded that the selling price of different categories across Dhaka metropolitan city is homogeneous. The following table depicts the value various wastes including plastic wastes.

Table 5.7: Value of different types of scraps

Types of waste		Buying Price(TK/KG)	Added value (%)	Selling Price (TK/KG)
Plastic Scraps	PET Bottle	12-20	20-25	15-25
	PP	10-20	15-25	15-20
	HDPE	12-25	20-25	20-30
	LDPE	10-20	10-20	15-25
	PS	4-10	10-12	5-12
	PVC	5-15	10-15	6-18
Paper		10-15	20-30	15-20
Cardboard		5-10	40-50	10-15
Aluminum Cans		40-50	90-100	90-100
Tin Cans		10-15	90-100	20-30
Metal		10-20	90-100	20-40
Glass		2-3	100-110	4-7

Note: PET= Polyethylene Terephthalate, PP= Polypropylene, HDPE= High Density Polyethylene, LDPE= Low Density Polyethylene, PS= Polystyrene

The study found that the value of metal and aluminum scrap is comparatively higher than other plastic wastes such as cardboard, paper, and plastic wastes. Reversely, glass waste gets the lowest value (2 TK/KG) at the initial stages of the value chain. Based on the interview with the dealers regarding the quantities of wastes dealt daily almost 90% were small scrap dealers (less than 300 KG daily) and about 10% were medium-scale scrap dealers (300 kg to 1000 KG daily). For the dealers, volatile transportation cost is the main expense to sell recyclables. Transportation costs has considered due to the waste volume, narrow roads, and traffic jams in addition to unseen charges that need to pay in most cases along the route. Interview reveals that most scrap dealers face undue disturbance from the police and hence have to count penalty most of the time.

5.1.4 RECYCLERS/RE-PROCESSORS

A group of 10 people who are the proprietors, managers, and supervisors of 10 different small and medium-sized plastic recyclers engaged in this sector for a minimum of 5 years were interviewed depicted in the below table:

Table 5.8: List of Interviewees

No.	Name	Place	Position of interviewees
1	Sharna Plastic Industries	44, East Islambagh	Proprietor
2	Firoz Plastic	37/1 IslamBagh	Proprietor
3	Tamim Plastic	Islam Bagh	Proprietor
4	Lal Plastic	45/2 Islambagh	Proprietor
5	Zazira Plastic	88 East Islambagh	Manager
6	Sonali Plastic	East Islambag	Manager
7	M/S Akhi Plastic	East Islam Bagh	Supervisor
8	Rahim Plastic	East Islambagh	Proprietor
9	Bismillah Enterprise	Kalambagh	Proprietor
10	Al-amin Enterprise	Kalambagh	Supervisor

The interviewing process was continued with ten recyclers until perceived data saturation point. Each interview lasted for half an hour. Plastic Recycling Factories are mainly located on the bank of the Buriganga River, in the Islambagh, Lalbagh, Kamrangirchor and Kalambagh area of Dhaka City.

5.1.4.1 Summary of Major Findings (Recyclers)

The outcomes of the interviews have been analyzed applying some basic mathematical tools and techniques that are described in the following sections. Since it is a qualitative study no statistical formula and techniques has been used here.

There are various types of Plastic recyclers depending on the types of plastic scraps. Polyethylene Terephthalate (PET) plastic scrap is shredded to form PET Flakes and is mainly sold in India, and Vietnam where the yarns are made from it and used for making fabrics, polyester staple fiber, and other types of plastic products. Apart from this, other types of plastic scraps such as PP, HDPE, LDPE, PVC, and PS are recycled to manufacture various things such as pellets, hangers, crates, food containers, non-food items, furniture, jute & textile spare, boxes, etc. The data reveal the selling price of different recycled plastic scrap pellets and flakes shown in the below table.

Table 5.9: Value of different types of plastic scrap granules (After reprocessing)

Types	Selling Price Plastic Scrap Granules (from Industry) in TK/KG (ranked based on quality)			Selling Price of Average to low-quality plastic scraps (from collectors, dealers, wholesale market middle dealers, and public gathering hubs) in TK/KG
	Superior	Good	Average	
PET	-	-	-	35-50
PP	80-100	70-90	40-70	20-30
HDPE	90-100	80-90	50-70	30-40
LDPE	90-120	80-110	70-80	25-35
PS	-	-	-	15-20
PVC	40-50	30-40	20-30	15-20

The study found that the price of reprocessed plastic scraps of various types is very much dependent on the quality and the recycling of post-industrial plastic scraps can yield high-quality pellets and granules. But data also reveals that the volume of postindustrial recycled plastic pellet flakes is very nominal to take into consideration. However, the volume of mixed and dirty waste is much higher which is eventually collected from households, curbside, and other public gatherings hubs. As a result, it yields, low-quality pellets and flakes which cannot produce value-added products. The presented results reveal that recycling facilities already exist in Bangladesh. But the expected level of value addition is missing mostly as compared to the global trend.

The key gaps in the current activities of scrap dealers and recyclers, as it relates to top “on the ground” realities and which need to be urgently addressed to improve current practice enabling a pathway to attain circular economy goals are:

1. Lack of authentic data and information on the use of plastics and plastic waste recycling.

2. Gaps in a capacity relating to scrap collection, sorting, and segregation infrastructure.

3. Gaps in the capacity building of plastic recycling infrastructure and advanced technology.

4. Transportation cost of recyclables is one of the main constraints that hamper the value chain as stated by the scrap dealers these costs are attributed to the narrow road to the middle dealers, wholesale markets, and final manufacturers mostly located in the periphery of old Dhaka. Furthermore, scrap dealers have to count high police “fees”, bribes, etc.in almost all cases for road access.

The main purpose of conducting this open-field interviews with the value chain actors was to investigate the current stage of plastic recycling value chain in order to find out the challenges and opportunities of plastic recycling in Bangladesh. Though the study has not found is any concrete data about the exact volumes of plastic wastes, rather the study discovered that plastic recycling businesses are active in Bangladesh to some extent without any value creation like global trend considering sustainability index. It has been also found from the field interview that the majority of these recycling activities are located in or near the Old Town of the capital Dhaka. Findings from the open-field interviews with the recyclers are illustrated in the below table (Table 21):

Table 5.10: Summary of open-field interview findings with Recyclers

Question	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Average daily collection	1500 kg	1800 kg	2000 kg	1500kg	1650 kg	1400kg	900kg	2000 kg	1500 kg	2920 kg
Collection Method	Wholesale dealers, Collectors, Industry, brokers	Wholesale dealers, Collectors, Industry, Households, middlemen	Wholesale dealers, Collectors, Industry, Households, middlemen	Wholesale dealers, Industry, Households, middlemen	Wholesale dealers, Collectors, Industry, Households, middleman	Wholesale dealers, Collectors, Industry, Households, middlemen	Wholesale dealers, Collectors, Industry, brokers	Wholesale dealers, Collectors, Industry, Households, middlemen	Wholesale dealers, Collectors, Industry, Households, middlemen	Source separation & from Dump sides of Municipal solid waste
Methods & sources of cleaning	Manual washing, river water	Manual washing, river water	Manual washing, tap water	Manual washing, river water	Manual washing, tap water	Manual washing, tap water	Manual washing, river water	Manual washing, river water	Manual washing, tap water	Manual washing, tap water
Methods of Identifying & sorting	Color, sound, Manual	Color, Manual	Color, Manual	Color, Manual	Color, Manual	Color, Manual	Color, Manual	Color, Manual	Color, Manual, sound	Sound, manual
Sorted types of collected plastic waste	PET, HDPE	PP, LDPE, PS	HDPE, PS	PP, LDPE	PP, PET	PP, LDPE	PP, PET	PET, PS	PP, PET,	PET, PS, LDPE
Avg. daily recycling capacity	500-1000	300-600	1000-1500	500-800	400-500	500-800	200-600	500-1000	500-800	400-800 kg
Technologies used to recycle	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Blow moulding	Extrusion, Injection moulding
Average energy consumption for recycling	35-40 KW/Hour	35-40 KW/Hour	60-70 KW/Hour	35-40 KW/Hour	35-40 KW/Hour	35-40 KW/Hour	35-40 KW/Hour	50-60 KW/Hour	40-45 KW/Hour	35-40 KW/Hour
Current Recycled products	PET Flakes, HDPE Pellets	Backpack board, Jar, Mug, Itching stick, Pot, toys etc.	HDPE & PS Pellets, Food containers	Backpack board, Jar, Mug, Itching stick, Pot etc.	PET Flakes, PP pellets, Jar, Pot, Mug, Sweat box	PP Pellets, LDPE Pellets	PP Pellets, PET Flakes, Jar, Mug, Chair, Shower pot etc.	PET Flakes, PS pellets	PET Flakes, Backpack board, Jar, Mug, Itching stick, Pot, toys etc.	Pen covers & pen holders, Backpack board, Jar, Mug, Itching stick, Pot etc.
Quality of recycled products	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material	Always lower than the virgin material

5.1.4.1.2 Collection of Plastic Waste for Recycling

Fundamentally, plastic wastes are collected by means of the two methods- source separation & separating from households, public gathering places like markets, parks, industries, and the dumpsites of municipal solid waste.

5.1.4.1.3 Source Separation

Plastic wastes are collected from numerous generating sources such as households, government institutions, private institutions & schools, industries, and public gathering hubs, etc. Waste is isolated considering types of wastes such as plastic, paper, glass and organic degradable.

5.1.4.1.4 From the Dumpsites of Municipal Solid Waste

Almost all waste dealers, traders' collectors and re-processors gather raw waste plastic items from waste pickers, middle dealers, and the wholesale market as well as directly from dumpsite collection points and streets. Wastes that are being rejected from industries are considered to be the second-highest plastic waste source for waste collectors and re-processors.

5.1.4.1.5 Average Daily Collection and Recycling Capacities

Interview cited that the average daily collection of the most recyclers is about 2,660 kg with an average daily recycling capacity 2,080 kg. The surplus volume of waste is warehoused for impending re-processing.

5.1.4.1.6 Cleaning of Collected Plastic Waste

It has been discovered that almost all recyclers apply traditional manual washing techniques getting out their collected plastic waste cleaned. Highly polluted river water is mainly used by the most of the recyclers who set up their facilities at the periphery of the river as the source of water. Conversely, water from deep tube well water, tap water and other available water sources are used by some of the recyclers.

5.1.4.1.7 Identifying and Sorting Collected Plastic Waste into Different Varieties

Various identification techniques are applied for sorting plastic waste. To identify various types of plastic waste, many recyclers use color code in order and the sound of waste plastic material is used by a few recyclers following plastic codes, and moulding types.

All recyclers apply manual sorting techniques through their long work experience to sort waste for recycling. Plastic waste collectors and recyclers equally practice mechanical sorting techniques such as NIR technology used in Germany followed by many other western countries. Infrared rays detect and sort plastics through this modern technology as per the functional groups these are made of. Since this technology is a precise, cost-effective and value-driven sorting technique it is desirable to see the possibility of introducing this modern method in Bangladesh.

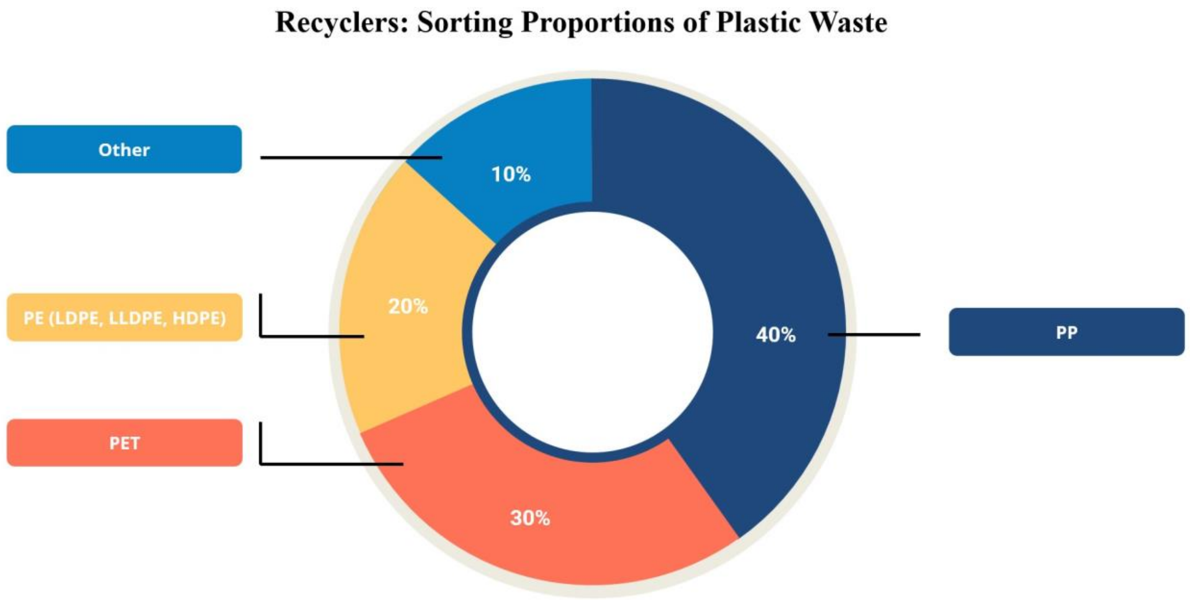
5.1.4.1.8 Sorting Proportions of Plastic Waste

Recycling industry mainly collect and process various types of plastic waste such as Polypropylene (PP), Polyethylene terephthalate (PET), Low-density polyethylene (LDPE), and High-density polyethylene (HDPE), Polystyrene (PS), and other mixed plastics (Table 5.11 & Figure 5.19).

Table 5.11: Plastic sorting proportion by recyclers

Type of Waste	Sorting Percentage (%)
PP	40%
PET	30%
PE (LDPE, LLDPE, HDPE)	20%
Other	10%

Figure 5.19: Sorting proportion of plastic waste by Recyclers



5.1.4.1.9 The Common Plastic Recycling Process

After collection, the recyclers begin recycling process with sorting various collected items into detailed types. Almost all recyclers interviewed apply manual sorting where they do some additional sorting in many occasions considering the plastic color. The process of plastic recycling is harder than other waste recycling due to the availability of diverse plastic. Furthermore, mixed plastic cannot be used in the next stage of manufacturing. Therefore, the recyclers were found highly cautious considering waste segregation into different types prior transfer to next stage of recycling process.

After sorting, size reduction takes place into process where the waste is chopped into small pieces and lumps. These small pieces and lumps are then cleaned for removing imported substances such as dust, mud, paper label etc., that was inside the plastic.

Plastic pieces and lumps are melted down and compressed into small pellets after cleaning. Recyclers argued that this phase of recycling is treated as the most critical phase after sorting that encompasses the most exclusive process in the whole recycling method. Finally, recycled plastic pellets are produced and fashion into different products either by injection molding or blow molding.

It has been observed from the open-field interviews that each stage of recycling process is required to improve for making superior quality secondary raw materials and new value-added products, and thus, improve the superiority of new product.

5.1.4.1.10Technologies Used to Recycle Plastic Waste

Several production techniques are applied for manufacturing new value-added products originated from plastic waste and these are: 1) Blow moulding and 2) Injection moulding 3) Film Extrusion Blowing 4) Plastic Sheet Extrusion 5) Roto-moulding extrusion etc. PE film rolls are produced using film blowing extrusion technique. Various other products such as flower vases, toys, mug, pots, plastic plate for backpack, plastic crates, plastic sheets, jars, etc. are produced by using injection moulding technique.

5.1.4.1.11 Energy Utilization for Recycling

Though not the exact figure, most of the recyclers use an average amount of 3,000 Watt daily in the recycling process and some of the recyclers use 3,500 Watt. In terms of monetary value, it comes at an average of two thousand taka per day.

5.1.4.1.12 Current Recycled Products from Plastic Waste

The study found that recyclers are producing various substandard products special for the people of the bottom layers of the society. Some these products are various types of plastic pellets to be used as raw materials for production, PE film rolls, jar, mug, stick, plate for backpack, flower vases, plastic crates, plastic boxes, electronic covering items, pen covers, pen holders, pots of different types, plastic containers, etc. are manufactured using plastic waste.

5.1.4.1.13 Quality of the Recycled Products from Plastic Waste

It has been deeply assessed that recycled products are found inferior in terms of superiority and durability compared to virgin plastic material. However, literature reviews and expert interviews revealed that superior quality material could be produced by recycled plastic by putting cleaner recycled plastic possibly adding some virgin plastic in the production process. Bangladesh has a prolonged history of plastic waste recycling none of recyclers are producing food graded plastic products and wrappings as recycled plastics are associated with impurities and contaminant particles.

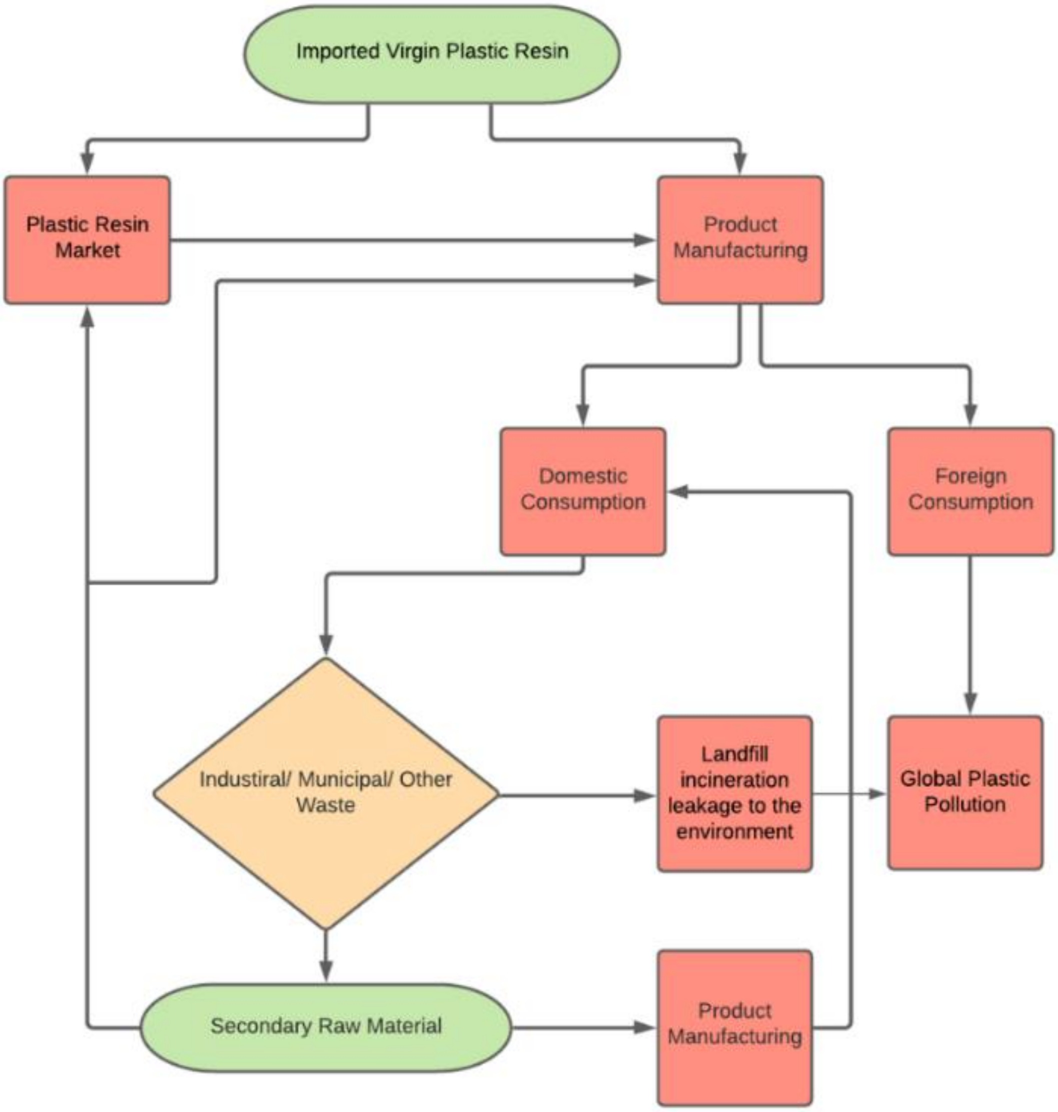
It was observed during the interview that this sector is going through lots of issues. In many cases the recycling centers are operating under actual production capacity due to volatile supply of recyclables. Absence of modern waste sorting techniques, shortage of funds, space constraints for the formation of large-scale recycling facilities. In addition, incapability to recycle mixed and multilayered plastic waste are the other noteworthy issues presently confronted by the recyclers in Bangladesh. On top of that, existing unstructured and unplanned recycling process roots multiple environmental contamination by releasing untreated and contaminated washing effluent into the soil.

5.1.5 Overview of the Flow of Plastic Material and Recycling Value Chain in Bangladesh

This section analyses the existing flow of plastic material and the performance of the recycling chain in Bangladesh discovering important obstacles and opportunities.

Plastic sector is developing at a faster pace in Bangladesh and it has become one of the remarkable sectors in Bangladesh. Bangladesh consumed around 1.5 million metric tons of polymers in 2017 (Ijaz, 2019) and the consumption has been rapidly increasing. This ever-rising trend in plastic consumption in Bangladesh leads to plastic waste that needs proper reprocessing to achieve economic gain and environmental sustainability. At present, 31% of plastic waste is used to recycle (World Bank 2020). Plastic products manufactured in Bangladesh mostly rely on imported virgin material since the country does not have any petrochemical refinery to produce virgin pellets and sometimes on recycled sources even though the quality is not up to the mark as the international standard (Figure: 5.20).

Figure 5.20: The flow of plastic material in Bangladesh



Adopted from various literature sources

As mentioned in earlier chapter four, the plastic recycling value chain involves a multitude of actors from the collection, transport, dismantling, sorting, and finally to recycling& product manufacturing/offtake from a circular economy perspective where all value chain actors are interconnected with each other and one small change within an actor can create a significant impact across the whole value chain that has been discovered in this study through field interviews. Thus, this part analyses the existing performance of the recycling chain in Bangladesh and identifies the key barriers and opportunities:

High Diversity of Products

Diverse product design yields multilayer products that are difficult to sort and are not viable commercially to recycle. These multilayered plastic products are mostly disposed into the soil. The dark and black plastic wastes make it difficult to recycle because of appropriate technology like optical sorting technology. The recycling functions have been proven complex causing the combination of several resins and grades within a single product. Discrete waste movements usually are not combined into presently practiced collection structures. Since the waste flows, it is tough to adapt suitable treatment schemes. On top of that high volume of contamination in some waste streams is caused by mixed wastes.

Waste Collection

Typically, Incineration and landfilling remain the cheapest treatment methods. The low economic value of recycled materials represents an additional obstacle. Industrial & commercial waste stream are assessed as better quality compared to the household waste stream which contains mixed waste in most cases.

Sorting & Recycling

The existence of manual & crude sorting & recycling technology produces poor and low-value products. Lack of advanced sorting and recycling technology which eventually needs high investment which is beyond the capacity of collectors and processors.

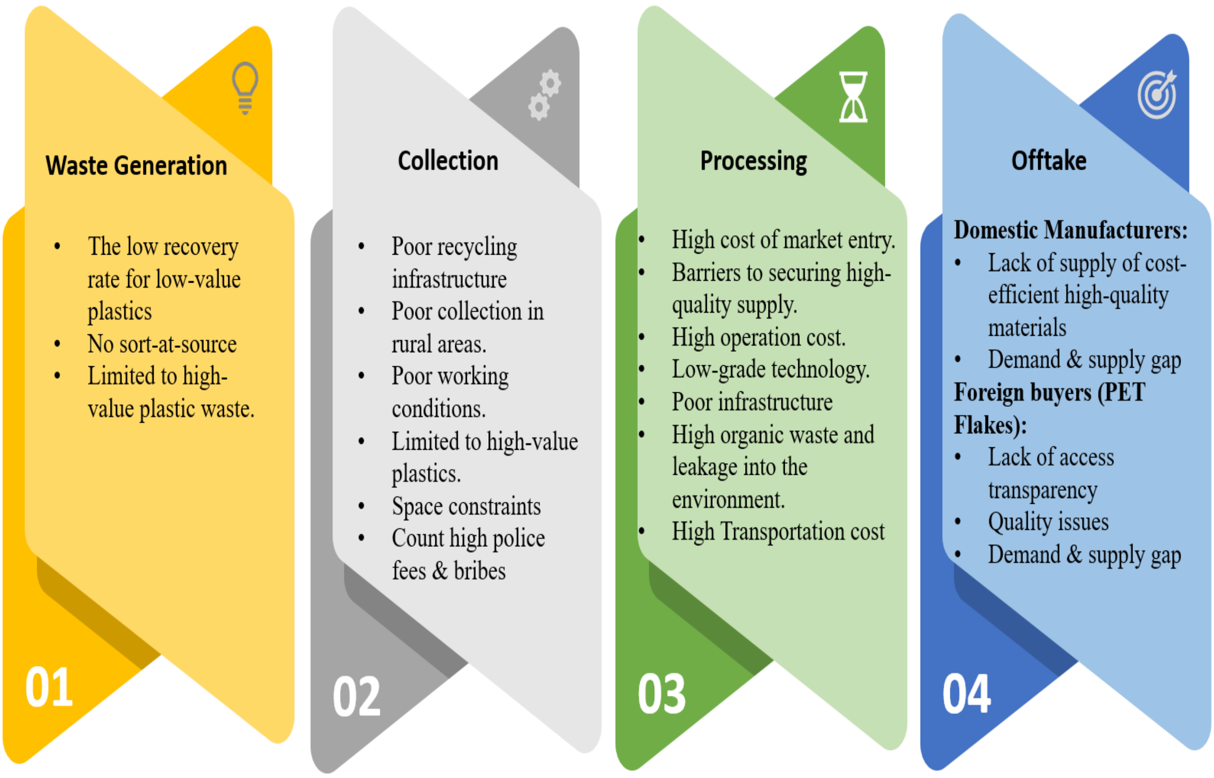
End-Use

Fluctuating supply leads to distractions in production and affects products' quality. Because of contamination, quality imposed by the end users are the significant challenges to the re-processors. Because of varied output capacity, the needs of the end-users cannot be met at the desired level.

Lack of Cooperation across the whole Value Chain

Manufacturers and end-users avoid disclosing information between themselves**.** Consumers have limited knowledge of plastic recycling characteristics. Cooperation between manufacturers, sorting & collection centers, and processors is weak. Cooperation between manufacturers from different sectors is limited. The below figure depicts the constraints across the plastic waste recycling value chain in Bangladesh found from the study:

Figure 5.21: Constraints across Recycled Plastic value Chain in Bangladesh



5.1.5.1 Challenges and Opportunities

Based on the investigation of the current state of plastic waste recycling value chain in Bangladesh, the following challenges and opportunities are summarized below:

Challenges

Because of marketing and intrinsic needs, goods are becoming more multifaceted and split under the endeavor of manufacturers to distinguish goods conforming required standards. Because of the complex characteristics, plastic packaging waste pays high contamination from the collected waste that send to the recycling facilities. In addition, existing crude waste treatment methods fails to produce the necessary signals that would direct the collected plastic waste for recycling. Regarding of supply of recyclates, both the recyclers and end-users face lots of difficulties such as the recyclers receive heterogeneous waste streams in their plants. Thus, the supply of recycled plastics can divert end-users' choice to virgin supplies and are mostly preferred for the negative impression and health concerns of recyclables, as plastic waste flows are not supervised effectively, and the identification of improvement areas remains a difficult task.

Opportunities

Literature review and expert interviews revealed that there are also numerous opportunities that could stalwart progresses in the whole value chain. There is a trend of an improved consciousness from the supply and demand side equally considering plastic issues and this rising awareness though in a slow and steady state is replicated in marketing as well as CSR strategies of companies, along with communication movements. In terms of sorting and collection, some schemes are increasing in value and volume. Unlike global practice, implementation of the EPR schemes would have played a pivotal role in attaining high efficacy and creating investment motivations for modern sorting and recycling technologies. The incorporation of standards and certificates into the recycling operations, demonstrating acquiescence in aligning end-users' requirements, allows a larger consumption of recyclables. Concurrently, transforming from a linear economy to a circular economy throughout the whole value chain optimizes resources through this circulation trend of plastics, and thus, reduces the environmental outwardness. The study found the summarized challenges and opportunities mentioned in the below table:

Table 5.12: Challenges & Opportunities

Challenges	Opportunities
• Increasingly complex packaging and (other) products	• Increased awareness between consumers and businesses
• Increased landfilling rates and the absence of proper laws regarding bans on landfilling	• Execution of design for recycling and use of recyclates by various reputed brands
• Variations in the quality and quantity of supplies delivered to recyclers and end-users.	• Increased quantity and quality of separate collection schemes gradually
• Insufficient and un-harmonized monitoring activities of the performance of plastic waste stream.	• Existence of standards and certificates • Positive environmental effects and favorable laws inspired by circular economy principles.
• Negative image and health concerns towards the use of recyclates originating from plastic waste.	• Low labor cost • Vibrant informal sectors can be drawn into the mainstream economy

5.1.5.2The Link between Source/Collection System, Treatment Technology, and Quality and Application Options in Comparison with Bangladesh and the World

The table below summarizes the findings from the interview with the recyclers considering the qualities and applications that is gettable for the recyclable plastic wastes from diverse sources and different treatment possibilities explicit benchmarking with the global practices of the same.

Table 5.13: The Link between Source/Collection System, Treatment Technology, and Quality and Application Options in Comparison with Bangladesh and the World

Waste Source	Treatment		Quality		Application option	
	Bangladesh	Global	Bangladesh	Global	Bangladesh	Global
Municipal, Industrial, Commercial, Others Closed-loop (bottle to bottle)	Manual sorting & washing/hot washing technology (limited)	Fine/ Auto sorting, washing/hot washing (NaOH), vacuum reactor	Standard (Up to 70%)	Highest	ET Sheet, Plastic Jr, PET Flakes	Drink bottles (often PET)
Municipal, Industrial, Commercial Others Mixed plastic Source separation of mixed plastics	Manual sorting & washing/hot washing technology (limited)	Positive sorting from stream (NIR), quality control, fine sorting, washing/hot washing (NaOH), vacuum reactor	Moderate (Up to 60%) N.B: cannot handle all types of plastic wastes	Highest (up to 99,9% purity)	Plastic household products and resins for making plastic goods	Food packaging, e.g., HDPE milk bottles
Municipal, Industrial, Commercial Others, Mixed plastic Source separation of mixed plastics (mono-origin or co-mingled)	Manual sorting & washing/hot washing technology (limited)	Positive sorting from stream (NIR), quality control, fine sorting, washing	Average (Up to 50%) N.B: Because of technological constraints cannot handle all types of plastic wastes.	Highest (up to 98% purity)	Low-quality household products	High quality products with high performance criteria
Households, Mixed plastic, Source separation of mixed plastics (mono-origin or co-mingled)	Manual & crude technology	NIR sorting. Fine sorting, washing.	Poor quality (Below 50%)	85-92 % purity.	Low-quality products	Relatively high quality products with lower performance criteria
Households Mixed dry residual waste	Manual & crude technology	NIR sorting. Fine sorting, washing	Poor quality	80-90 % purity		Products with lower performance criteria
Residual mixed plastic streams from sorting plants	Manual & crude technology		Poor quality	Low quality	Low-quality products	Low quality products

5.1.6 Implications Against the Evolution of Initiatives, Policies, and Regulations Related to Addressing Plastic Issues in Bangladesh

The government has been positive towards starting environmental principles and solving the pollution caused by plastic waste. Despite this positive planning, supervision, evaluation, and implementation is noticeably penniless. The following table depicts the summary of existing legislative policies and regulations, and their implications on the plastics recycling industry:

Table 5.14: Implication of initiatives, policies and regulations in Bangladesh

Policies and Regulations	Year	Implications
Ban on polyethylene bags through a regulatory order (under the 1995 Environment Act	2002	The lack of institutional resources and the high cost of alternative materials made the policy challenging to enforce, and hence the ban has limited results.
Composition of plastic waste & market. Assessment of plastic recycling sector in Dhaka	2005	The first comprehensive study to assess plastic waste and most researchers used it as a baseline study related to plastic waste composition & recycling.
Medical waste management rules,2008	2008	This rule applies only to medical wastes from collection to disposal.
Mandatory Jute Packaging Act, 2010	2010	National 3R (Reduce, Reuse, Recycle) was enacted to promote recycling and hence eliminate waste disposal in dumps, rivers, canals, etc. But in practice, this policy is not working as yet.
Implementation of the 3R (Reduce, Reuse, Recycle) pilot initiative in Dhaka & Chittagong	2012	In order to promote the jute sector and reduce the reliance on plastic, the MandatoryJutePackagingAct,2010, andMandatoryJutePackagingRules,2013wereenacted. Because of its cheap price and varied features of plastics, jute and jute-related products could not make any impact on plastic products.
Base line study of refuse-derived fuel (RDF)from municipal waste in	2015	For establishingsustainablerecyclinginitiativesandbusi

Dhaka		nessesinvolvingtheurbanpoorin the collection, production, and marketing process of RDF. With the passing of time, the appeal of the study has not given any glimpse.
Plastic Park Project to relocate old plastic factories	2015	BSCIC relocated the old Dhaka plastic factories to a new park in 2018 to improve the working condition and sustainable growth of the plastics investing BDT 500 million with an allocation of 50 acres of land. Despite this most of the factories still operate their activities in the old town.
Survey on soiled packaging waste and existing management practices for the recycling project	2015	The study focused on the existing value chain of soiled packaging and evaluated existing formal and informal facilities located in Kamrangir Char, the Matuail dump site area, Amin Bazar, and the Tongi area of Dhaka metropolitan city and its periphery.
Clean Dhaka Master Plan (2018-2020	2018	The study targets a combination of 3R and the establishment of intermediate treatment plants such as compost, recycling facilities, e-waste, industrial waste management, and incineration plants. Since it is a contemporary study, the implications are yet to achieve.
National Environment Policy	2018	This policy has envisaged pollution control, environment & biodiversity conservation, and mitigation of the adverse effect of climate change to ensure sustainable development.
National workshop	2019	Policymakers and stakeholders were involved in a day-long workshop on plastic product production and consumption, waste management, and recycling. Rather than focusing solely on downstream management of plastic waste, it was determined that upstream management of plastic

		packaging waste involving manufacturers of packaging materials, brand users, and importers could be part of the solution. During the workshop, A technical advisory committee was formed to develop sustainable management of plastic goods and plastic waste.
Public-private partnership (PPP) regulatory framework	2019	Provides guidelines on how to implement PPP projects and specifies the roles and responsibilities of respective line ministries. For promoting investment in the recycling of plastics, PPPs will help develop innovative technologies and skilled manpower.
NationalPlasticIndustryDevelopmentPolicy2020(7thDraft).	2020	The Ministry of Industries developed this policy aiming to achieve zero waste for plastic and packaging consumption by 2030 and hence to manage & standardize recycling.
Waste-to-energy projects using incineration technology to reduce the amount of land filled waste	2020	The DNCC and NCC have got approval for Public Purchase to establish a 42.5 MW waste-to-energy plant in the DNCC and a 5 MW waste-to-energy plant in the NCC that are expected to be operational in 24–36 months.
Piloting of EPR	2020	The World Bank is providing technical support to develop and establish a pilot project on EPR in Dhaka with the active participation of local stakeholders such as DoE, reputed brand owners, BPGMEA, city corporations, and research bodies).
Eighth Five Year Plan, July2020–June2025	2020	The following strategies are recommended: 1. Provide incentives for firms to provide door-to-door waste collection 2. Increase sorting and recycling and promote 3R 3. Promote waste-to-energy projects where appropriate

		4. In the case of high organic content, composting is the preferred option.
Handover of canals to the DNCC and DSCC	2021	To address the long-standing waterlogging and environmental problems, Dhaka Water Supply and Sewerage Authority formally handed over the obligation to maintain and manage 26 canals (84.5 kilometers [km]), and 10 km of box culverts to the DSCC and DNCC, along with the necessary manpower, equipment, and technical documents.
Electrical and Electronic Waste (Management and Handling) Rules	2021	Mandates extended producer responsibility (EPR) for manufacturers and assemblers, with five-year e-waste collection targets and will be applicable to all producers, traders, shopkeepers, stores, collectors, transporters, repairers, collection centers, crushers, grinders, refurbishes, recyclers, auction dealers, exporters, distributors, and large users involved in the production, marketing, purchase, sale, or distribution of electrical and electronic products.

5.2 EXPERTS INTERVIEW

During the study, the researchers conducted 32 expert interviews where 13 respondents were purposefully selected from Bangladesh associated with the plastic industry. The researchers also conducted interviews with 19 foreign experts who have working experience in the same field on the global platform. The interviews were taken at various international plastic exhibitions & conferences in Bangladesh, India, Taiwan, Thailand, China, and Korea since the experts were available at those exhibitions and conferences. Otherwise, it might not have been possible (in terms of time and financial means) to take interviews with those experts as an integral part of the research method.

An open-ended questionnaire has been made for several plastic industries to get present practices and future possibilities of the plastic waste recycling sector in Bangladesh. The researcher contacted all companies by himself. Among them, almost all companies were very cooperative with the researcher and a few of them just gave some ideas on this subject. Fourteen questions were made for the questionnaire and the representatives of all those companies were interviewed for a better understanding of the plastic waste recycling industry in Bangladesh. Similarly, an open questionnaire has been made for industry experts from and abroad to obtain knowledge about present practices and future possibilities of plastic waste recycling. Five questions were made for this questionnaire and were asked all those experts for a better understanding of the subject. Though the interview duration was not fixed in advance it lasted for about half an hour to one hour long concentrating on portraying the plastic waste/recycling problem and opportunities in Bangladesh and global perspective. The interviewing process was continued until the perceived data saturation point.

The researcher got the required information about those companies and industry experts from websites, exhibitions, industry people, and associations first. Since there isn't sufficient information publicly available regarding those questionnaires, it was necessary to contact the companies and experts through some other means such as by phone, email, and also by visitation program.

5.2.1 Detailed findings from in-depth expert interviews (Representative of plastic industry in Bangladesh)

The following table depicts the outcomes of the interviews taken with the representative of some of the renowned plastic industries in Bangladesh.

Table 5.15: Findings from in-depth expert interview (Industry Representatives)

Question	Theme	Participant Response
Do you have in-house plastic scrap recycling facilities?	In-house recycling facility	AllPlast: Yes Bengal: Yes Akij: Yes BPCL: Yes Luna: No Famous: No
How do you process plastic scrap as generated from your own industry?	Processing in-house waste	AllPlast: Crushing, Color wise Sorting, and Bagging for Scrap generated from Production Bengal: Do Akij: Do BPCL: Do Luna: Not applicable here

		Famous: Not applicable here
Do you source plastic scraps from outside? If so, how do source and process these scraps?	Plastic waste souring	AllPlast: Not responded Bengal: Not responded Akij: No Post-consumer Scrap usage in its Process BPCL: Yes. From middlemen Luna: Yes, from recyclers Famous: Not applicable here
What types of plastic scraps do you usually source from outside?	Types of sourced waste	AllPlast: Not responded Bengal: Not responded Akij: No Post-consumer Scrap usage in its Process BPCL: PET Bottle waste Luna: PET sheet and PET granules Famous: Not applicable here
Do you use locally sourced recycled plastic pellets?	Locally sourced waste	AllPlast: Yes Bengal: Yes Akij: Not applicable here BPCL: Yes Luna: Yes Famous: Not applicable here
What types of recycled plastic pellets do you usually source locally?	Types of locally sourced waste	AllPlast: Yes Bengal: Yes Akij: Not applicable here BPCL: Yes Luna: Yes Famous: Not applicable here
Do you import recycled plastic pellets regularly?	Import option of recycled plastic pallets	AllPlast: Yes. But in a different identity since the import policy of Bangladesh does not support Bengal: Do Akij: Doesn't. Because of Import Policy BPCL: Not applicable here Luna: Not applicable here Famous: Yes. But in a different identity since the import policy of Bangladesh does not support
What types of recycled plastic pellets do you usually import from abroad?	Types of imported plastic pellets	AllPlast: Mainly LDPE, HDPE, PP Bengal: Do Akij: Not applicable here BPCL: Not applicable here Luna: Not applicable here Famous: Not applicable here
According to you, how do you differentiate the quality of locally recycled plastic waste pellets and imported recycled plastic wastes?	Difference between imported and locally recycled plastic pellets	AllPlast: Superior quality Bengal: Do Akij: Not applicable here BPCL: Not applicable here Luna: Not applicable here Famous: Superior quality
What about the consumers' perception about the finished	Consumers' perception of	AllPlast: Bad (recycled products) and good (virgin pellets)

products which are usually made from recycled plastic pellets and virgin pellets?	recycled products and virgin pellets	Bengal: Do Akij: Not applicable here BPCL: Not matter Luna: Not matter Famous: Doesn't matter since it handles only export buyers
Considering the present trend and practice, what's the future of the plastic waste recycling business in Bangladesh for sustainability index?	Future of plastic recycling	Allplast: Have a bright future if processed through a global standard Bengal: Do Akij: Recycled Products have a bright future if they were properly processed. BPCL: Do Luna: Do Famous: Do
How would we improve plastic waste recycling in Bangladesh coping with global trends and practices?	Improvement Possibilities of plastic recycling in Bangladesh	Allplast: Emphasizes public-private partnership Bengal: All stakeholders must work together for the fruitful processing of plastic waste Akij: Government Intervention in the proper Processing of Recycling and certain Ratio wise usage. BPCL: Government and policymakers should work together on processing plastic waste and awareness building Luna: Do Famous: Do
What do you think about the future trend of the plastic waste recycling business in the global context?	Future trend of plastic recycling	Allplast: Absolutely bright future Bengal: Do Akij: Do BPCL: Do Luna: Do Famous: Do
Since you are a large conglomerate in the plastic field, do you have any future plans to set up a large-scale commercial plastic waste recycling plant?	Future Plan for plastic waste recycling	Allplast: Yes, it is their active consideration Bengal: Do Akij: Yes, they are observing the market trend BPCL: They are already in this sector and have a plan to further extend of plant Luna: Presently no plan Famous: Presently no plan

N.B: Allpast= AllPlast Bangladesh Ltd (Concern of RFL Group), Bengal: Bengal Plastic Ltd., Akij: Akij Plastics Ltd., BPCL: Bangladesh Petrochemical Company Ltd., Luna: Luna Plastic Industry Ltd., Famous: Famous Plus Industry Ltd.

5.2.2 Detailed findings from In-depth expert interviews (Domestic & Foreign)

The following table depicts the outcomes of the interviews taken with the industry experts (from home and abroad) who are working in plastic industries as well as in the circular economy across the world.

Table 5.16: Findings from in-depth expert interview (Domestic & Foreign)

Question	Theme	Participant Response
Considering the present trend and practice, what's the future of the plastic waste recycling business in Bangladesh for sustainability index?	Future of Plastic Waste Recycling Business in Bangladesh	S Ahmed: A bright future ahead S Faheem: If one follows global practices then a bright future ahead Dr. Haripada: If one follows global practices then a bright future ahead Khadem Mahmud: Bright future
How would we improve plastic waste recycling in Bangladesh by coping with global trends and practices?	Improvement Pathway of plastic recycling in Bangladesh in the global context	Altaf Hossain: Emphasizes public-private partnership A Kashem: Advance technology, public awareness, government positive initiatives Hasnat: Adequate plastic waste for processing Dr. Haripada: Advanced technology, government positive policy, public awareness, adequate supplies of waste, continuous R&D
What do you think about the future trend of the plastic waste recycling business in the global context?	Future trend of plastic recycling	Khadem Mahmud: Bright future ahead S Ahmed: Do Dr. Haripada: Do Piyush Jain: Do Chaivudh: Do David Lo: Do Jennifer: Do
How could we mix up virgin and recycled plastic resin to minimize production costs? In doing so, will it degrade the quality of the final products as produced?	Way of mixing recycled and virgin plastic pellets to minimize production cost	VN Srinivasan: Depends on the type and grade of waste Dharmes Oraon: Depends on types, grades and quality of waste Alex Lee: Can be used 100% if the waste is fully clean S.Y KIM: Do Kalpesh: Do

		Alex Sungtaik Chung: Clean, dust-free, contamination-free waste can be used up to 100%
According to you, how technology plays an important role to get the utmost result from plastic waste?	Role of Technology in plastic waste recycling	Daniel Szymanek: Technology plays a pivotal role in proper waste processing Robin: Do Joanna Liang: Do S.S CHIA: Do

N.B: S. Ahmed: President of BPGMEA, S Faheem: Freelancer, Dr. Haripada: Professor, DU & Consultant and Trainer BPGMEA, Altaf Hossain: Executive Engineer (BITAC), A Kashem: Machine Maker, Hasim Hasnat: Packaging Development Manager(Uniliver Bangladesh), Khadem Mahmud Yusuf: CEO& MD (BPCL), Chaiyudh Sripraipran: Consultant (INACT Corporation), David Lo: Manager (POLYSTER), Jennifer Chen: Sales Manager (SSK Machinery), VN Srinivasan : Business Manager (SABIC), Dharmes Oraon : AVP (Reliance), Alex Lee: Manager (Petronus), S Y KIM: Manager (SK Global), Kalpesh Jani: Global Technical Manager (EMARUD), Alex Sungtaik Chung: Manager (Hanwa), Daniel Szymanek: Area Sales Manager (NGR), Robin Yang: Head of Sales (Atlas), Joanna Liang: Manager (KOWIN), KK Cheung: Manager (KRAS), S.S CHIA: Director (CHESO)

The study outcomes obtained from the expert interview have been described below:

The representatives of all the above companies were interviewed with the same questions. The study has revealed that four companies have their own recycling plants to process in-house generated waste and two companies do not have their own recycling plants. Among those four companies that have their own recycling plants, three companies had not responded on the point of outsourcing plastic waste for recycling. Another one strongly claimed that it never outsources plastic waste to process in its facility. One company is directly involved in post-consumer PET bottle recycling and manufacturing PET sheets, PET Flakes, and PET granules from them. Apart from selling to the local market, this company is also involved in exporting its goods. All those companies are either engaged in the export market or highly interested in exporting their products to abroad. All the representatives of different companies said that global buyers are continuously pushing them to add recycling contents with virgin raw materials to attain economic gain and environmental sustainability. Unfortunately, they fail to meet the requirements of global buyers because of poor-quality recyclables. On the other hand, there is a prevailing restriction on importing recyclables from abroad. Furthermore, domestic buyers have a negative perception of plastic products made from recycled plastic waste. That is why most of the companies are engaged in manufacturing plastic products from virgin raw materials. Even though many other small companies are making various low-cost products by mixing virgin materials and recycled raw materials of poor quality for the bottom layer of the people. Although some of them are directly or indirectly engaged in plastic recycling, they demand and feel the absence of advanced technology and scientific method for collecting, sorting, transporting, and processing plastic waste in Bangladesh. All of the interviewees unanimously agreed that the government should take necessary steps for plastic waste recycling through systematic advanced waste management across the country. The interviewees also said that workers in the plastics industries and actors in the informal sector will be happier if they get enough support, rightful wages, safety, and the opportunity to get experience and education. They firmly believe that the government as well as the companies will take mandatory steps to improve them. Besides this, raising awareness among commoners about plastics, their uses, and waste management is also necessary. People should be aware, trained, educated, and given enough support to get the utmost benefits from plastic waste.

Experts in the plastic industry who are working on plastic and the circular economy were interviewed with the same questions. Many experts suggested that governments should take pragmatic steps in the fruitful handling of plastic waste by raising awareness about plastic, its waste, and the benefit of waste recycling among commoners. Because of its versatile features plastic recycling sector has a bright future across the world. According to experts, all stakeholders including government should work hand in hand to get the max benefit out of it. Many experts cited that the incorporation of advanced technology, proper infrastructure, people's awareness, sound investment environment, smooth supply chain, required R& D, public-private partnership, and strong regulatory policies will help attain the utmost benefits from plastic waste recycling in Bangladesh. The government, trade bodies, law enforcement authorities, plastics industries, etc. have to work together with a clear roadmap for achieving economic gain and environmental sustainability.

5.2.3 Summary of Findings from In-depth Expert Interview

Insights from Domestic and overseas experts show that plastic waste management is considered to be a challenging issue Bangladesh should think about. There is not any single solution for those challenges. Therefore, a more integrated and comprehensive approach is needed by focusing on legal, financial, and communication instruments. The study found the following functional activities of the action plan that are highly needed to take into consideration for extracting the ultimate benefit from plastic waste:

Policy & Economic Instruments

- The public-private partnership will be required to enforce existing rules and regulations with an integrated approach.
- EPR regulation must be ensured to build a recycling market, and produce innovative products towards attaining a circular economy.
- Proper budget planning is recommended, including cost-benefit analysis, and financial analysis to implement the policies.
- Promotes alternatives before banning as bans on certain plastic products are not effective unless economically viable alternatives are available.
- Inclusive policy and regulatory interventions are required to add the existing vibrant informal sectors into the mainstream economy with a coordinated approach.

Infrastructure & Technology

- Relocate existing factories from the old town to a designated zone.
- Facilitate existing factories located in the old town to upgrade their respective infrastructures with contemporary advanced recycling technology and processes.
- Expedite investment in infrastructure for effective collection, sorting, and processing technology. Allocate adequate funds for research and development for upstream and downstream technologies as well as for determining the allowable recycling contents for various plastic products.

Research & Development

- Innovation in design and manufacturing must be driven by involving all value chain actors seeking PPP initiatives.
- Regulate design, standardized labeling, and content to ensure proper implementation of EPR so that different types of plastic waste can be identified in the waste stream and plastic recycling can be made more efficient.

Community engagement

- Create a national campaign to raise awareness among people and empower them for making informed decisions.
- Implement consumer education, awareness campaigns, and social mobilization highlighting the economic and environmental benefits of recycled plastics

Chapter Summary

This chapter started with the findings and analysis of information obtained from open-field in-depth interviews with value chain actors of plastic recycling value chain and presented the outcomes along with the summarized findings from expert interviews. This chapter has also exemplified the implications of the evolution of Initiatives, Policies, and Regulations related to addressing plastic issues in Bangladesh. There are numerous issues explored in this chapter where plastic recycling value chains are mostly unstructured, unregulated, unauthorized, and unmonitored. As a consequence, this sector causes noteworthy ecological hazards along with negative health effects on the community assuming their lack of required knowledge, lack of waste treatment infrastructure, supply chain constraints, lack of funding, and inadequate data related to plastic waste recycling. On top of that adoption of substandard crude recycling technology could not make any significant impact for getting economic gain and environmental sustainability. These aspects are discussed extensively.

CHAPTER 6: CASE STUDIES- FINDINGS AND DISCUSSIONS

Outcomes of the specific objective 2

To study existing plastic waste recycling industry for replication and scalability of the business model on the circular economy principles

CHAPTER CONTENTS

This chapter includes the case study of the organizations that are on the journey towards developing circular economy principles, as well as those who have the ambition of the same.

CHAPTER 6: CASE STUDIES- FINDINGS AND DISCUSSIONS

The transition from Linear Economy to Circular Economy is a global agenda focused on enabling organizations and their value chains to transform towards a more feasible, sustainable, and competitive economic model. Based on this, the study's mission is to explore the feasibility of a viable plastic recycling industry in Bangladesh. Through these engagements, the study aimed to carry out an independent analysis of eight selected foreign organizations and two domestic organizations, and identify new opportunities for Bangladesh, to change and thus, presented in this chapter.

This aspect appears predominantly important for Bangladesh when judging the prospect and opportunities for replication and scalability of the business model on the circular economy notion.

The process of accumulating information, desk research, and interviews conducted in the period December 2018- January 2020. The preparation of the final report on these case studies ended in June 2022 with additional changes implemented later.

Based on the information obtained, a representation of the case organization's business model has been developed using the Business Model Canvas template, while showing relationships between the elements and adopting Lowell Center Framework for sustainable products to understand how companies are offering products that are greener, safer, and healthier from a sustainability perspective.

6.1 TeraCycle, USA

6.1.1 Overview

TerraCycle, the USA-based plastic waste recycling company is spearheading the world engaged in the collection and recycling of non-recyclable plastic waste. TerraCycle was founded in 2001 in Trenton, USA. It operates the recycling business in 21 countries across the world (Europe: 21 Countries) through its allied companies, employing roughly 250 people, and those associates are co-owned by other companies in some cases aiming to develop its business model in addition to block the ever-increasing waste problem effectively.

With a distinct mission to "eliminate the idea of waste" considered a profitable business, TerraCycle runs to three exceptional extents. The first one emphasizes "making everything recyclable" which creates most of their functional activities as "recycling the non-recyclable". It has been claimed by the company that packaging items are measured as non-recyclable since reclaiming and processing cost is higher than the value of the item. Nevertheless, it effectively handles to process of those products by using its collaborative business model with incentives for all stakeholders.

As a consequence, TerraCycle has established itself as the world front-runner in plastic waste collection and fruitful recycling functions. TerraCycle characteristically sets up distinctive collection stands for the complex plastic waste streams that are typically backed by brand owners along with retailers, municipalities, manufacturers, distribution hubs, small industries, etc. The waste collected by the value chain actors against a charitable endowment is re-processed and then sold to producers for making new products and materials. In applicable cases, TerraCycle along with its associates emphasizes integrating reclaimed materials into distinct products.

The second one is on "making everything from waste" which is the ultimate consequence of the first one through using them in new products. For making varied products, reclaimed material is used. Starting from seashore cleaning and concluding with the items ready for the production process.

The third one is on "eliminating the concept of waste by altering the current consumption patterns." To this end, particular operations have not been underway yet since they are in the groundwork stage. Nevertheless, the implementation of durability for non-durable packaging products is the primary stage in this process as announced by the company.

Till now, TerraCycle has created around 200 products licensed to producers rather than made by TerraCycle. Products of TerraCycle could be divided into two main groups' up-cycled products (creating products from other waste streams) and recycled products (parks, lumber, pavers, bike racks, park benches, garbage, and recycling cans, etc.).

For the collection of non-recyclable plastic waste, TerraCycle has several programs types:

Collection Programs: The programs facilitate the collection of plastic waste (usually considered non-recyclable) at home, school, or office, public gathering hubs, and deliver free delivery labels for waste to be sent for recycling funded by brands, manufacturers, and retailers. In some cases, various types of plastic waste are exchanged to attain rewards for schools or non-profit organizations.

Municipal Programs: It is based on zero waste solutions that range from city-wide to curbside programs for recycling non-recyclable products.

Zero Waste Boxes programs: Through this program businesses and consumers purchase a turnkey recycling solution in the form of a box for specific waste collection and then the waste is sent to TerraCycle.

Industrial waste solutions: Apart from partnering with manufacturing to recycle waste traditionally considered non-recyclable at the industry level, the company also provides zero-waste consultation and closed-loop Research & Development support.

Commercial services and route logistics: With the distinguished recycling programs, the company collaborates with mobile, service-based companies to develop their platforms.

Event services: Regarding collection, recycling, promotion, and sponsorship issues, TerraCycle provides comprehensive event services for businesses and organizations.

TerraCycle's operations and activities are typically waste streams that are considered mostly non-recyclable. Because of the collection and processing cost, they are not recycled - and are instead sent to landfills or incinerated and compensate for the value generated from the recovered material.

Nevertheless, the company discovered systems to enable profitability for every entity in the value chain through various pragmatic programs stated above.

TerraCycle generates additional value for the sponsoring company mainly by increasing its positive perception with the use of the media coverage of their programs based on their sheer publicity that translates into a meaningful return on investment through a variety of measures from driving increased market share and incremental sales. TerraCycle earns revenue from the services and products they provide to corporations. Apart from the recycling activities, incentives are provided to collectors, by donating money on waste collection rates to a charity or school and to a smaller extent in the form of incremental promotions.

In the near future, TerraCycle is planning to expand its business model in order to challenge the excessive waste generation issues from non-durable packaging. In this connection, the company will introduce a program that will offer over a thousand non-durable products in durable, refillable packaging and it will be supplemented with the system for logistics and purification of the packages to answer consumers' needs and simplify their experiences.

6.1.2 Applying Business Model Canvas to TerraCycle

This case study takes on the TerraCycle recycling program, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.1: TERRACYCLE (USA) Business Model Canvas

Case Study on TERRACYCLE (USA)

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Recycling companies Shipping & Freight Companies Storage Companies School, charities, NGOs	• Design, Reusing, Upcycling Recycling Process • Organize Collection • Marketing & PR	• Cooperation for Collection and Further usage of waste considered non-recyclable. • From the viewpoint of circular economy, the company establishes a platform that facilitates circular sourcing - greater material reuse and decreases usage of virgin raw materials.	• Long term business relationships • Cooperation for closed loop solutions	• Perishable goods producers • Retail Sector • Municipalities • NGOs and Individuals with specific environmental concerns
	Key Resources Human Resources Volunteers Technological Know-how Operational Know-how Brand Recognition		**Channels** Customer approaches to TeraCycle for Cooperation Customers reach directly	
Cost Structures Operational costs People Subcontractor costs			**Revenue Stream** Annual fixed fee for collection programs Zero waste box revenue Sale of the reclaimed materials	

Key partners

Subcontractors are the key partners of TerraCycle since it does not own any production, warehousing, or sorting facilities for waste processing and related services. Recycling companies are TerraCycle's most important partners as they are used to provide the fundamental processing services for the collection of material. Depending on the waste type, collection program, and location TerraCycle uses the valued services of many recycling companies. After identifying the exact type of waste, TerraCycle aggregates the waste and then sends it to the recyclers of different locations. A lower volume of waste is used to send the recyclers against their actual production capacity to minimize the demand and supply gap and hence to make use of the economic effects of scale in their cooperation with recycling companies in case of the growing amount of waste collected. The cooperation with recycling companies is assessed positively that process waste by either using their existing technology & equipment to process the company's unique waste streams or installing all-new machinery & equipment as required. Shipping and freight companies are other noteworthy key partners. TerraCycle finances the aggregated waste transportation from the collection point using money paid by the sponsoring company. For example, it has been largely reliant on the UPS shipping company since 2012 soon after starting their cooperation. Relying upon a single global transportation services provider may be assessed as posing uncertainties to the company's business model. Later the company identified that UPS services are expensive compared to transportation using its own fleet. Considering this, the company needs to diversify its logistic services in the future. Freight services to transport waste materials between warehouses and recycling facilities are provided by various companies depending on the location.

Key activities

The collection program usually starts with designing the process of reusing/up-cycling/recycling the product or its packaging with tailor-made for each type of product because of its varied characteristics. With its own R&D facilities, tools, workforce, and relevant know-how in material processing, TerraCycle organizes the system for the collection of used products and product packages. The company has established a platform that facilitates finding the collection point by users, provides free shipping labels that can be printed and used by collection points, and promotes the programs via media coverage that results in an increased number of collectors., etc. TerraCycle educates on the proper waste collection which is dependent on the reusing/up-cycling/recycling process designed earlier. Apart from this, TerraCycle establishes business relationships with warehouses and recycling companies, and product manufacturers. Since the marketing of the program is essential for success, the company takes a distinctive approach to marketing and public relations and is a great example for other lean operations as it never uses paid media.

Key resources

It has been identified that TerraCycle's key resources are interconnected since every resource is essential to delivering its value propositions. The R&D team and marketing team are renowned for their engagement in economic and environmental issues. Equipped with sound technical and operational know-how, these people spearheaded the company over the last 20 years which is considered another key resource. The process for reclaiming material and hence manufacturing it into value-added new products are designed with this knowledge. This design emphasizes enabling a circular economy principle incorporated with the business model that allows the company to establish effective collection systems. Brand recognition is considered to be a unique key resource of TerraCycle's that is a result of media coverage of the company's activity throughout the year and it is a strength of its brand recognition since the company has no direct competitors to date.

Value proposition

TerraCycle's value proposition is to cooperate for the collection and further usage of waste usually considered to be non-recyclable. Through public engagement in the collection network, the sponsoring brands increase their environmental performance and receive positive recognition in the press and social media for their role in enabling the recycling of otherwise non-recyclable waste. Programs are targeted at establishing the customer brand as eco-friendly which then can result in increased brand recognition, higher market reputation, and consecutively growth in sales. From a circular economy perspective, the company creates a platform that facilitates circular sourcing and reuse and hence minimizes the usage of virgin raw materials.

Customer relationships

A personalized relationship has been established by TerraCycle there is no standard approach to specific problems. The bond with customers is long-term with fully collaborative effort and in the majority of cases, the contracts are renewed every year. Regarding the working relationships, TerraCycle engages senior management and the revenue-producing side of major corporations. TerraCycle seldom enters clients through the customer's operational and procurement teams. If there is the opportunity for extending the program, TerraCycle engages aiming to provide wider cooperation, e.g., by using the reclaimed material from the used product in a specific manner chosen by the customer. Delivering those closed-loop solutions to its clients requires holistic collaboration with the customer and other entities. Individuals and organizations used to take on the Zero Waste Boxes program of TerraCycle without any close relationship with the purchaser rather they were willing to waste considered non-recyclable. Nevertheless, the sale of Zero Waste Boxes purchase is a recurring operation in many cases. Municipalities are maintaining long-term, continual relationships by using the company's services to decrease littering and implement circular solutions into their operations.

Channels

Usually, the customer reaches out to TerraCycle and then TerraCycle employees engage in talks on possible cooperation and its design. This channel is ended by TerraCycle's brand recognition and high media presence. However, it was not always the case. Before establishing the world recognition of the TerraCycle brand the customer was searched for proactively.

Customer segments

Non-durable goods manufacturers are considered to be the main customers for TerraCycle whose used products are sent to landfills or incinerated? They pack their products in a type of packaging considered non-recyclable, and their products themselves are considered inappropriate for recycling due to their characteristics such as material complexity and lack of eco-design. Typically, these are low-cost products, small in size, that need massive work to collect and aggregate, and thus this process becomes uneconomical. On the other hand, the products that are used for a relatively long time in small quantities, and therefore, it is hard to collect significant volume for recycling functions.

Organizations and individuals are also the customers of TerraCycle who buy zero waste boxes to answer specific environmental needs.

Municipalities are also of TerraCycle's customer segments since they use curbside services to decrease littering and implement circularity as a whole.

Cost structure

The circular economy is rooted within each program since the products and product packages would be diverted from landfills, incineration, or else which is enabled by establishing a favorable collection system and then reusing/upcycling/recycling used products. Recycling, warehouses, and shipping companies are subcontracted for this process to work since TerraCycle does not own processing facilities. The steps involved in the subcontracted services are sorting and aggregation, storage, logistics, cleaning, shredding, recycling, etc. Therefore, their compensation is considered to be one of the main costs of the programs. Except for subcontracting costs, human resource expenses seem to be another important cost structure in TerraCycle. For standard collection programs, this particularly concerns the dedicated account manager, marketing and communications, and R&D design team.

Revenue streams

The Key revenue sources of TerraCycle are as follows:

1) Contract with brand manufacturers: Collection programs functioned under contract with brand companies and the contracts pay the material shipping, sorting, segregating, and processing costs. Customers pay an annual fixed fee for the recycling program which is based on the quantity of collected material.

2) Material sales: Selling of recycled materials collected via the collection programs and Zero Waste Boxes. TerraCycle estimates only 3 % of the material is sent to disposal. Even though the margin is lower than other TerraCycle's other revenue sources, this business segment is growing steadily.

3) Zero Waste Boxes: selling prepaid shipping boxes for a specific category of waste where the material handling and processing costs are factored into the price of the box which is dependent on size, weight, costs to recycle, and the value of recycled materials, and whether sorting is needed.

6.1.3 Applying Lowell Center Framework for Sustainable Products to TerraCycle

The following table classifies TerraCycle's current position from a sustainability perspective under the Lowell Framework and all of the metrics currently employed by TerraCycle fall into this Framework. TerraCycle has been operating its recycling business over the last 20 years across different parts of the world complying with country/association/industry regulations and conformance that are duly audited and evaluated by renowned firms like Bureau Veritas. TerraCycle is not typical recycling rather it has developed ways to collect & recycle plastic waste that is not usually considered recyclable. TerraCycle's unique business model and advanced technology can recycle hard-to-recycle waste by partnering with brand manufacturers, retailers, recyclers, and other concerned stakeholders and hence produce more than 200 products safely, responsibly, and efficiently.

Table 6.1: Current Indicators related to Framework Level

Framework Level	Current practicing Indicators
Level 1: Compliance/Conformance	Fully comply with regulations and industry standards audited by renowned audit firms like Bureau Veritas.
Level 2: Facility Material Use & Performance	Partnered with brand manufacturers and recycling facilities to source, process plastic waste, and make the valued added products safely, responsibly, and efficiently. Finally delivers to the customers efficiently.
Level 3: Facility Effects	The journey from over linear to a circular economy where environmental and public health issues are highly prioritized.
Level 4: Supply Chain & Product	Closely work with the supply chain actors from plastic waste sourcing, and processing to new product making & shipping.
Level 5: Sustainability Indicators	Working with businesses, communities, state authorities, policymakers, and individuals to eliminate the idea of waste and establish a sustainable society.

Being a mission-driven company, TerraCycle is built on a sustainable model that combines economic, social, and environmental value creation. The main impact of TerraCycle's activities is to create the utmost possibility to collect those wastes that are considered non-recyclable. The involvement of different stakeholders in this process helps promote the transition towards a circular economy by providing innovative solutions to reduce plastic as well as better use of plastic waste. The reduction of plastic waste is the biggest positive environmental impact where ongoing environmental education and volunteering attitude promotion helps accomplish social and environmental sustainability.

6.1.3.1 Are TerraCycle's Products Sustainable?

The following table summarizes the case study in the context of the Lowell Center Framework for Sustainable Products, illustrating that TerraCycle is on its way to meeting the criteria.

Table 6.2: Sustainability measures of TerraCycle

Measures	Significance
Is the product healthy for consumers?	TerraCycle avoids additives and chemicals with its unique technology that can leach out of plastic and harm the users of its products and also avoids painted coatings that may contain toxic chemicals therefore, TerraCycle products are safe to use.
Is the production process safe for workers?	Although an in-depth workplace inspection was not conducted for this case study, the interview cited that the working conditions of TerraCycle are safe, workers receive health and safety training and are treated respectfully and with utmost care. Because the design and unique technology avoid hazardous materials, workers are not exposed to chemical toxins in the production and delivery process.
Is the product environmentally sound?	TerraCycle processes various plastic with their most modern unique technology to produce the greenest materials that meet its functional requirements. In choosing plastic wastes of different types, TerraCycle removes hazardous material from the waste stream to make a new product, saving energy in the process. Products are further recyclable. The reduction of packaging waste is the biggest positive environmental impact. On top of that, the main impact of TerraCycle's activities is to create the utmost possibility to collect those wastes that are considered non-recyclable.
Does production benefit local communities?	TerraCycle has created a model of local production in 21 countries across the world and so has created many jobs as a result. In addition, by contracting with the Work Center, TerraCycle works dedicatedly to improving the social welfare of individuals across the world it operates by linking to ongoing environmental education and volunteering attitude promotion.
Is the product economically viable?	As the company has been in existence for twenty-one years, it is the right time to evaluate long-term economic viability and the company is thriving and growing, continuing to introduce products and making improvements as needed with expanding its business horizon from a global perspective.

6.1.4 Critical Analysis

It has been observed in this study that at every stage of TerraCycle's operations, a drive toward the circular economy is visible. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. Keeping it in mind, the study has considered "TerraCycle" as one of the cases because of its determination: "eliminating the idea of waste".

It does not appear to be the case that profit is only the final goal for TerraCycle. It is a sustainable value creation-oriented organization and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, TeraCycle presently emphases collecting, processing waste into valuable raw materials, and manufacturing new recyclable products in possible cases.

The basis of TerraCycle's business model is classified as a resource recovery program that forms the main part of the company's business The resource recovery program consists of collecting waste materials at end-of-life that are then recycled/upcycled into different products or used as inputs for another process.
TerraCycle established itself as a strong brand that is associated with eco-friendly collection programs and products are manufactured in cooperation with its customers.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Key activities and resources hard to duplicate or obtain
- Increasing corporate sustainability powered by the mounting environmental consciousness of customers
- Remarkable customer satisfaction
- Solid and long-term customer relationship

Key Barriers:

- Low volume of products that can be recycled in a socially-accepted other different ways
- Probable limitations of using few non-recyclables
- Comparatively low economies of scale

The circular business model of TerraCycle appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on resource recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for resource recovery
- Use environmental-minded volunteers
- Make well-organized resources in diverse life cycle phases

- Design for reusability ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations
- Introduction of limiting requirements in managing plastic waste is necessary
- Introduction of a circular public procurement on a wider scale
- Monitor implementation of circular economy legislation

The current business model of TerraCycle has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. Nevertheless, the scalability and replicability of the business model is slightly limited due to two core aspects. Firstly, every product cannot be recycled in a socially recognized way using the existing technology. Since the recycling procedure essentially be effective and highly sustainable, else it could tarnish. The main asset of TerraCycle is its brand reputation. Therefore, possible replication of TerraCycle's business model would require long-term commitment which is a significant barrier to new entry. Secondly, the non-recyclable products are minor and low-priced which confines economies of scale.

Despite all these, it would be better to decrease waste generation, the processing of various wastes has significant benefits for society and the environment.

TerraCycle could use its vast network and experiences in offering closed-loop solutions as a standard to enhance its collection program. Presently, resolutions for closing the loop are only a possibility, not a default. Such a program would assure the final products made from recycled material are recyclable without any additional resources to establish such systems by TerraCycle as already functioning collection points could be used.

6.2 ByFusion, USA

6.2.1 Overview

Founded in 2017, ByFusion® is a USA-based, highly innovation-driven manufacturing company committed to preserving the recycling industry, protecting the environment, and giving plastic a new life by reshaping its future. Observing plastic on the verge of becoming one of the earth's most devastating environmental threats ByFusion took the lead to be a part of the solution. After prolonged research and development, ByFusion apprehended that plastic which is strong, flexible, and built to last was not invented to be just merely thrown away after the intended use finished. Thus, plastic isn't a problem, rather the problem is in the mind of people that we do not have a good plan for its prospective future. Therefore, it sends to landfills, and burns, and there are continents of it floating at sea killing precious wildlife. After years of incessant research and development, ByFusion successfully developed its patented Blocker systems the first construction-grade building materials in the world that can consistently convert all types of plastic waste into high-performing advanced building materials named ByBlock®. The salient unique features of ByBlock® enable communities, corporations, industries, tourists, and governments to make fruitful use of their plastic waste while cleaning up the earth and eventually creating jobs, improving infrastructure, and revitalizing neighborhoods everywhere.

ByFusion's mission is "Protect the environment by enabling the recycling industry to recycle the unrecyclable." and the goal is "Recycle 100 million Ton plastic waste by 2030."

The core value of the company is to strive for making positive effects to create a sustainable future for the planet. In order to attain this, the company invested a significant amount to work with the people in the communities in a team effort to clean up the planet rather than doing it alone. As aligned on their mission, creating a common purpose, ByFusion works tirelessly to yield the best solutions, achieve results and create possibilities that would not otherwise exist rather than stopping themselves until the work is done. Thus, ByFusion leads by example and does its best to do well and be good that feels great all the way.

ByFusion is devoted to enabling communities across the world to transform traditionally unrecyclable plastic waste into reusable and highly functional building materials to collectively address the global plastic crisis. Its patented unique systems convert varied plastic waste (including marine debris &fishing nets) into an advanced building material named ByBlock that enables communities, corporations, industries, and governments to block plastic waste for good.

Being a part of combating climate change, ByFusion is working incessantly through innovative uses of technology. Most commonly installed in a community's materials recovery facility (MRF), the ByBlock® uses steam and compression to convert all types of plastic waste into revolutionary building material and thus diverts trash destined for the landfill, repurposes the mixed plastic waste materials into a consolidated building block while giving plastic waste a long term, sustainable purpose. ByBlocks can be utilized for various types of structures like sheds, walls, and anything else requiring construction-grade building material. It is worth mentioning here that ByFusion's ByBlocks account for 41% less greenhouse gas emissions compared to conventional concrete building blocks, as per the report in the Waste Reduction Model (WARM) generated by Environmental Protection Industry in 2012. Unique features of ByBlock can be summarized below:

- ByFusion recycles the unrecyclable without sorting, prewashing, hot washing, etc.
- The company significantly reduces plastic waste management hassle and recycling infrastructure
- It scales to meet the volume demands of the recycling facilities.
- It does not require any chemicals, additives, adhesives/glues, fillers, or else
- It protects the planet, oceans, waterways, and wildlife
- It customizes specific densities
- It has an easy installation mechanism which is 75% faster than a conventional concrete block
- It saves more than 50% on material and labor expenses
- It generates 41% less greenhouse gas emissions than conventional concrete blocks

Because of their innovative technology with varied features, ByFusion has been recognized by many renowned organizations such as Fast Company, The New York Times, Forbes, Architect, Recycling Today, US Green Building Council, B Corps Best for the World, 1% for the Planet's Innovation of the Year, Waste Dive's "Most Disruptive Innovation of the Year", and an essential cog in the wheel of the circular economy.

6.2.2 Applying Business Model Canvas to ByFusion

This case study takes on the ByFusion recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.2: BYFUSION (USA) BUSINESS MODEL CANVAS

Case Study on BYFUSION(USA)

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Communities, corporations, Industries and governments	Accessible Building Products manufacture	• Recycles the unrecyclable without sorting or prewashing • Does not require any chemicals, additives, adhesives, or fillers	Working together as a team to clean up the planet as well as to accomplish economic gain	• Industries • Individuals • Municipalities • Government
	Key Resources		**Channels**	
	• Human Resources • Skilled Engineers • Environmentally sensitive technology which needs less people to operate		• Customer approaches to BYFUSION for Cooperation • BYFUSION reach to Customers directly	

Cost Structures	Revenue Stream
• Technology • Operational costs, and R& D • Logistics • People	• From selling Building materials • Turnkey-based project solution

Key partners

Materials recovery facilities (MRF) are the main partners of ByFusion as they are cornerstones for every community regarding recycling or plastic waste diversion. Despite their key role in every community for cleansing various types of waste, MRFs are often underappreciated and caught in the middle of volatile global recycling markets and regional environmental goals. ByFusion designed its product to give MRFs a unique new technology that increases their resilience to this volatility, creates a new revenue source, and offers increased agility to meet overall sustainability goals. Since ByFusion is a waste Infrastructure Company where communities, materials recovery facilities, construction companies, and architects are considered to be its key partners. The company used to have a lot of demand for ByBlock as people are always in search of finding alternative building materials. Moreover, there is a lot more incentive for architects and builders for using sustainable products. Therefore, communities, architects, engineers, and builders are a major part of ByFusion's key partners. The sole mission of ByFusion is to enable communities and corporations to take control of their own generated plastic waste into a building material that can then be used within communities to serve those local communities. Thus, ByFusion acts as a platform that enables change, to enable cities to take more responsibility, accountability, and transparency in the waste management process where ByFusion provides the hardware, infrastructure, and training for cities, communities, and corporations to do that themselves.

Key Activities

ByFusion does not view itself as a product manufacturer rather than they view itself as a service provider. ByFusion recognized that cities and corporations do not necessarily know how to sell building materials, nor do they need to. Realizing that fact, ByFusion has set its goal to be a service provider to cities. The activities of the company vary in different ways. ByFusion does a hardware-only service where it comes in, plops the system down, helps train local operators to run the operation as well as works with local builders on how to build with the material. Apart from this, the company comes in and does all the quality inspections, and makes sure the building material continues to live up to the standards that were required, then also provides services and upgrades along the way. If the city or corporation doesn't have a surplus or make enough blocks that they cannot use, then the company will come in and help move those materials into the market by doing either a guaranteed buyback or a revenue split.

Therefore, there are different ways to think about ByFusion activities. The base service that ByFusion provides starts at about $300,000/year which is a really affordable piece of technology that enables companies or communities or else to take control of their wastes and create their own building materials with a lot of advantages from a cost perspective.

Key resources

It has been identified that ByFusion's key resources are intertwined with each other since every resource is essential to delivering its value propositions. With technological savvy, the founder & CEO, Mr. Heidi Kujawa, is the mastermind of creating ByFusion because of his previous waste handling experience and he is the main resource person of the company. Moreover, the CEO of ByFusion is a visionary leader who has a passion for innovation, technology, and sustainability and has a proven track record of developing, executing, and managing plans strategically that address complicated problems across multiple industries including technology, construction, and sustainability. The R&D team and marketing team are renowned for their engagement in economic and environmental issues. Equipped with sound technical and operational know-how, these people spearheaded the company since its inception which is considered another key resource. ByFusion has a unique process for treating mixed plastic waste (which is otherwise, almost impossible to process by conventional recycling technology) material and hence manufacturing it into a construction building block named ByBlock. This design emphasizes enabling a circular economy principle incorporated with the business model that allows the company to establish effective collection systems.

Value proposition

ByFusion’s value proposition is to recycle the unrecyclable without sorting, prewashing, hot washing, etc. by creating a partner network. As a consequence, the global plastic crisis will significantly be solved by empowering communities to block their own generated waste in place and by leveraging it to solve the ever-increasing challenges considering job creation, affordable housing, and crumbling infrastructure, the support of aggressive waste reduction goals, and supply the local market with an incredibly cost-effective, 100% recycled advanced building material which is to:

- recycle the unrecyclable without sorting, prewashing, hot washing, etc.
- reduce plastic waste management hassle and recycling infrastructure
- scale to meet the volume demands of the recycling facilities.
- cut chemicals, additives, adhesives/glues, fillers, or else
- protect the planet, oceans, waterways, and wildlife
- customize specific densities
- install 75% faster than a conventional concrete block
- save more than 50% on material and labor expenses
- yield 41% fewer greenhouse gas emissions than conventional concrete blocks

Considering the above features and unique characteristics, ByFusion is recognized by many organizations and institutions such as the Alliance to End Plastic Waste, the New York Times, Fast Company’s World Changing Ideas (2019), US Green Building Council Net Zero Accelerator (2019), B Corps Best for the World (2019), 1% for the Planet’s Innovation of the Year (2018) and Waste Dive’s ‘Most Disruptive Innovation of the Year Award (2016).

ByFusion is dedicated to the healing of Earth and truly believes its patented process is a key component to regenerating the planet and reshaping its relationship to plastic.

Customer relationships

ByFusion has been established with the customers and there is no standard approach to specific problems. The bond with customers is long-term with a fully collaborative effort. ByFusion allows MRFs to create saleable construction-grade building products named ByBlock, creating a revenue stream and decreasing the overall cost associated with plastic waste disposal.

With its modular technology to custom fit, ByFusion’s Blockers are designed to support small facilities and waste streams or scaled to meet the needs of large volumes and expansive facilities and hence to establish a long-term relationship with customers like MRF, Construction companies, and government as well. ByFusion offers its customers something no other plastic recovery technology does– the opportunity to locally divert a community's plastic waste and turn it into a product for building local facilities and structures as a true local diversion and local recycling. Materials Recovery Facilities (MRF), communities, and construction companies are maintaining long-term, continual relationships by using the company's services to decrease littering and implement circular solutions into their operations.

Channels

Usually, the customer reaches out to ByFusion and then ByFusion authorities engage in talks on possible cooperation and its design. Since ByFusion provides technological and support services there is no such specific distribution channel to be considered. Usually, the company gave installation service at the facility center on the customer premises which takes a single time. After that, they provide support services such as training, troubleshooting, etc.

Customer segments

Material Recovery Facilities (MRF) are the main customer segment of ByFusion since they use curbside services to decrease littering and implement circularity as a whole. Apart from this, construction companies, the government, and common people are also considered to be the main customers of ByFusion. Organizations and individuals are also the customers of ByFusion who buy its technology and install it in their facilities.

Cost structure

Since ByFusion is a technology-driven company that designs & developed technology through incessant research and development with regular up-gradation huge costs are involved in doing so. Apart from this regular, operational, marketing, and advertising costs take the place of the nature of business as well as human resource expenses seem to be another important cost structure in ByFusion.

Revenue streams

The Key revenue sources of ByFusion are as follows:

1. Selling of patented Technology: Technology selling functioned under contract with the MRFs, Government, Construction Companies & Individuals, and the contracts pay machine and installation costs. Apart from this, customers pay a monthly/annual fee for the after-sales service as settled mutually based on customers' requirements.

2. Material sales: Selling of construction building block named ByBlock.

6.2.3 Applying Lowell Center Framework for Sustainable Products to ByFusion

The following table classifies how ByFusion's current activities fall into the Lowell Framework from sustainability.

After years of incessant research and development, ByFusion successfully developed its patented Blocker systems and started producing the first construction-grade building materials in the world that can consistently convert all types of plastic waste into high-performing advanced building materials complying with USA regulations and all required industry standards & conformance. ByFusions' construction materials are duly certified, audited, and evaluated by renowned firms like Fast Company, Forbes, Architect, Recycling Today, US Green Building Council, and many more.

Table 6.3: Current Indicators related to Framework Level

Framework Level	Current practicing Indicators
Level 1: Compliance/Conformance	Fully comply with regulations and industry standards of the USA recognized by many renowned organizations like Fast Company, Forbes, Architect, Recycling Today, US Green Building Council, and many more.
Level 2: Facility Material Use & Performance	The eco-friendly process of ByFusion uses steam and compression to convert all types of plastic waste sourced from material recovery facilities (MRF) into a revolutionary building material called ByBlock that has numerous applications such as sound wall, retaining wall, shed, terracing fence, furniture, and many more.
Level 3: Facility Effects	Enable communities, corporations, industries, tourists, and governments to extract the ultimate benefit from the mixed plastic waste while cleaning up the surrounding environment and eventually creating jobs, improving infrastructure, improving the health condition of communities, and revitalizing neighborhoods everywhere.
Level 4: Supply Chain & Product	Closely work with the supply chain actors (especially MRF) from plastic waste sourcing, and processing to new product making & shipping or technology transfer to customer premises.
Level 5: Sustainability Indicators	Strive for making positive effects to create a sustainable future for the planet by working with businesses, communities, Material Recovery Facilities, and individuals to eliminate the idea of waste and establish a sustainable society.

Being a highly innovation-driven manufacturing company, ByFusion is committed to protecting the environment by recycling mixed plastic waste for producing high-quality construction materials with its patented technology and giving plastic a new life by reshaping its future. The technology developed by ByFusion is the first of its kind in the world that is periodically tested, and evaluated along with continuous product R&D in order to produce sustainable products for the ultimate betterment of the environment and community well-being. Regarding the supply chain activities, ByFusion mainly works with the Material Recovery Facilities (MRF) and it has limited supply chain partners to maintain such activities precisely from plastic waste sourcing and processing to new product making & shipping.

Being a part of combating climate change, ByFusion is working incessantly through innovative uses of technology. ByFusion's construction materials produced from mixed plastic wastes account for 41% less greenhouse gas emissions compared to conventional concrete building blocks, as per the report in the Waste Reduction Model (WARM) generated by Environmental Protection Industry in 2012 that eventually protects our planet, oceans, waterways, and wildlife since the mixed plastics will go otherwise landfills, incineration, and ocean through waterways. Therefore, ByFusion is devoted to enabling communities, corporations, industries, and governments across the world to transform traditionally unrecyclable mixed plastic waste into reusable and highly functional building material to collectively address the global plastic crisis while cleaning up the earth and eventually creating jobs, improving infrastructure, and revitalizing neighborhoods everywhere.

6.2.3.1 Are ByFusion's Products Sustainable?

The following table summarizes the case study in the context of the Lowell Center Framework for Sustainable Products, illustrating that ByFusion is on its way to meeting many of the criteria.

Table 6.4: Sustainability measures of ByFusion

Measures	Significance
Is the product healthy for consumers?	ByFusion significantly recycles the unrecyclable without sorting, prewashing, hot washing, etc. that need not require any chemicals, additives, adhesives/glues, fillers, or else. As a consequence, ByFusion's products are safe for consumers.
Is the production process safe for workers?	The company mostly uses its own patented automated technology for making construction materials and needs fewer workers & technicians. Even though the working conditions of ByFusion are safe, workers receive health and safety training and are treated respectfully and with utmost care. Because of the design and unique patented technology that avoids hazardous materials, workers & technicians are not exposed to chemical toxins throughout the whole operation of the company.
Is the product environmentally sound?	Compared to conventional concrete building blocks, ByBlocks account for 41% less greenhouse gas emissions that eventually protect our planet, oceans, waterways, and wildlife. The different stakeholders' involvement in the whole process helps promote the transition towards a circular economy as the biggest positive environmental impact.
Does production benefit local communities?	Municipalities, governments, and policymakers have the challenging position of meeting regional or statewide waste diversion requirements, yet are subject to the incoherence of national and international waste markets and trends. In this connection, ByFusion offers the world something new and unique that no one has experienced before. Through this unique technology community's plastic waste turn it into a product for building local facilities and structures with true local diversion and local recycling with the job creation of many people.
Is the product economically viable?	Aiming to give MRFs such a new technology that increases their resilience to this volatility, creates a new revenue source, and offers increased agility to meet overall sustainability goals, ByFusion emerged with its patented technology which is second to none in the world. As the company has been in existence for about four years, it is too early to evaluate long-term economic viability. Nevertheless, the company is thriving and growing, continuing to introduce new construction materials and making improvements as required in the short term.

6.2.4 Critical Analysis

This study identified that ByFusion's operation is an ambition towards attaining a circular economy. Since one of the main purposes of this study is to formulate a sustainable product strategy from plastic waste recycling that will facilitate the circular economy implementation in Bangladesh. Considering this, ByFusion was chosen as one of the cases because of their ambition: "Solving the Global Plastic Waste Crisis".

ByFusion is the first company in the world to take control of various types of mixed plastic wastes and convert them into value-added reusable building materials by applying custom-engineered systems to meet the specific needs of the communities. It is a sustainable value creation-oriented organization that appears most important when assessing the possibilities for probable replication of the business model in line with the circular economy principle. Considering the circularity principle at every step of its operations, ByFusion presently emphasizes collecting, processing all types of mixed plastic waste into high-demand building materials.

The basis of ByFusion's business model is classified as a profit-driven company through a mixed plastic waste recovery program. The plastic waste recovery program consists of collecting mixed plastic waste materials and converting them into different building materials. ByFusion closely works with Material Recovery Facility (MRF), companies, and municipalities with eco-friendly collection programs, and building materials are manufactured in cooperation with them.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Reduce the cost burden of low-value plastics
- Exclusively designed to plug in any existing sorting lines
- Reducing transportation costs and other handling fees
- NO WASTE PROCESS and Accessible Building Materials of ByFusion make it very easy to measure the contribution of any organization
- Provide a solution to insert into the existing curbside recycling programs
- Create a building material that can be used to address failing infrastructures

- Key activities and resources easy to duplicate or implement
- Increasing corporate-social responsibility and sustainability powered by an ever-increasing environmental consciousness of customers

Key Barriers:

- High cost of technology
- Recently launched in the USA and need time to popularize across the world
- Capable to produce certain types of building materials
- Patented technology is hard to replicate without royalties.

The circular business model of ByFusion seems to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on resource recovery, companies in different sectors and city corporations in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Collaborate across different stakeholders such as Material Recovery Facilities (MRF), Corporations, and Municipalities to find the finest solutions for resource recovery and reprocessing
- Use environmental-minded volunteers
- Make well-organized resource recovery facilities in diverse phases
- Design for reusability of reprocessed building materials ensuring the lowest negative impact on the environment and human well-being
- Design affordable technology with easy installation and operation procedures to spread across the world

Key Considerations for Policy Makers:

- Ensure constant support with viable regulatory affairs
- Introduction of restrictive requirements in mixed plastic waste reprocessing is necessary
- Introduce on a wider scale a circular public procurement
- Monitor implementation of circular economy legislation

The current business model of ByFuson has been founded on circularity notions. Over the years, the company is constantly converting all types of plastic waste into value-added building materials that are second to none in the world. Nevertheless, the scalability and replicability of the business models are slightly limited due to the high technology transfer cost since it is a patented technology of ByFusion. However, it is anticipated that the high technology transfer cost will be reduced gradually in the days ahead. In spite of this, it is a more suitable option for Bangladesh to adopt for processing mixed types of plastic waste. Moreover, the technological investment will mostly consider a one- time.

ByFusion could spread its patented technology across the world to decrease the plastic waste generation that enables neighborhoods, companies, policymakers, and governments to clean up the planet.

6.3 IntegriCo Composites Inc., USA

6.3.1 Overview

Founded in 2007, IntegriCo Composites Inc. is considered one of the forerunners in the industrial product manufacturing industry. With an aim to build a comprehensive recycling infrastructure with expansion strategies on sourcing programs in capturing an increased volume of landfill-bound plastic to transform back into raw material, the company has started its journey.

The mission of IntegriCo is to be the most trusted, dominant, and leading manufacturer of composite industrial products by ensuring a safe environment for the employees with the highest ethical fashion.

Through its patented technology, IntegriCo’s Lousiana production facility produces various composite products from 100% recycled plastics. A unique technology of its kind mixes landfill-bound plastic wastes to create composite railroad ties, construction & rig matting parts, pipeline skids, and other related products that far exceed industry standards for high quality, consistency, and structural integrity. IntegriCo’s composite plastic products are usually sold to the railroad, E&P, pipeline, and industrial companies. Being a fully R& D-based and technology-savvy company, IntegriCo continues to improve its technology and infrastructure to help the world divert plastic waste away from landfills and make strides toward attaining the circular economy goal.

IntegriCo's unique patented composite products provide superior strength, impact and crack resistance, durability, and maintenance-free. Prolonged experience in the same field allows them to continually test, scale, and innovate high-quality composite products to meet customers' needs at their best. Extremely high cross-linked plastic materials that are near impossible to recycle by convention technology, IntegriCo's patented unique technology can do it without fail by specialized formulation. Their specialized low–heat process unleashes mechanical properties that are resistant to deformation and cracking when under heavy load and preserve plastic properties that make it such a good raw material for railroad ties without negative environmental impact. IntegriCo's product with such distinctive characteristics offers the needed balance of strength, stiffness, hardness, and toughness for reliable performance in harsh environments that are ideal for industrial applications. To date, 80 million pounds of landfill plastic waste diverted and reused since 2009 through IntegriCo's patented and innovative technology with the unique product-making formulation.

IntegriCo works with the post-consumer and post-industrial sources to collect plastic waste for composite product manufacturing that often would not otherwise be used and instead be dumped into landfills or incineration. IntegriCo operates a circular economy principle by offering a solution to reuse plastic and have less waste in the US.

IntegriCo has a solid health & safety plan that is committed to maintaining an effective effort throughout the entire organization aiming to protect its team members and employees. The management of IntegriCo assumes responsibility and provides employees with the necessary direction to ensure a safe and congenial working environment.

The goals of IntegriCo's health & safety plan are:

- Conforming safety & health regulations by periodic evaluation of all systems, a strong communication of safety performance, and recognizing exceptional safety achievements.
- Elimination of workplace injuries, and employee protection from plant exposures.
- Promotion of the safe use of products

6.3.2 Applying Business Model Canvas to IntegriCo

This case study takes on the IntegriCo recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.3: INTEGRICO (USA) Business Model Canvas

Case Study on INTEGRICO (USA)

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Material Recycling Facility (MRF) National Recycling Coalition (NRC) Institute of Scrap Recycling Industries (ISRI) Louisiana Recycling Coalition (LRC) Industrial Brands Government NGOs Individuals	Manufacture Paving Stones, Marine Piling & Foundations, Rail Sleeper, Fence Posts, Highway Guardrail Posts, Plastic Lumbers, Marine Bumper etc. **Key Resources** Human Resources Statistical Process Control (SPC) system Innovative technology Patented technology	• Processing hard to recycle plastic into durable • Produce durable, environmentally friendly & superior strength products	IntegriCo exceeds the expectations of its rapidly expanding list of repeat customers, every time. **Channels** • Customer approaches to INTEGRICO for Cooperation • INTEGRICO reach to Customers directly	Government Individual Municipalities Industry Contractor Erectors

Cost Structures	Revenue Stream
Manpower R& D Technological innovation & Up gradation	Various diversified product selling such as Rail sleepers, Fence Posts, Guard-Rails, Plastic Lumbers, marines Bumpers and other products

Key Partners

Since IntegriCo is such a company that makes strides towards attaining a circular economy, where products are reused instead of discarded after a single use, it works with the Material Recovery Facilities (MRF) and industrial brands across the US to source the plastic needed for composite manufacturing on sustainability perspective. Therefore, MRFs and Industrial brands are the key partners of IntegriCo. Through IntegriCo's active work with post-consumer and post-industrial sources, it has circular economy principles and is environmentally conscious in all of its business avenues. Therefore, actors involved in collecting post-consumer and post-industrial plastic waste are considered to be the key partners of IntegriCo.

Key Activities

IntegriCo manufactures composite industrial products made from 100% recycled plastics with its patented technology that mixes landfill-bound plastics to create railroad ties, matting parts, skid & cribbing, and other related products. IntegriCo's products provide all major industrial applications from the extreme loading conditions of class I heavy axle load applications to the caustic environment of an industrial chemical processing plant. IntegriCo processes tough plastic waste that is nearly impossible to process by any other technology available in the world for a similar application with minimizing the cost of production while retaining the qualities of plastics that make it a strong material as well as permitting the use of unwashed scarp plastic that was previously destined for the landfill or incineration.

Key resources

Like other successful and innovative plastic waste recycling companies, InetegriCo's key resources are its patented technology, innovative business ideas, and strong R& D team which are common among the organization. Apart from these, considering the Low processing temperatures of recycled plastic and formulation of product making, IntegriCo is far ahead of others in the same or related areas of business and helps produce the highest quality products at a lower cost than others. IntegriCo's patented extrusion technology with unique low-temperature processing formulation enables to enhance of the intrinsic strength of recycled plastic products compared to hot melt extruded plastic products, leading to an overall higher quality product due to bonds formed among components at lower temperature and no issues with voids created in the final product. Therefore, innovative patented technology with low-temperature processing with a unique formulation methodology is the other key resource of IntegriCo.

Value proposition

Since IntegriCo's technology processes extremely tough plastic material that cannot be processed by conventional recycling technology, its production costs are lower than others in the industry. Its patented manufacturing process retains the qualities of plastic that make it a durable material, as well as permitting unwashed plastic waste that used to be destined for landfills otherwise. This method reduces relative costs that require pre-processing steps to clean the raw materials as well as eliminates the disposal challenge at the end of the lifecycle through repurchase options. On the other hand, IntegriCo's unique extrusion recycling technology with low melt temperature & formulation technique results in a significant advantage by lowering manufacturing costs. Furthermore, the technology used to produce industrial products allows for the use of varied raw materials leading to lower costs that allow for the substitution provided if one class of recycled plastics rises in price relative to other classes.

IntegriCo's products have successfully undergone extensive independent performance testing at independent testing facilities including the world's most recognized Transportation

Technology Center Inc. (TTCI) of the American Railway Association in Pueblo, Colorado. IntegriCo has implemented a series of due care tests to simulate potential extreme handling conditions with installation from the QC and standard testing perspectives. Because of its unique features and characteristics, IntegriCo is highly recognized by some of the world's renowned organizations such as Composite World, Recycling Today, Progressive Rail Road, Resource Recycling, Thomas, Plastic News, American Recycler, Plastic Technology, Forester Media, Waste Advantage, Plastics Decorating, Composites Weekly and many more.

The overall value proposition of IntegriCo is to meet the present needs while making a long-lasting impact for the next generations with sustainable products made from 100% hard-to-recycle plastic waste and a unique technology & formulation that does not require re-processing or washing, leading to lifecycle sustainability.

Customer Relationship

IntegriCo closely works with Material Recovery Facilities (MRF) and industrial bands especially those engaged in the construction business to source the plastic needed for composite products. IntegriCo has established a strong bonding with its customers and there is no formal approach required to interact with the customers. The company's top management and senior management used to maintain a good working relationship with the customers in association with the revenue-producing side from both ends. IntegriCo always provides noteworthy cooperation to its customer and delivers the closed-loop solution in applicable cases. Apart from this, IntegriCo provides required training for the proper use of its products as well as installation procedures.

Channel

Transportation of the materials from the Material Recovery Facilities (MRF) to IntegriCo's recycling. Various types of plastic waste are currently collected from MRFs by trucks and will continue to be collected in this manner. On the other hand, the distribution of products takes place in both ways, where the customer reaches out to IntegriCo and then IntegriCo's employees engage in talks on possible cooperation and its design for distributing the products.

Customer segment

IntegriCo has varied customer segments such as government, industries, contractors, and individuals since it produces various types of industrial composites to be used in numerous sectors. For example, government and the big contractors are buyers of railway ties. On the other hand, construction matting and wood matting are important parts of any construction job site, used to provide a safe and stable work surface for cranes and other heavy construction equipment.

Cost Structure

IntegriCo's cost structure cannot simply be classified as either cost or value-driven, as the activities revolve around optimization and collection, which are value-driven, but as it is a business entity working in an environment where supplies are scanty, costs must be reduced. This means the cost used fluctuates on the supply of plastic waste. Apart from this, there are several other costs involved such as continuous research and development costs, fixed salary, incentives, regular office management costs, promotional costs, etc.

Revenue stream

IntegriCo generates revenue through the sale of industrial composites of varied types and features. The revenue from the composites is volume-dependent and depends on the material stream and the required characteristics. Higher processing costs will also allow IntegriCo to increase its price.

6.3.3 Applying Lowell Center Framework for Sustainable Products to IntegriCo

Considering the current perspective of sustainability, IntegriCo falls into the Lowell Framework that meets the indicators of this Framework. In relation to the level one and level two indicators, IntegriCo has been operating its recycling business over the last 15 years in the USA complying with country regulations and industry standards that are highly recognized & certified by some of the world's renowned organizations such as Composite World, Recycling Today, Progressive Rail Road, Resource Recycling, Thomas, Plastic News, American Recycler, Plastic Technology, Forester Media, Waste Advantage, Plastics Decorating, Composites Weekly and many more. IntegriCo works with the post-consumer and post-industrial sources to collect plastic waste for composite product manufacturing that often would not otherwise be used and instead be dumped into landfills or incineration.

In relation to level three indicators, IntegriCo operates a circular economy principle by offering a solution to reuse plastic and has less waste in the US complying with the safety & health regulations by periodic evaluation of all systems that are committed to maintaining an effective effort throughout the entire organization aiming to protect its team members and employees.

Table 6.5: Current Indicators related to Framework Level

Framework Level	Current Practicing Indicators
Level 1: Compliance/Conformance	Fully comply with the USA regulations and industry standards audited by renowned highly recognized & certified by some of the world's renowned organizations like Composite World, Recycling Today, Progressive Rail Road, Resource Recycling, Thomas, Plastic News, American Recycler, Plastic Technology, Forester Media, Waste Advantage, Plastics Decorating, Composites Weekly and many more.
Level 2: Facility Material Use & Performance	IntegriCo manufactures composite industrial products made from 100% recycled plastics with its patented technology that mixes landfill-bound plastics to create railroad ties, matting parts, skid & cribbing, and other related products that are tested regularly with proper R& D and sold to the government, contractors, industries, and individuals.
Level 3: Facility Effects	Comply with safety & health regulations by periodic evaluation of all systems, a strong communication of safety performance, and recognizing exceptional safety achievements.
Level 4: Supply Chain & Product	Closely work with the supply chain actors like MRFs, and plastic industries that generate waste from plastic waste sourcing, and processing to new product making & shipping.
Level 5: Sustainability Indicators	Working with businesses, communities, state authorities, policymakers, and individuals to eliminate the idea of waste and establish a sustainable society.

In relation to the level 4 and level five indicators, IntegriCo closely works with the stakeholders of the prevailing supply chain like MRFs, plastic industries, and transport companies to minimize demand and supply gaps and hence produce high-quality construction materials. The overall value proposition of IntegriCo is to meet the present needs while making a long-lasting impact for the next generations with sustainable products made from 100% hard-to-recycle plastic waste and a unique technology & formulation that does not require re-processing or washing, leading to lifecycle sustainability.

6.3.3.1 Are IntegriCo's Products Sustainable?

The following table summarizes the case study in the context of The Lowell Center Framework for Sustainable Products, illustrating that IntegriCo is on its way to meeting many of the criteria.

Table 6.6: Sustainability measures of IntegriCO

Measures	Significance
Is the product healthy for consumers?	IntegriCo's product with distinctive characteristics offers the needed balance of strength, stiffness, hardness, and toughness that are odor-free, contamination-free, and non-hazardous for reliable performance in harsh environments that are ideal for industrial applications and eventually safe for consumers.
Is the production process safe for workers?	IntegriCo has a solid health & safety plan that is committed to maintaining an effective effort throughout the entire organization aiming to protect its team members and employees while ensuring a safe and congenial working environment. Thus, its health & safety plan includes workplace injury elimination, employee protection from plant exposure, and promotion of the safe use of products.
Is the product environmentally sound?	IntegriCo's composite products can perform in and protect any environment, for any big or small project. IntegriCo remains a leader in this particular industry and continues making massive strides toward a more sustainable future for the next generation. IntegriCo remains dedicated to protecting the environment and operating a circular economy with everything that it puts forth.
Does production benefit local communities?	IntegriCo has converted more than four million pounds of recycled plastic waste into composites that are 100% recyclable, eliminating the disposal challenge after the products' intended use is no longer needed and hence helping the communities to live well. The involvement of management and a vast workforce of the company in this process helps promote the transit towards a circular economy as the biggest positive environmental and social impact.
Is the product economically viable?	IntegriCo generates revenue through the sale of industrial composites of varied types and unique features that have huge demand from various users across the world. As the company has been in existence for about fifteen years, it is now in a strong and sustainable position from the long-term economic viability perspective and the company is thriving and growing, continuing to introduce new composite materials with possible improvements as required.

6.3.4 Critical Analysis

It has been explored in this study that IntegriCo is one of the leading producers of composite products manufactured from 100% recycled plastic and thus heading towards the attaining circular economy goal. One of the purposes of this study is to explore the feasibility of a sustainable plastic waste recycling market in Bangladesh. Keeping it in mind IntegriCo was purposefully selected as one of the cases because of their ambition: “hard to recycle plastic and a process that does not require processing or washing, leading to lifecycle sustainability”.

IntegriCo seems to be the case that is profit focused and environmentally conscious. It runs from a circular economy principle that is environmentally conscious in all avenues of its business endeavors.

The basis of IntegriCo’s business model is classified as a plastic waste collection program from diverse sources and then converting these into high-value plastic products like railroad ties, construction matting, skids and crabbings etc. that form the main part of the company’s business The plastic waste recovery program consists of collecting post-consumer and post-industrial plastic waste for composite manufacturing, that would otherwise be deposited into landfills or incineration.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Unique forming process delivers higher strength, impact, and crack resistance and durability, and requires no maintenance
- In-house production facility ensures 100% product quality
- Unique product portfolio
- Compatible and versatile product ranges
- Extremely tough cross-linked plastic finished products that cannot be processed by others
- Fully recyclable and easy to dispose of
- Recycle the unrecyclable or hard-to-recycle plastic waste

Key Barriers:

- Limited to only high-value plastic
- Hard to manage both post-consumer and both-industrial plastic waste

- Plant is not strategically located to get the utmost economic benefit

The circular business model of IntegriCo appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on resource recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for the recovery of post-consumer and post-industrial plastic waste
- Use environmental-minded volunteers to process all types of plastic recyclables
- Make well-organized resources in diverse life cycle phases
- Design for reusability ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations
- Introduce restrictive requirements in processing various types of plastic wastes
- Introduce a wide-scale circular public procurement
- Monitor and implement circular economy legislation

The current business model of IntegriCo has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. The scalability and replicability of the business model is possible to implement in Bangladesh since technology allows for the processing of mixed types of plastic waste that are widely available. Though the technology transfer cost is too high in the long run it would be beneficial to deliver the utmost value. Therefore, replicating the business model of IntegriCo would require a high investment cost on technology procurement which is a noteworthy barrier to the new entrants.

Despite all these, it would be better to decrease the waste generation in the long run, the processing of various waste has significant benefits for society and the environment.

IntegriCo could use its vast network and experiences in offering closed-loop solutions as a standard to enhance its collection program of various types of plastic wastes and set up more recycling plants in strategically good locations.

6.4 Gemini Corporation N.V, Belgium

6.4.1 Overview

Aligning with the core value to make the world a better place Gemini Corporation N.V. was founded in 1989, in Belgium with a plastic waste recycling business. Gemini is considered one of the largest value generators from a circular economy perspective with an annual turnover of $ 350 million, offices in Belgium, Mexico, USA, Canada, and India, operations across 500 locations in 60 countries, and a workforce of 500+ highly trained professionals. The vision of Gemini is to leverage its global network with centralized solutions to function as a preamble for a future-focused, sustainably-minded society that is conscious of the limited planetary resources available. Initially started with recyclable Plastics scrap, Gemini has created its brand name by standardizing the non-standard plastics scrap industry by working on the concept of total recycling, i.e., supplying plastic scrap to recyclers and buying back their reprocessed output which is a raw material for new products. Gemini also operates through its own recycling plants. Gemini is one of the renowned international distributors of various Polymers such as Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), and Styrene. Its Recyclable Plastics Portfolio includes HDPE, LDPE, PET, PP, ABS, MLP, etc., and the company regularly buys Off Grade & Reprocessed Plastics from Petrochemical Companies & blending it with plastic scrap to improve the quality of recycled material. Gemini's annual recycling capacity of plastic waste is more than 400,000 MT. Gemini seeks to strengthen the plastic recycling ecosystem in a fair and equitable way with a strong focus on efficient logistics, provision of finance for working capital, education, and on-ground action.

With its extensive experience in planet-positive solutions, Gemini's mission stems from its commitment to sustainability and dedication to developing worthwhile uses for end-of-life, harmful substances.

Gemini endeavors to create new materials created with the addition of use cycles into the innovation process by fully complying with the international standards stipulated by environmental authorities across the world. Overall, the company strives to create a beautiful planet where equal space and respect are given to all forms of life.

Gemini is highly focused and dedicated to bringing positive change in all aspects of life including culture, health, education, environment, rural development, and much more by giving back to society.

- Mobilizing the entire value chain (both the developed and developing countries) to bring in the much-needed circularity of waste.
- Providing adequate training and developmental activities for every stakeholder involved in this value chain amid creating a successful model of the circular economy.
- The proactive customer-centric focus of its business is based on the philosophy of considering the entire world as a small village and striving tirelessly to ensure fair distribution of resources at every level of the value chain and the availability of feedstock even in regions that do not have it at the optimum level.

6.4.2 Applying Business Model Canvas for GEMINI

This case study takes on the GEMINI recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.4: GEMINI (BELGIUM) Business Model Canvas

Case Study on GEMINI (Belgium)

<table>
<tr>
<td rowspan="2">Key Partners

Municipalities
Industries
Recyclers
Companies
Brand owners & manufacturers</td>
<td>Key Activities

Gathering recyclable plastics and reproduce plastic granules</td>
<td rowspan="2">Value Proposition

• Enablement is only way forward to achieve economic gain, environment sustainability, and societal benefit.
• Creating sustainable infrastructure to enable long term recycling solutions in developing countries.</td>
<td>Customer Relationships

Creating sustainable business deals with customers to enable long term business relationships</td>
<td rowspan="2">Customer Segments

Manufacturers
Brand owners</td>
</tr>
<tr>
<td>Key Resources
Head Quarter in Belgium with worldwide team of 210 professionals
Offices and Associates in 26 countries
Over 30 Warehouse facilities worldwide
6 collection and sorting facilities</td>
<td>Channels
Transparent and traceable Logistics
Network Marketing
Internet Marketing</td>
</tr>
<tr>
<td colspan="2">Cost Structures
Human Resources
Administrative and R&D cost
Collection, Sorting & Reprocessing
Investment in advanced technology</td>
<td colspan="3">Revenue Stream
Exporting diversified reprocessed plastic resin/granule/pellets as secondary raw materials and export to various palstic industries across the world.</td>
</tr>
</table>

Key Partners

The core competencies of Gemini are the collection, recycling, sourcing, and logistics of plastic waste and off-grade plastic. Considering these core activities there are several types of key partners of Gemini exist. The group collects over 400,000 MT of recyclable plastic wastes from over 500 locations in 35 countries for reprocessing at over 250 plants in 60 countries. For doing such a massive task the company closely works with MRF, investors, collectors, aggregators, supply chain actors, and recyclers who are the key partners of Gemini. Partnering mutually with renowned brands, Gemini also helps ensure Extended Producer Responsibility (EPR) to achieve global sustainability & recycling goals for brand manufacturers.

Key activities

Gemini works on the concept of total recycling i.e.; It supplies plastic waste to re-processors and buys back their reprocessed output which is a raw material for new products. Apart from this, it also operates through its own recycling plants spread across many regions of the world. . Gemini is one of the renowned distributors of various Polymers like Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), Styrene and its recyclable Plastics Portfolio includes HDPE, LDPE, PET, PP, ABS, MLP, etc. The company regularly buys Off Grade & re-processed Plastics from Petrochemical Companies & blending them with plastic scrap to improve the quality of recycled material. Based on socio-cultural distinctiveness, Gemini introduces its operations. For example, the group promotes the villagers to segregate their plastic waste in their homes. In doing so, the company deployed special carriers to transport the segregated waste to Gemini's collection center. It is then sorted and shredded for recycling or processing. This model is easily scalable and replicable in any part of the developing world.

Key resources

Gemini always seeks to strengthen the plastic recycling ecosystem in a fair and equitable way with a strong focus on efficient logistics, provision of finance for working capital, upliftment, education, and on-ground action. Considering these, the company has already spread across different parts of the world with 27 offices and 250 operation plants in 60 countries and processes over 400,000 MT of recyclable plastic. To accomplish all these activities over 500 highly skilled professionals are considered to be the key resources under the prudent headship of the Founder and Chairman of Gemini Corporation, Mr. Surendra Patawari. Under the leadership of Mr. Patawari, Gemini has succeeded in becoming one of the world's leading circular economy market makers who is very passionate about recycling and also delivers great importance to social responsibility. Apart from these, other resources are investors in the value chain (strengthens its value chains through machinery, infrastructure & financial support), supply chain experts (end-to-end transparency & traceability to ensure businesses meet EPR compliance), Responsible recyclers (all collected waste is recycled at Gemini premises or through PCB certified recyclers) and social upliftment (uplifting at least 5 families, involved in waste collection and segregation, every week)

Value proposition

Expertise in multi-modal logistics facilitates Gemini enabling it to provide high-quality, timely service at the most affordable pricing to its vast, globalized network. The company provides the ultimate solutions and implements them based on best practices, compliance, and traceability. Its collaborative approach to finding and implementing effective solutions for the betterment of the environment and society on the whole. Gemini is recognized by Dun & Bradstreet, credit safe, recycling today, etc.

Customer relationship

Regarding relationships, Gemini maintains remarkable relationships giving them a topmost priority. Since it processes various types of recyclable plastic waste, customers' type also varies. Gemini authority carefully assesses this and delivers quality products to its customers at a competitive price and thus creating loyal customer groups who buy goods regularly.

Channel

Since Gemini has established a wider network by setting up its offices and facilities it usually maintains a strong distribution channel. Their shipment takes place from Europe to North America, Africa to the Middle East, Australia to South America, China, and Bangladesh. In doing all such shipping activities Gemini used to maintain congenial relationships and connections with renowned shipping lines across the world.

Customer segment

Since Gemini is one of the renowned distributors of various Polymers, recyclable Plastics as well as off-grade plastics collected from petrochemical companies it has various types of customers across the world. Different type of plastic has different type of applications. Gemini deals with virgin plastic of various types, off-grade plastic, and recyclable plastics like HDPE, LDPE, PET, PP, ABS, MLP, etc. customer has varied option to buy as per their requirement. Mainly product manufacturers across the world buy Gemini's products as the raw material to produce finished products of a different kind. Thus, Gemini is a one-stop solution for meeting all customers' demands from the perspective of plastic no matter whether is it virgin, off-grade, or recyclable.

Cost structure

Apart from regular operating costs, the company invests a significant amount in the value chain which strengthens its value chain through the collection, segregating, sourcing, and processing of plastic waste, machinery, infrastructure, and logistics operation mostly. Gemini provides robust training for waste collectors to sort and shred plastic waste for processing or recycling by investing a huge amount of money. As it has offices and production facilities across different parts of the world, Gemini invests regularly in marketing, sales, and promotional campaigns like seminars, advertisements in print and electronic media, and participating in various exhibitions on the global platform.

Revenue stream

At Gemini revenue generates in numerous ways as the company sells virgin plastic raw materials, off-grade plastic raw materials, and recyclable plastic raw materials of different types. Thus, profit also varies based on product type. For example, virgin plastic prices are almost similar across the world. Being the renowned distributor of various polymers, Gemini used to get good prices from petrochemical companies, especially for virgin and off-grade polymers and then can sell at a good margin to its customers. On the other hand, revenue from selling recyclable plastic is higher than virgin and off-grade polymers as Gemini has a wide collection and selling network across the world with a significant number of offices and production facilities.

6.4.3 Applying Lowell Center Framework for Sustainable Products to Gemini

Gemini's present activities and future projections fully comply with the indicators of the Lowell framework that are described here.

Founded in 1989 coping with all international regulations & standards, Gemini is considered one of the largest value generators from a circular economy perspective with an annual turnover of $ 350million, offices in Belgium, Mexico, USA, Canada, and India, operations across 500 locations in 60 countries, and a workforce of 500+ highly trained professionals.

Gemini works on the concept of total recycling i.e.; it supplies plastic waste to re-processors and buys back their reprocessed output which is a raw material for new products. Apart from this, it also operates through its own recycling plants spread across many regions of the world with a centralized solution that manages precisely. The company regularly buys Off Grade & re-processed Plastics from Petrochemical Companies and blends them with plastic scrap to improve the quality of recycled material.

Gemini closely works with the value chain actors like MRF, Investors, collectors, aggregators, and recyclers who are the key partners of Gemini. Partnering mutually with renowned brands, Gemini also helps ensure Extended Producer Responsibility (EPR) to achieve global sustainability & recycling goals for brand manufacturers. It mobilizes the entire value chain to bring in the much-needed circularity of waste through the required training and developmental activities for every stakeholder involved in this value chain amid creating a successful model of the circular economy.

Table 6.7: Current Indicators related to Framework Level

Framework Level	Current Practicing Indicators
Level 1: Compliance/Conformance	Gemini is founded fully complying with international regulations and industry standards from a circular economy perspective that is certified and audited by renowned organizations like Dun & Bradstreet, Creditsafe, Recycling Today, etc.
Level 2: Facility Material Use & Performance	Gemini sources various Polymer wastes like Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), Styrene, and its recyclable Plastics Portfolio includes HDPE, LDPE, PET, PP, ABS, MLP, etc. and reprocess these to make secondary raw materials for production and then export all over the world with centralized solution precisely that is monitored and evaluated properly.
Level 3: Facility Effects	Ensure required safety & health regulations by periodic evaluation across the systems, a strong communication of safety performance, and recognizing exceptional safety achievements. Providing adequate training and developmental activities for the employees amid creating a successful model of the circular economy.
Level 4: Supply Chain & Product	Working closely with MRF, Investors, collectors, aggregators, supply chain actors, brand manufacturers, and recyclers who are the key partners of Gemini.
Level 5: Sustainability Indicators	Working with businesses, communities, state authorities, policymakers, and individuals to eliminate the idea of waste and establish a sustainable society.

Gemini seeks to strengthen the plastic recycling ecosystem fairly and equitably with a strong focus on efficient logistics, provision of finance for working capital, education, and on-ground action to accomplish planet-positive solutions. Gemini's mission stems from its commitment to sustainability and dedication to developing worthwhile uses for end-of-life, harmful substances. Therefore, Gemini is highly focused and dedicated to bringing positive change in all aspects of life including culture, health, education, environment, rural development, and much more by giving back to society.

6.4.3.1 Are Gemini's Products Sustainable?

The following table summarizes the case study in the context of the Lowell Center Framework for Sustainable Products, illustrating that Gemini is on its way to meeting many of the criteria.

Table 6.8: Sustainability measures of Gemini

Measures	Significance
Is the product healthy for consumers?	Gemini applies up-graded technology that efficiently removes contaminated and hazardous particles from the recyclables and need not require any chemicals, additives, adhesives/glues, fillers, or else. Therefore, Gemini's products are safe for the end users.
Is the production process safe for workers?	The company uses such a unique automated technology for making diverse products from which workers and technicians enjoy a safer and congenial work environment. Even though the working conditions of Gemini are safe, workers receive periodic health and safety training and are treated respectfully and with utmost care. Because of the technological advancement that avoids hazardous materials, workers & technicians are not exposed to chemical toxins throughout the whole operation.
Is the product environmentally sound?	Gemini's products are easily repaired, remanufactured, repurposed, upgraded, and at the end of the final use cycle can be reprocessed into new materials. Gemini endeavors to create new materials are created with the addition of use cycles into the innovation process by fully complying with the international standards stipulated by environmental authorities across the world. Overall, the company strives to create a beautiful planet without doing any damage to the environment.
Does production benefit local communities?	Gemini is highly focused and dedicated to bringing positive change in all aspects of life including culture, health, education, environment, rural development, and much more by giving back to society. Some of Gemini's endeavor includes: • Change the lives of many families involved in unorganized plastic waste collection and segregation, • ensuring proper safety and sanitation at all registered collection centers, • Conducting free medical camps at the centers for the local community. • Reduction in child labor
Is the product economically viable?	Gemini has a portfolio of a diverse range of products with strong customer bases across the world that are continually buying its products. Therefore, all of Gemini's products are economically viable that generate repeated buyers for the company. As the company has been in existence for about four decades, it is now in a fully stable position from the long-term perspective and hence moving forward at a faster pace.

6.4.4 Critical Analysis

It has been observed in this study that Gemini is one of the prominent circular economy market creators that give a second life to millions of tons of recyclables across the world. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. In this consideration GEMINI was selected as one of the case organizations because of their vision: “mobilizing the entire value chain in both the developed and developing countries to bring in the much-needed circularity of waste”.

GEMINI is not only a profit-focused company but also a sustainable value-creation organization and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, GEMINI presently focuses on collecting and processing various types of waste into valuable raw materials and manufacturing new recyclable products in varied applications.

The basis of the GEMINI business model is classified as a waste collection program through a collaborative approach that forms the main part of the company’s business. This approach helps find and implement effective solutions for the betterment of the environment and society as a whole. The waste collection program consists of collecting waste materials at end-of-life that are then recycled/upcycled into different products or used as raw materials for another process.

GEMINI established itself as a strong brand across the world that is associated with eco-friendly collection programs and products are manufactured in cooperation with its numerous stakeholders.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Mobilizing the whole value chain across the world to bring circularity of waste
- Providing required training to every stakeholder in the value chain to create a successful circular economy model

- Considering the whole world as a small village while tackling waste trading business across borders
- Striving diligently to ensure impartial circulation of resources at every stage of the value chain and the obtainability of feedstock
- Providing high-quality multi-modal logistics facilities with timely service at affordable prices through a globalized network

Key Barriers:

- Handing all types of waste could hamper business growth in the long term on a circular economy notion
- Probable limitations of using few non-recyclables
- Comparatively low economies of scale

The circular business model of GEMINI appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on resource recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for resource recovery
- Use environmental-minded volunteers
- Make well-organized resources in diverse life cycle phases of various types of wastes
- Design for reusability ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations of different regions of the world
- Introduction of restrictive requirements in waste collection and processing is necessary
- Introduce on a wider scale a circular public procurement on regional considerations
- Monitor implementation of circular economy legislation

The current business model of GEMINI has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. Since GEMINI handles various types of wastes such as plastic, paper, metal etc. the scalability and

replicability of the business model is a bit hard to implement. However, to a certain extent of the circular business model of GEMINI seems to be replicable and transferable to any entity in Bangladesh. Therefore, replicating the business model of GEMINI would require a long-term commitment and a wide waste collection network which is a high barrier to the new entry.
Despite all these, it would be better to decrease waste generation, the processing of various wastes has significant benefits for society and the environment.
GEMINI could use its vast network and experiences in offering closed-loop solutions as a standard to enhance its collection program. Such a program would ensure the final products made from recycled material are recyclable without any additional resources to establish such systems by GEMINI as already functioning collection points could be used.

6.5 DAISAKU Co., Ltd., Japan

6.5.1 Overview

Founded in 2002, Daisaku is the leading plastic waste recycling and manufacturing company in Japan. East Japan-based company, Daisaku set out to create high-quality recycled plastic materials that can support businesses around the world as well as help the environment in the process. Currently, Daisaku has got a highly professional team of over 40 people, supported by a large array of top industry high-quality produce high-quality recycled polymers which ship globally to over 20 countries, including China, India, Bangladesh Australia, Indonesia, Netherlands, and many others.
Daisaku purchases various types of plastic waste and unused plastic sourced from factories and companies around Japan. This means that not only is post-industrial resin (PIR) higher quality, compared to Post-Consumer Resin (PCR), but also leads to less smell and contamination, resulting in a top-quality granule/pellet/flake. The use of PIR plastics, compared to PCR, is why the company believes its partners keep coming back for more, as the net result is of a much higher quality almost similar to virgin resin/pellet.
Daisaku maintains a strong relationship with various renowned manufacturers in Japan, which supply it with high-quality plastic waste and unused plastic. This together with its large-scale

factories and storage facilities means it can constantly supply regular volumes of granules and flakes to customers around the world without hampering the supply chain.

Daisaku has a wealth of prolonged history and experience in the plastic waste recycling industry, having shipped to over 20 countries since its inception back in 2002. Daisaku's professional team has been supporting customers across the world throughout the years and keeps the highest standard of products and services, Daisaku and Japan, as a whole, are known for. A highly knowledgeable support and service team dedicated to helping the customers import their cargo smoothly and effectively, means customers are always in safe hands with Daisaku, wherever they may be in the world.

6.5.2 Applying Business Model Canvas to DAISAKU

This case study takes on the DAISAKU recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.5: DAISAKU (JAPAN) Business Model Canvas

Case Study on DAISAKU (Japan)

<table>
<tr>
<td rowspan="2">Key Partners

Plastic Industries
Packaging
Industries</td>
<td>Key Activities

• Gathering industrial plastic waste
• Reproduce plastic granules of different types</td>
<td rowspan="2">Value Proposition

Recycle post consumed industrial waste and turning these into near prime virgin granule which reduce the use of virgin material to produce new products
Reduce production cost
Reduction of industrial waste
Economic gain</td>
<td>Customer Relationships

Establishing repeated customers' belt globally by providing superior quality of recycled plastic granules
Long term business relationship.</td>
<td rowspan="2">Customer Segments

Plastic industries</td>
</tr>
<tr>
<td>Key Resources
• Skilled manpower with strong R& D Team
• Top Industry equipment
• Large Facility Large Logistics center Well-equipped Laboratory</td>
<td>Channels

• Website, email
• Seminar
• Exhibition</td>
</tr>
<tr>
<td colspan="2">Cost Structures
Human Resources
Purchase of post-consumer industrial waste
Processing and R&D cost</td>
<td colspan="3">Revenue Stream
Through export of reprocessed post-industrial plastic granules to abroad as well as domestic market in Japan</td>
</tr>
</table>

Key partners

Daisaku maintains a strong relationship with various renowned manufacturers in Japan, which supply it with high-quality plastic waste and unused plastic. This together with its large-scale factories and storage facilities means it can constantly supply regular volumes of granules and flakes to customers around the world without hampering the supply chain. Shipping companies and value chain actors are also considered to be the key partners of Daisaku to accomplish the whole job properly.

Key activities

Daisaku works on the concept of total recycling of various Polymers like Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polyethylene Terephthalate (PET), and Styrene through its own recycling plants in east Japan. The company regularly buys Post-Industrial Resin (PIR) waste from the 1st grade-renowned Industries and recycles them with state-of-the-art technology to produce superior quality secondary raw materials for production and finally export globally to over 20 countries, including China, India, Bangladesh Australia, Indonesia, Netherlands, and many others. Apart from these, Daisaku also sells these to the domestic market.

Key resources

Equipped with the most modern state-of-the-art technology, Daisaku has a large-scale production & storage facility along with a highly professional team of over 40 people, supported by a large array of top industry high-quality produce high-quality recycled polymers which ship globally to over 20 countries, including China, India, Bangladesh Australia, Indonesia, Netherland, and many others. Since Daisaku sources post-industrial plastic waste only, the quality of reprocessed materials (that will be used for further producing various products) must be better than recyclates of post-consumer plastic waste. Therefore, Daisaku's key resources are its ultra-modern technology, production & storage facilities, skilled & professional manpower, and definitely the sourcing options and mechanism for which customers used to get contamination and smell-free secondary raw materials that are almost closer to virgin materials from a quality perspective.

Value proposition

Since Daisaku purchases postindustrial plastic waste that is usually clean, free of contamination, and bad odor yields superior quality output after being reprocessed which is almost impossible in the case of reprocessing post-consumer plastic waste. Furthermore, Japanese technology, socioeconomic culture, strong work ethics, and professionalism are the keys to its success to establish such a sustainable business on a global platform and the company believes its partners from both home and abroad keep coming back for more, as the net result is of a much higher quality almost similar to virgin resin/pellet.

Customer relationship

Daisaku maintains a strong relationship with various customers both in Japan and the rest of the world by supplying high-quality secondary raw materials for production. Equipped with ultramodern reprocessing technology and large-scale factories and storage facilities, Daisaku can constantly and effectively supply regular volumes of granules and flakes to customers around the world without hampering the supply chain. For this reason, there has been a long last trust already established between Daisaku and its customers across the world.

Channel

With favorable relationships with various shipping companies as available when needed, Daisaku is closely in contact with them to ship goods both home and abroad to meet customer needs in timely ship goods. For documentation-related activities, Daisaku used to choose some renowned courier companies like DHL, FEDEX, UPS, etc.

Customer segment

Since Daisaku processes only postindustrial plastic waste of different types like HDPE, LDPE, PET, PP, ABS, and MLP, its customer segment is also limited and specific. Daisaku has varied customers of plastic and has different types of applications. Mainly product manufacturers across the world buy Daisaku's products as the raw material to produce finished products of different kinds.

Cost structure

Apart from regular operating costs, Daisaku invests a significant amount in the value chain which strengthens its value chain through the collection, segregating, sourcing, and processing of plastic waste, machinery, infrastructure, and logistics operation mostly. The company allocates a significant amount of money for continuous R&D as well as invests regularly in training manpower, marketing, and sales.

Revenue Stream

Revenue generates by selling reprocessed raw materials of different types. Thus, profit also varies based on product type. For example, reprocessed plastic waste generates from LDPE, HDPE usually has a higher price than other reprocessed polymers because of high demand. Sometimes, maximum revenue comes from the polymer waste collected at PIR sources at a good price.

6.5.3 Applying Lowell Center Framework for Sustainable Products to Daisaku

The following table classifies how Daisaku's current activities fall into the Lowell Framework from sustainability. Daisaku was founded in 2002, in East Japan as a plastic waste recycling company complying with the Japanese rules & regulation from a circular economy perspective that process post-industrial plastic waste into superior quality secondary raw materials for the plastic industry and other related industries which are trusted across the world. Over the years, the company has been proven as a trusted source of secondary raw materials that enable it to produce sustainable products for the world. Thus, the company successfully complies with first-level indicators of the Lowell Framework.

For second-level indicators, Daisaku sources post-industrial plastic waste from renowned manufacturers maintaining the world's renowned Japanese quality ethics & standards and then processes these into functional secondary raw materials to produce various plastic goods again with state-of-the-art Japanese Technology by keeping good care of the surrounding environment, workers and the suppliers as well. All these activities and processes are monitored regularly and the n periodic evaluation takes place always to keep the business unhindered and sustainable.

About the third & fourth-level indicators, Daisaku is highly aware to ensure a good working environment within the company by providing health safety, a good remuneration package, and required training to acquire economic gain and environmental sustainability. Since the company source only post-industrial plastic waste, there exist limited supply chain actors and it is comparatively easy to maintain hassle-free sourcing functions to produce quality products originating from post-industrial plastic waste.

Table 6.9: Current Indicators related to Framework Level

Framework Level	Current Practicing Indicators
Level 1: Compliance/Conformance	Fully compliant with the Japanese rules, regulations, and quality principles that exceed internal standards by miles enables to produce near prime secondary raw materials for production.
Level 2: Facility Material Use & Performance	Source, process post-industrial plastic waste, and then produce plastic pellets/resin/granules of different types and grades with modern technology that yields quality in every aspect. The overall performance is monitored regularly and evaluated periodically both internally and by a third-party audit.
Level 3: Facility Effects	Enable communities, corporations, and industries, to extract the ultimate benefit from post-industrial plastic waste while cleaning up the surrounding environment, creating jobs, and revitalizing neighborhoods with economic gain.
Level 4: Supply Chain & Product	Closely work with the supply chain actors mainly with the renowned industries for plastic waste sourcing, and processing to new product making & exporting across the world.
Level 5: Sustainability Indicators	Strive for making positive effects to create a sustainable future for the planet by working together with industries, and individuals to eliminate the idea of post-industrial plastic waste and hence establish a sustainable business and society from a broader perspective.

Like other successful and sustainable plastic recycling companies across the world, Daisaku is devoted to enabling communities, corporations, industries, and governments across the world to transform post-industrial plastic waste into highly functional secondary raw materials for new products manufactured and then creating jobs, saving energy, and revitalizing neighborhoods everywhere.

6.5.3.1 Are Daisaku's Products Sustainable?

The following table summarizes the case study in the context of the Lowell Center Framework for Sustainable Products, illustrating that Daisaku is on its way to meeting many of the criteria.

Table 6.10: Sustainability measures of Daisaku

Measures	Significance
Is the product healthy for consumers?	Daisaku purchased only post-industrial plastic waste that is usually odorless, nonhazardous, and contamination free resulting in a top-quality granule/pellet/flake. Therefore, Daisaku's products are safe for the end users.
Is the production process safe for workers?	Although an in-depth workplace inspection was not conducted for this case study, the interview cited that the working conditions of Daisaku are safe, workers receive health and safety training, and are treated respectfully. Because of the design and unique automated Japanese technology that dodges hazardous materials, workers are not exposed to chemical toxins in the production and delivery process.
Is the product environmentally sound?	Daisaku, has set a network across its value chain to function as a preamble for a future-focused, sustainably-minded society that is conscious of the limited planetary resources available by visualizing futuristic environmental management, where products are easily sourced, reprocessed, and at the end of final use-cycle can be reprocessed into value-added new materials.
Does production benefit local communities?	Daisaku has created a model of local production in Japan and so has created many jobs as a result. In addition, by contracting with the Work Center, it works dedicatedly in improving the social welfare of individuals across Japan. Apart from these, additional benefits are linked to ongoing environmental education and volunteering attitude promotion.
Is the product economically viable?	As the company has been in existence for about twenty years, the company became a sustainable product manufacturer from a long-term economic perspective and continues to grow further.

6.5.4 Critical Analysis

Daisaku is one of the leading plastic recycling and manufacturing companies in Japan aiming towards attaining a circular economy at every stage of its operations. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. Keeping it in mind DAISAKU was selected as one of the cases because of their recycling endeavors.

Daisaku is a sustainable value creation-oriented organization and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, Daisaku presently emphasizes collecting and processing post-industrial plastic waste of different types and grades into valuable raw materials for making plastic finished goods.

The basis of the DAISAKU business model is classified as the collection and reprocessing of post-industrial plastic wastes that form the main part of the company's business. The plastic waste collection program consists of collecting post-industrial waste materials at end-of-life that are then recycled/upcycled into different granules as inputs for another process.

Daisaku established itself as a strong brand that is associated with eco-friendly collection programs and products are manufactured in cooperation with its valued suppliers.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Processing only post-industrial plastic wastes and lumps
- Unique Japanese technology that makes superior-quality granules and flakes similar to virgin raw materials
- Neat and Clean production facilities across different parts of Japan
- Increasing corporate sustainability powered by the mounting environmental consciousness of customers
- Remarkable customer satisfaction
- Solid and long-term customer relationship

Key Barriers:

- Low volume of post-industrial plastic waste sometimes cannot meet customer demand at the desired level
- Sometimes collection cost goes up

The circular business model of DAISAKU appears to be replicable and transferable to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on post-industrial plastic waste recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for post-industrial plastic waste recovery
- Create a wide collection network to minimize the demand and supply gap
- Focusing on the global price trend of virgin plastic raw materials and then fixing the price of reprocessed plastic granules
- Use environmental-minded volunteers
- Make well-organized resources in diverse life cycle phases

Key Considerations for Policy Makers:

- Ensure constant rules and regulations
- Introduction of restrictive requirements in plastic waste collection and processing is necessary
- Introduce on a wider scale a circular public procurement
- Monitor implementation of circular economy legislation

The current business model of DAISAKU has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. As a consequence, DAISAKU has established a strong brand image all over the world. Therefore, replicating the business model of DAISAKU would require a long-term commitment which is a high barrier to the new entrants. However, if any new entity is determined to replicate DAISAKU's business model with state-of-the-art technology and a wide post-industrial plastic waste collection network then it will definitely be successful in the long run. That eventually helps decrease industrial plastic waste generation as well as create economic value and environmental sustainability.

6.6 Union J. Plus (Thailand)

7.6.1 Overview

Founded in 2001, Union J. Plus (Thailand) is the leading plastic waste recycling company. Union J. Plus has been in the recycled plastic raw materials business with a well-trained professional management team for over the last 10 years realizing the importance of the recycled plastic raw materials market which will be reprocessed to recycle plastic resin as secondary raw materials. The concept results in hugely reducing the plastic waste, pollution, and production cost of the plastic industry and increasing choices for consumers to use recycled plastic products to save the environment towards accomplishing the circular economy.

With a wide array of networks, Union J. Plus regularly buys various types of postindustrial plastic waste and unused plastic from factories and companies around Thailand. Since post-industrial plastic waste has comparatively less odor and contamination than post-consumer plastic waste, the output (granule/pellet/flakes) quality is far better with reduced processing cost. Considering this, the company solely processes post-industrial plastic waste to produce good quality secondary raw materials for production which is almost similar to virgin resin/pellet/flakes.

By maintaining a mutual and favorable business relationship with various renowned manufacturers in Thailand, which supply Union J. Plus with high-quality post-industrial plastic waste and unused plastic, it produces superior quality recyclates with state-of-the-art technology and big storage facilities. As a consequence, it can constantly supply regular volumes of granules and flakes to customers around the world.

Union J. Plus has a long history and experience in the plastic waste recycling industry in Thailand, having shipped to many countries since its inception back in 2001 with a strong professional & dedicated team to helping the customers.

There are several kinds of products that are produced by Union J. Plus from the post-industrial recycled plastic resin of varied types such as High-Density Polyethylene (HDPE Low-Density Polyethylene (LDPE), Polypropylene (PP), High Impact Polystyrene (HIPS), and Polyethylene Terephthalate (PET). The popular ones and generally seen as plastic bags, pipes, crates, baskets, plastic pallets, and so on.

6.6.2 Applying Business Model canvas to UNION

This case study takes on the UNION recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.6: UNION J PLUS (THAILAND) Business Model Canvas

Case Study on Union. J (Thailand)

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
Municipalities Households Industries	Collection, Sorting, re-processing various types of plastic wastes such as PP, LDPE, LLDPE, HDPE, HIPS, ABS, PET **Key Resources** • Professional Management Team • Wide network of collectors • Skilled Human Resources • Advanced Technology	Reduce the waste, pollution and production cost of plastic industry	Established a long term business relationship with the domestic and overseas clients by providing competitive price with quality products. **Channels** • Network Marketing • Internet Marketing	Plastic industries across the world

Cost Structures	Revenue Stream
Management, Scarp collection & processing cost R&D Cost Technological Up-gradation cost	Selling of various types of reprocessed plastic resins to be used as secondary raw materials for production of new products.

Key partners

Since Union J. Plus collects post-industrial plastic waste mainly from industries, it maintains a strong relationship with various renowned manufacturers in Thailand, which supply it with high-quality plastic waste and unused plastic. Therefore, various renowned manufacturers that generate plastic waste during production are considered to be the key partners of Union J. Plus. Apart from this, shipping companies and value chain actors are also considered to be the key partners of Union J. Plus to accomplish its endeavor.

Key activities

Like Daisaku, Japan (as stated in the earlier case), Union J. Plus also works on the concept of total recycling of various Polymers like Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), and Polyethylene Terephthalate (PET), and Styrene through its own recycling plants in Japan. Based on its production capacity and market demand, it regularly buys Post-

Industrial plastic waste from renowned Industries & reprocessed them with state-of-the-art technology and large storage facilities to produce superior quality plastic pellets/granules/flakes of different types, and finally export them globally. Apart from these, it also sells these to the domestic market.

Key resource

Union J. Plastic has a strong industry network that regularly generates postindustrial plastic waste and unused plastic. It has large-scale production & storage facilities, modern recycling technologies, and a dedicated & professional team of over 100 people. Since Union J. Plus sources and buys post-industrial plastic waste from designated & trusted manufacturers and companies only, the quality of reprocessed materials (that will be used for further producing various products) must be better than recyclables of post-industrial and post-consumer plastic waste.

Value proposition

It is well regarded by all that postindustrial plastic waste yields better quality plastic pellets/granules/flakes than post-consumer plastic waste. Setting it as the main objective, Union J. Plus sources and purchases postindustrial plastic waste that is usually clean, contamination-free, and mostly odor-free and yields superior quality output after reprocessed which is near impossible in the case of reprocessing post-consumer plastic waste. Furthermore, modern technology, recycling policies & infrastructure in Thailand, and professionalism are the keys to its success to establish such a sustainable business on a global platform, creating a strong customer belt both at home and abroad.

Customer relationship

Customers across the world always desire and want recycled plastic pellets/granules/flakes originating from postindustrial plastic waste sources. Since Union J. Plus. Since Union J. Plus only reprocessed postindustrial plastic waste that has favorable demand across the world, it has a wide customer network, and thus Union J. Plus keeps maintaining a solid relationship with various customers both at home and abroad by supplying high-quality plastic pellets/granules/flakes originated from industries. Equipped with ultramodern reprocessing technology and large-scale factories and storage facilities, Union J. Plus constantly supplies regular volumes of granules and flakes to various customers around the world and is hence able to establish a long last trust with its customers across the world.

Channel

Union J. Plus is meticulously in contact with various renowned shipping companies to timely ship goods for meeting ever-increasing customers' needs and wants across the world while maintaining a favorable and long-lasting relationship with those shipping companies that are the main distribution channel of Union J. Plus as well as a close tie up with some renowned currier companies like DHL, FEDEX, UPS, etc. for documentation-related affairs.

Customer segment

Like Daisaku, Japan (as stated earlier) Union J. Plus also processes only postindustrial plastic waste of different types like HDPE, LDPE, PET, PP, ABS, and MLP, its customer segment is also limited and specific. Based on individual customers' application patterns, Union J. Plus has varied customers with different types of plastic a different type of applications. Mainly product manufacturers across the world buy its products as the raw material to produce finished products of different kinds.

Cost structure

Core activities involved in the business portfolio of Union J. Plus are sourcing postindustrial plastic waste from different manufacturers and then selling the final products after the required processing steps to the raw materials producers across the world. Therefore, a significant cost involves sourcing postindustrial waste, processing waste, and then after selling and distribution cost. Apart from these, there are other costs too such as regular administrative costs, operating costs, machinery up-gradation and maintenance costs, infrastructure, and logistics operations mostly. The company allocates a significant amount of money for continuous R&D as well as invests regularly in training manpower, marketing, and sales.

Revenue Stream

Revenue is generated by selling reprocessed raw materials of different types. Thus, profit also varies based on product type. For example, for reprocessed plastic waste used to generate from LDPE, HDPE usually has a higher price than other reprocessed polymers because of high demand. Sometimes, maximum revenue comes from the polymer waste collected at PIR sources at a good price.

6.6.3 Applying Lowell Center Framework for Sustainable Products to Union. J Plus

Founded in 2001, Union J. Plus (Thailand) is the leading plastic waste recycling company that was established in Thailand complying with the available country rules and regulations as well as the internally accredited industry standard which enables it to fall into level one indicators of the Lowell Framework.

Considering level two indicators of the Lowell Framework, Union J. Plus regularly buys various types of postindustrial plastic waste and unused plastic from factories and companies around Thailand to produce good quality secondary raw materials for production which is almost similar to virgin resin/pellet/flakes. The company uses the latest available technology for reprocessing post-industrial plastic waste and then producing secondary raw materials for the production of plastic goods. Finally, export to different countries across the world.

About the third & fourth-level indicators, Union. J Plus is trying to ensure a good working environment within the organization and considers health and safety measures. Since the company source only post-industrial plastic waste it has limited supply chain actors and it is comparatively easy to maintain hassle-free sourcing functions and thus produce quality products originating from post-industrial plastic waste.

Table 6.11: Current Indicators related to Framework Level

Framework Level	Current Practicing Indicators
Level 1: Compliance/Conformance	Fully compliant with Thailand's rules, regulations, and industry standards producing secondary raw materials for production from plastic waste.
Level 2: Facility Material Use & Performance	Source, process post-industrial plastic waste, and then produce plastic pellets/resin/granules of different types and grades. The overall performance is monitored regularly.
Level 3: Facility Effects	Enable communities, corporations, and industries, while cleaning up the surrounding environment, creating jobs, and revitalizing neighborhoods with economic gain.
Level 4: Supply Chain & Product	Effectively manage supply chain activities by closely working with the major supply chain actors like renowned industries for plastic waste sourcing, and processing than making secondary raw materials for production for customers across the world.
Level 5: Sustainability Indicators	Strive for making positive environmental and societal effects to create a sustainable future by working together with industries, and hence establish a sustainable business and society from a broader perspective.

By following other sustainable plastic recycling companies across the world, Union J Plus is trying hard to enable communities, corporations, industries, and governments to transform post-industrial plastic waste into highly functional secondary raw materials for production and then create jobs, saving energy, and revitalizing neighborhoods everywhere from a perspective of the circular economy.

6.6.3.1 Are Union's Products Sustainable?

The following table summarizes the case study in the context of Lowell Center Framework for Sustainable Products, illustrating that Union is on its way to meeting many of the criteria.

Table 6.12: Sustainability measures of Union

Measures	Significance
Is the product healthy for consumers?	Union J. Plus applies up-graded technology that efficiently removes contaminated and hazardous particles from the recyclables and the final products will be used as secondary raw materials for other industry and need not require any chemicals, additives, adhesives/glues, fillers, or else. Therefore, its products are safe for those manufacturers.
Is the production process safe for workers?	The working conditions of Union are comparatively safer, workers enjoy a congenial environment with periodic health and safety training and are treated respectfully without age and gender discrimination.
Is the product environmentally sound?	Union's products are easily repaired, remanufactured, repurposed, upgraded, and at the end of the final use-cycle can be reprocessed into new materials and the company tries to create a beautiful planet without doing any damage to the environment.
Does production benefit local communities?	The company is highly focused on bringing positive change in all aspects of life including culture, health, education, environment, rural development, and much more by giving back to the communities.
Is the product economically viable?	Union's product portfolio is limited to the secondary raw materials that have customer bases across the world and the products are economically viable that creating repeated buyers for the company. As the company has been in existence for more than two decades, it is now in a sustainable position from the long-term perspective and hence keeps itself moving forward at a faster pace.

6.6.4 Critical Analysis

It has been explored from the study that Union J. Plus (Thailand) is the leading plastic waste recycling company aiming towards attaining the circular economy principle.
One of the main purposes of the study is to learn the existing plastic waste recycling industry for replication and scalability of the business model on the circular economy principles. Keeping it in mind Union was selected as one of the cases because of its endeavor to effectively process discarded plastic wastes into secondary raw materials for production.

It does not appear to be the case that profit is the final goal for Union It is a sustainable value creation-oriented organization and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, Union presently emphases collecting and processing waste into valuable raw materials, and manufacturing new recyclable products in possible cases.

The basis of the Union's business model is classified as post-industrial plastic collection and recycling program forms the main part of the company's business. It consists of collecting post-industrial plastic waste materials at end-of-life that are then recycled into plastic granules of different types and grades that are used as secondary raw materials for production.
Union J Plus has established itself as a strong brand in southeast Asia that is associated with eco-friendly post-industrial plastic waste collection programs and secondary raw materials manufactured in long-term cooperation with its customers.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Deals only post-industrial plastic wastes of different types and grades that are comparatively cleaner than post-consumer plastic wastes.
- Advanced technology yields a superior-quality output of materials
- Wide collection networks
- Processing plant is strategically located to accumulate and process plastic waste
- Increasing corporate sustainability powered by the mounting environmental consciousness of customers
- Remarkable customer satisfaction

- Solid and long-term customer relationship

Key Barriers:

- Price of post-industrial plastic waste is comparatively higher than post-consumer plastic waste
- Declining of virgin granules' prices always be a big threat
- Probable limitations of using few non-recyclables

The circular business model of Union J Plus seems to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on post-industrial plastic, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for specific types of post-industrial plastic wastes
- Use environmentally savvy collectors
- Make well-organized resources in diverse life cycle phases of plastic

Key Considerations for Policy Makers:

- Ensure constant environmental regulations
- Introduction of restrictive requirements in waste management is necessary
- Introduce on a wider scale a circular public procurement
- Monitor implementation of circular economy legislation

The current business model of Union J Plus has been made on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. Nevertheless, the scalability and replicability of the business model is slightly limited due to the scarcity of post-industrial plastic wastes in some cases. However, if the collections hub and processing plant are in suitable locations then it will be a very good option for the new entrants. Despite all pros and cons, it would be better to process various types of post-industrial plastic wastes for the utmost betterment of society and the environment.

6.7 SHUNHUA Plastic Co. Ltd. (Taiwan)

7.7.1 Overview

Founded in July 2010, SHUNHUA Plastic Co., Ltd, is considered one of the forerunners in product manufacturing to logistics & storage delivery. With an aim to build a comprehensive recycling infrastructure, the company has started its journey.

The mission of SHUNHUA is to be the most trusted, dominant, and leading manufacturer of various value-added products such as egg cartons, fruit baskets, vegetable baskets, conveyor & storage, logistic equipment, plastic pallet, etc. by ensuring a safe environment for the employees and the mass people with the highest ethical fashion.

Through its state-of-the-art technology, SHUNHUA production facility produces various products from 100% recycled plastic waste. SHUNHUA's composite plastic products are usually sold to common people, brand manufacturers of various products, and logistic companies.

SHUNHUA's products deliver greater strength, effect, and crack resistance, durability, and maintenance-free.

SHUNHUA closely works with both the post-consumer and post-industrial sources to collect plastic waste for product manufacturing that often would not otherwise be used and instead be dumped into landfills or incineration.

SHUNHUA has a solid health & safety plan that enables it to keep an effective effort throughout the entire organization for the protection of its team members and employees.

The goals of SHUNHUA's health and safety plan are:

- To comply with safety & health regulations of the country by periodic evaluation of the whole system.
- To remove workplace injuries and employee protection from plant exposures

The company is upholding the spirits of diligent and sincere, cautious, conscientious, and get-to-the-bottom working attitudes to serve social people by creating more outstanding and value-added products.

Taking into consideration, the working attitudes and belief of "Love, Attention, Concentration", SHUN HUA has gathered specialists, technicians, professional designers, and market salesmen to serve its clients from customer requirements, market-oriented analysis, product R&D, product design, steel die manufacturing, injection forming product manufacturing, extrusion forming product manufacturing to logistics & storage delivery.

For complaint handling to customer service, respective departments are all operated by specialists and skilled professionals.

SHUN HUA has become a systematic and professional plastic products manufacturer and the supplier under the holistic management of all personnel.

The company has kept continuous R&D and provides fast, convenient, comfortable, efficient, and automated new products, constantly developing new patterns, human-based and considerable household plastic products to improve modern life. "Quality Best" and "Service First" are the goals SHUN HUA strives for. The company warmly welcomes peoples' responses and encouragement from all circles.

6.7.2 Applying Business Model Canvas to SHUNHUA

This case study takes on the SHUNHUA recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.7: SHUN HUA Plastic (TAIWAN) Business Model Canvas

Case Study on SHUNHUA (Taiwan)

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
• Municipal Collectors • Government • Companies	Produce household items, logistic equipment from recycled plastic scrap **Key Resources** • Specialist technician, professional designers and salesman • Market-oriented analysis, product R&D, Advanced technology	Serve people and planet by creating economic value from recycled plastic waste.	Customers' requirement and market-oriented analysis help creating long term business relationship with customers and used to get repeated orders on regular basis **Channels** • Website, email • Seminar • Exhibition • Transport, Network Marketing, Online Marketing	• Retailers • Wholesalers • Companies

Cost Structures	Revenue Stream
Collection, sorting, recycling & new product making cost R&D, Marketing and Distribution cost Technological Up gradation and maintenance cost	From Domestic Sale and Export Sale

Key Partners

The core competencies of SHUNHUA are the collection, recycling, sourcing, and logistics of postindustrial and postconsumer plastic waste and for these, there is a number of key partners SHUNHUA. For doing such a massive task the company closely works with MRF, Investors, collectors, aggregators, supply chain actors, and recyclers who are the key partners of SHUNHUA. Partnering mutually with renowned brands manufacturers & logistic companies, SHUNHUA also helps ensure Extended Producer Responsibility (EPR) to achieve global sustainability & recycling goals for brand manufacturers.

Key activities

SHUNHUA works on the concept of recycling postindustrial and postconsumer plastic waste and then after producing various value-added products such as egg cartons, fruit baskets, vegetable baskets, conveyor & storage, logistic equipment, plastic pallet, etc. by ensuring a safe environment for the employees and the mass people with the highest ethical fashion. In doing so, the company deployed designated people to source, collect and transport the segregated plastic waste to its collection center and facilities. It is then sorted and shredded plastic waste for recycling or processing for producing new products.

Key resources

SHUNHUA is always in search of strengthening the plastic recycling ecosystem in a reasonable and impartial way with a translucent vision and mission on efficient sourcing, collection & logistics, financing for working capital, upliftment, education, and on-ground action with over 50 highly skilled professionals and technicians. Apart from these, other resources are value chain actors, supply chain experts, and state- of -the art modern recycling technology.

Value proposition

Expertise in multi-modal logistics facilitates sourcing and unique processing technologies, SHUNHUA enables it to provide high-quality, timely service at the most affordable pricing to its vast customer network. The company provides various types of products as stated above and gives the ultimate solutions to its valued clients and implements them, based on best practices, compliance, and traceability. Its collaborative approach to finding and implementing effective solutions for the betterment of the environment and society on the whole.

Customer relationship

SHUNHUA maintains outstanding relationships with all of its customers giving them a topmost priority. Since it processes various types of recyclable plastic waste, customers' type also varies. SHUNHUA delivers quality products at a competitive price to its customers with a clear &customer assessment of customers' needs and thus creating loyal customer groups who buy goods regularly.

Channel

Since SHUNHUA has established a wider collection network across Taiwan by setting up several collection points and strategically well-located large production & storage facilities, it usually maintains a strong distribution channel. Their shipment takes place both at home and in neighboring countries, and thus SHUNHUA is used to maintain congenial relationships and connections with renowned shipping lines across the world.

Customer segment

SHUNHUA is Taiwan's leading manufacturer of various value-added products such as egg cartons, fruit baskets, vegetable baskets, conveyor & storage, logistic equipment, plastic pallet, etc. and these products' users are different. For example, egg cartons are being sold to poultry farms, fruit baskets are sold to fruit producers & suppliers, vegetable baskets are sold to vegetable producers & suppliers, plastic pallets are sold to manufacturers and shippers, and many more.

Cost structure

Apart from regular administrative costs and operating costs, the company invests a significant amount in the value chain which strengthens its value chain through the collection, segregating, sourcing, and processing of postconsumer and postindustrial plastic waste, machinery, infrastructure, and logistics operation mostly. SHUNHUA provides robust training for waste collectors to sort and shred plastic waste for processing or recycling as well as to train its operators and technical manpower by investing a significant amount of money. SHUNHUA also invests regularly in marketing, sales, and promotional campaigns.

Revenue stream

Revenue comes from selling various types of products as stated above to different customers. Thus, profit also varies based on product type, cost of collection, cost of processing, etc. For example, plastic waste originating from industries and product manufacturers is odorless, and contamination-free, and the process involves fewer actors that eventually can be processed with reduced production cost hence the margin is comparatively higher than post-consumer plastic waste.

6.7.3 Applying Lowell Center Framework for Sustainable Products to Shunhua

The following table classifies Shunhua's current position from a sustainability perspective under the Lowell Framework and all of the metrics presently employed by Shunhua fall into this Framework. Shunhua has been operating its recycling business over the last 12 years in Taiwan complying with Taiwanese rules & regulations and international conformance that are duly audited and evaluated by renowned firms like Bureau Veritas. Shunhua is considered one of the harbingers in product manufacturing logistics & storage delivery. Shunhua's unique business idea and modern technology can recycle various types of post-industrial and post-consumer plastic waste to produce numerous products like egg cartons, fruit baskets, vegetable baskets, conveyors & storage, logistic equipment, plastic pallet, etc. by ensuring a safe environment for the employees and the mass people with the highest ethical fashion.

Shunhua maintains a good network of the supply chain by closely working with MRF, Investors, collectors, aggregators, and recyclers for the collection, recycling, sourcing, and logistics of postindustrial and postconsumer plastic waste.

Table 6.13: Current Indicators related to Framework Level

Framework Level	**Current practicing Indicators**
Level 1: Compliance/Conformance	Fully comply with Taiwanese regulations and international Industry standards are audited by renowned audit firms like Bureau Veritas.
Level 2: Facility Material Use & Performance	SHUNHUA sources postindustrial and post-consumer plastic waste and then produces various products such as egg cartons, fruit baskets, vegetable baskets, conveyors & storage, logistic equipment, plastic pallet, etc. safely, responsibly, and efficiently.
Level 3: Facility Effects	Ensuring a safe environment for the employees and the mass people with the highest ethical fashion where environmental and public health issues are highly prioritized to achieve economic gain, environmental sustainability, and social upliftment.
Level 4: Supply Chain & Product	Efficiently manage supply chain by actively working with the supply chain actors from plastic waste sourcing, and processing to new product making & selling within and outside Taiwan.
Level 5: Sustainability Indicators	Working with businesses, industries, MRFs, communities, state authorities, policymakers, and individuals to eliminate the idea of waste and establish a sustainable society through continuous economic gain.

Shunhua is constructed on a sustainable model that unifies economic, social, and ecological value creation through innovative solutions to reduce plastic as well as improved use of plastic waste, and thus, creating the biggest positive environmental, societal and economic impact.

6.7.3.1 Are Shunhua's Products Sustainable?

Considering the Lowell Center Framework for Sustainable Products, below table summarizes the case study illustrating whether Shunhua is on its way to meeting many of the criteria of this framework or not.

Table 6.14: Sustainability measures of Shunhua

Measures	Significance
Is the product healthy for consumers?	Shunhua adopted highly advanced technology that efficiently removes contaminated and hazardous particles from the recyclables and need not require any chemicals, additives, adhesives/glues, fillers, or else. And thus, yield a healthy product range for the end users.
Is the production process safe for workers?	Though SHUNHUA adopted highly advanced technology with full automation options that need not require many workforces, it has a solid health & safety plan that enables it to keep an effective effort within the organization for the protection of its team members and employees.
Is the product environmentally sound?	Shunhua's products are easily repaired, remanufactured, repurposed, and at the end of the final use cycle can be reprocessed again into new materials. Shunhua produces various products fully complying with the international standards stipulated by the environmental authorities across the world as well as Taiwan.
Does production benefit local communities?	Shunhua is highly focused and dedicated to bringing positive change in all aspects of life including culture, health, education, environment, and much more by giving back to the communities while cleansing the surrounding environment and delivering quality products all the way.
Is the product economically viable?	Shunhua has a portfolio of a diverse range of products that are in high demand from customers both at home and abroad making the company a successful company in attaining sustainability goals.

6.7.4 Critical Analysis

SHUNHUA is considered to be the most trusted, dominant, and leading manufacturer of various value-added products such as egg cartons, fruit baskets, vegetable baskets, conveyor & storage, logistic equipment, plastic pallet, etc. in Taiwan. With an aim to build a comprehensive recycling infrastructure, the company has formed by ensuring a safe environment for the employees and the people with the highest ethical fashion.

It has been observed in this study that at every stage of Shunhua's operations a drive towards the circular economy is visible. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. Keeping it in mind Shunhua has been selected as one of the case organizations because of its ambition: "Setting up a comprehensive and environment-friendly recycling infrastructure".

Shunhua is a sustainable value creation-oriented organization and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, Shunhua, presently emphases collecting and processing various types of post-industrial and post-consumer plastic waste into valuable raw materials, and manufacturing new recyclable products of varied ranges.

The basis of Shunhua's business model is classified as plastic waste collection and processing program forms the main part of the company's business. The resource recovery program consists of collecting plastic wastes at end-of-life that are then recycled/upcycled into different products or used as inputs for another process.

Shunhua established itself as a strong brand that is associated with eco-friendly collection, sorting, and processing programs, and products manufactured in cooperation with its customers.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Key activities and resources hard to duplicate or obtain
- State of art recycling technology yields superior-quality products
- Wide collection networks
- Large collection yard keeps the big volume of plastic wastes
- Strong supply chain networks with a fleet vehicle
- Increasing corporate sustainability powered by the mounting environmental consciousness of customers
- Remarkable customer satisfaction
- Solid and long-term customer relationship

Key Barriers:

- Low volume of products that can be recycled in a socially-accepted other different ways
- Probable limitations of using few non-recyclables
- Mixed plastic waste hard to sort and process
- Comparatively low economies of scale

The circular business model of Shunhua appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on resource recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for plastic waste collection
- Use environmental-minded collectors
- Make well-organized resources in diverse life cycle phases
- Design for reusability of products ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations
- Introduction of restrictive requirements in waste management is necessary
- Introduction of a circular public procurement on a wider scale
- Monitor implementation of circular economy legislation

The current business model of Shunhua has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. The scalability and replicability of the business model are possible to implement in Bangladesh since technology allows for the processing of mixed types of plastic wastes that are widely available. Though the technology transfer cost is too high in the long run it would be beneficial to deliver the utmost value. Therefore, replicating the business model of Shunhua would require a high investment cost on technology procurement which is a high barrier for the new entry.
Despite all these, it would be better to decrease the waste generation in the long run, the processing of various wastes has significant benefits for society and the environment.

Shunhua could use its vast network and experiences in offering closed-loop solutions as a standard to enhance its collection program of various types of plastic waste and set up more recycling plants in strategically good locations.

6.8 Ganesha Ecosphere Ltd. (India)

6.8.1 Overview

Founded in 1987, Ganesha Ecosphere Ltd. has appeared as one of the leading rPET Fiber, rPET Yarn, and postconsumer PET Bottle scrap manufacturers in India under the headship of its Chairman Mr. Shyam Sunder Sharma with a team of dynamic professionals.

Polyethylene Terephthalate (PET) is the most common type of polyester which was discovered in 1941 in England. "Two monomers named (modified Ethylene Glycol and purified Terephthalic acid) are combined to form the Polyethylene Terephthalate" (Recyclers Europe, 2020). Because of its numerous characteristics such as being lightweight, inexpensive, and re-sealable customers prefer PET that is 100% recyclable and can be recycled multiple times into many forms such as bottles, fiber for carpets; t-shirts fabric, or fiberfill for sleeping bags, fleece jackets; winter coats, sheet, and thermoformed (clamshell) packaging; and industrial strapping; dog beds; and automotive parts such as and door panels, headliners, bumpers and more.

Being in the sustainable business of PET waste Recycling, GANESHA purposes to collect significant PET waste through the countrywide networks in India and minimize its environmental impact by turning it into a resource. It has several manufacturing units in Kanpur (Uttar Pradesh), Rudrapur (Uttarakhand), and Bilaspur (Uttar Pradesh) and has a cumulative capacity of 1,18,800 TPA (1.08,600 TPA of RPSF and 7200 TPA of RPSY and 3000 TPA of Dyed and Texturized/ Twisted Filament Yarn) of rPET Fiber and yarn. Its products find application in the manufacture of textiles (T-Shirts, body warmers, etc.), functional textiles (non-woven air filter fabric, geotextiles, carpets, car upholstery), and fillings (for pillows, duvets, toys).

GANESHA recycles discarded PET bottles into user-friendly and value-added polyester staple fiber and polyester spun yarn having versatile applications. To source raw material (Pet plastic waste) we have developed a pan India network of plastic waste dealers and contractors who in turn work through rag pickers for supplying the PET plastic waste to the Company. Contractors also supply directly from various cities.

GANESHA enjoys a competitive PET waste-collecting capability through a robust pan- Indian network of collection centers mainly in the Northern and Eastern parts of India. These collection centers are being run on the franchisee model. GANESHA is in the process of increasing collection centers to address the problem of growing PET waste through legitimate recycling.

After collection, PET plastic waste is creased and baled at collection centers and received in its manufacturing facilities, and sent to factories for further processing. The network enables the collection of about 350 tons of PET plastic waste daily.

GANESHA's vision is "To become a global citizen committed to recycling every PET bottle which is thrown into waste with world-class recycling facilities and to create wealth for the stakeholders by conducting business around social and environmental concerns".

GANESHA's Mission is separated to:

- To be a high-performance PET waste recycler by making the best use of available resources and empowering people.
- To be the perfect choice for customers through world-class customer service.
- To keep superior quality products through continuous innovation, and periodic R&D in methods, products, and applications.
- To establish cohesive relationships with all stakeholders involved focusing on faith, transparency, and ethical business behavior.
- To contribute to making the planet a healthier place to live in for the present and future generations.

6.8.2 Applying Business Model Canvas to GANESHA

This case study takes on the GANESHA recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.8: GANESHA ECOSPHERE LTD (INDIA) Business Model Canvas

Case Study on GANESHA (INDIA)

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Proposition</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="2">• Waste PET Bottle Collectors
• Waste PET Bottle Stockiest
• Brokers</td><td>Gathering waste PET Bottle and produce value-added products</td><td rowspan="2">PET is inert, no-toxic and free from harmful chemicals. PET Waste can be reprocessed into wide arrays of value added products like apparel, home fashion products & technical textiles.</td><td>Long term business relationship</td><td rowspan="2">• Industry
• Government
• Engineers
• Individuals</td></tr>
<tr><td>Key Resources
• Strong collection network with several offices and distribution centers across India
• Skilled manpower to produce diversified products
• Advanced technology</td><td>Channels
• Transport and logistics companies
• Warehouse
• Network Marketing
• Internet Marketing</td></tr>
<tr><td colspan="2">Cost Structures
Human Resources
Purchase of waste PET Bottle
R & D
Technological up gradation and regular maintenance</td><td colspan="3">Revenue Stream
Revenue comes through exporting various value added products originating from PET Bottle waste.</td></tr>
</table>

Key partners

Entire value chain actors are the key partners of GANESHA since multiple actors are involved in sourcing, collecting, and sorting waste PET bottles for warehousing or sorting facilities for waste processing and related services. Material Recovery Facilities (MF), transport companies, and communities are also considered to be the key partners of GANESHA as they provide valuable services for the collection and processing of the material. The cooperation with value chain actors is assessed positively that collecting and supplying post-consumer PET Bottle waste for further processing. Shipping and freight companies are other noteworthy key partners of GANESHA since they provide noteworthy service and support to minimize demand and supply gaps and hence keep the business running. Freight services to transport PET waste materials and finished products between warehouses, recycling facilities, and customers' points are provided by various companies depending on the location.

Key activities

The collection program usually begins with designing a recycling process and then several tailor-made products because of their varied characteristics and applications. GANESHA has its own R&D facility with a dedicated workforce and relevant technical know-how on the material treatment of its kind. GANESHA categorizes collection systems of post-consumer PET bottle waste. Thus, GANESHA enjoys a competitive PET waste-collecting competence through a country-wide network of collection centers in India, mainly in the Northern and Eastern parts of India and these collection centers are being run on the franchisee model. To meet the ever-increasing customer needs for various types of products originating from post-consumer PET bottle waste, GANESHA is in the course of increasing collection centers considering the problem of mounting PET waste through legitimate recycling. PET plastic waste is being creased and baled at the collection points and received in its manufacturing facilities and sent to factories for additional treatment. This wide network allows the collection of approximately 350 tons of PET plastic waste daily.

Key resources

GANESHA's key resources are intertwined since every resource is important to delivering its value propositions. For the economic and environmental affairs, GANESHA's marketing and R&D teams are engaged closely and these highly skilled professional people have been spearheading the company over the last few decades as a key resource of the company. On top of that, the headship of its Chairman Mr. Shyam Sunder Sharmma helps accomplish the company's mission and vision to a height and further expansion of business. The process for reclaiming material from a circular economy perspective with an effective collection system spread across the different strategically important location in India and hence manufacturing it into value-added diversified products is designed with the required knowledge and modern technology.

Value proposition

GANESHA's value proposition is to cooperate for the collection of PET Bottle waste and further usage of PET waste typically by making diversified value-added products such as Dope Dyed Polyester Yarn, Non-woven for automotive, carpets & fabrics, Fiber filling (down-like micro-fiber, and various types of Spun Yarn of distinguishing applications. Equipped with the latest technology, GANESHA has set up three production facilities having a capacity of 118,800 MT/year in India with a team of over 2700 skilled members and over 250 suppliers for sourcing PET waste through a wide network of waste dealers in India. It has a large customer base (more than 300) across key sectors in 16 countries of the world that consume tarn and fiber. GANESHA has a huge product portfolio ranging over 500 product variants across recycled PSF and recycled polyester spun yarn. GANESHA's robust emphasis on R&D and the development of various types of value-added products that enlarge the current product portfolio from the current 25% to 50% over the upcoming years. GANESHA has put real plans to exponentially increase its income and develop the business using innovative latest technology, quality products, capacity extension, and exploring the foreign market and for these reasons, it became India's number one company in the field of PET bottle recycling.

Customer relationships

As mentioned earlier, GANESHA has a diversified product portfolio of more than 500 products variant with a large customer base of more than 300 customers across 16 countries in the world. A long-term bonding with those customers has been established with a fully collaborative effort that enables to renew the customer's order always and hence create new customers. Regarding the working relationships with such a large customer base, the company engages senior management, dedicated skilled professionals, and the revenue-producing side of major corporations. Through solid bonding, GANESHA is actively associating with manufacturers to supply its quality secondary raw materials and finished products for their processes towards attaining sustainability goals.

Channels

As stated earlier, GANESHA has established a country-wide collection network across India with over 250 suppliers and three large manufacturing & storage facilities that are strategically well-placed, it has to maintain a robust channel for the collection, processing, distribution, and shipping functions. Their shipment takes place both in home and overseas countries and thus GANESHA is used to maintaining congenial relationships and connections with renowned domestic and international transportation and shipping lines across the world. Apart from these, the company owned a large fleet of transport for the purpose of collection and distribution of materials.

Customer segments

GANESHA produces varied value-added products from post-consumer PET Bottle waste such as Dope Dyed Polyester Yarn, Non-woven for automotive, carpets & fabrics, Fiber filling (down-like micro-fiber, and Spun Yarn (Textile yarn spun from staple-length fiber). The diverse product portfolio of GANESHA has the following applications:

1. rPET Spun Yarn Products (Grey, Solid Dyed, Melange)
2. Filament Yarn Products (Texturized, Twisted & Doubled, Solid/Injection, Dyed Fancy Yarn)
3. rPET Fiber (Yarn Spinning, non-woven fabric/carpets/felts, non-woven carpets, non-woven scrubbers/felts, fiber filling)
4. Textiles (all kinds of textiles)
5. Functional textiles (non-woven, air filter fabric, geotextiles, cars, car upholstery)
6. Fillings (pillows, duvets, and toys among others)

Since GANESHA produces more than 300 varied products with a diverse range of applications, it has a distinctive customer base of over 500 spreads across 16 countries.

Cost structure

GANESHA works with the circular economy principles aiming to collect maximum PET waste through our PAN India network having its three production units at Kanpur of Uttar Pradesh, Rudrapur of Uttarakhand, and Bilaspur in Uttar Pradesh with a collective capacity of 1,18,800 TPA (1.08,600 TPA of RPSF and 7200 TPA of RPSY and 3000 TPA of Dyed and Texturized/ Twisted Filament Yarn) of rPET Fiber and yarn. Its products have diverse applications in the manufacture of textiles such as body warmers, T-Shirts, etc.), handy textiles such as geotextiles, non-woven air filter fabric, carpets, car fabric, and pillows, duvets, and toys fillings.

The company has established a country-wide network of scrap dealers and contractors who in turn work through rag pickers to source PET waste for the Company. Franchisees also supply directly from other regions of India. After collection, PET plastic wastes are crumpled and baled at collection points and received in its manufacturing facilities, and sent to factories for further processing and producing various types of value-added products through high-speed extruders and other applicable modern technologies in a non-chemical process. These are considered to be the main cost structure of the company along with regular administrative, marketing, sales, and promotional cost.

Revenue streams

GANESHA has been amongst the largest Indian PET waste recyclers for about 25 years. With its PET Bottle waste's raw materials, GANESHA produces versatile products used in highly diverse industries ensuring a stable supply for varied operations.

GANESHA’s revenue originated from selling the following products to diverse industries across 16 countries in the world:

1. Grey, Solid Dyed, Melange rPET Spun Yarn Products
2. Texturized, Twisted & Doubled, Solid/Injection, Dyed Fancy, Filament Yarn Products
3. Various rPET Fibers such as Yarn Spinning, non-woven fabric/carpets/felts, non-woven carpets, non-woven scrubbers/felts, fiber filling
4. Various kinds of textiles
5. Numerous functional textiles such as non-woven, air filter fabric, geotextiles, cars, car fabric
6. Fillings (pillows, duvets, and toys among others)

6.8.3 Applying Lowell Center Framework for Sustainable Products to Ganesha

Ganesha’s present activities and future projections fully comply with the indicators of the Lowell framework that are described here.

Founded in 1987 in India, Ganesha started a post-consumer PET Bottle scrap recycling business according to the Indian rules & regulations aligning with international standards.

GANESHA produces more than 300 products with varied applications from post-consumer PET Bottle waste like Dope Dyed Polyester Yarn, Non-woven for automotive, carpets & fabrics, Fiber filling (down-like micro-fiber, and Spun Yarn (Textile yarn spun from staple-length fiber) through a solid network of collection points spread mainly in the Northern and Eastern regions of India where collection points are being run on the franchisee model. Since GANESHA produces more than 300 varied products with a diverse range of applications, it has a distinctive customer base of over 500 spreads across 16 countries.

GANESHA has its own shared values on innovative products, result-oriented teamwork, uncompromising integrity, and mutual trust & respect for all. Therefore, it has established itself as a high-performance organization by making the best use of resources and empowering people while ensuring required safety and health regulations.

GANESHA enjoys a competitive PET waste-collecting ability through a wide network of collection centers diverse mainly in the Northern and Eastern regions of India run on the franchisee model. Ganesha has made a strong bonding with various associates built on utmost faith, transparency, and ethical business practice. Furthermore, GANESHA is in the progression of growing collection centers to meet the growing demand for PET waste through legitimate recycling. Therefore, the company efficiently manages its supply chain and hence produces quality products.

Table 6.15: Current Indicators related to Framework Level

Framework Level	Current practicing Indicators
Level 1: Compliance/Conformance	Ganesha founded fully complies with India's regulations and industry standards from a circular economy perspective that is certified and audited by renowned organizations like Dun & Bradstreet, Creditsafe, Recycling Today, etc.
Level 2: Facility Material Use & Performance	GANESHA produces varied value-added products from post-consumer PET Bottle waste like Dope Dyed Polyester Yarn, Non-woven for automotive, carpets & fabrics, Fiber filling (down-like micro-fiber, and Spun Yarn (Textile yarn spun from staple-length fiber) with the most modern technology and continuous R&D.
Level 3: Facility Effects	Establish it as a high-performance organization by making the best use of resources and empowering people while ensuring required safety and health regulations by regular evaluation across the whole system and established the company as a sustainable organization from a circular economy perspective.
Level 4: Supply Chain & Product	Regarding managing the supply chain and product selling and distribution, Ganesha has established a robust network of collection centers run on the franchisee model and has created a strong customer base that buys its products continuously.
Level 5: Sustainability Indicators	Being a mission-driven company, GANESHA is built on a circular economy model that combines economic, social, and environmental value creation.

Ganesha is dedicated to focusing on comprehensive progress and enlightening lives by contributing to society and the surrounding environment at large. For achieving its CSR objectives, the Company strives to benefit humanity through work in the area of **Education, Healthcare, and Hunger** Eradication by supporting the communities in which it lives and works. The company is solely responsible for keeping a healthy environment without polluting with advanced drawing and pressing machines for the entire treatment process. Since the company works with the circular economy principles, sustainability is at its core. In the connection, 20% of the energy consumption comes from renewable energy, with an aim to take it to 75% in the next 5 years through a zero liquid discharge facility. The ultra-modern technology uses only 2 liters of water while recycling 1 kg of PET bottle recycling, which is substantially lesser than the 5-6 liters of industry-standard usage.

6.8.3.1 Are Ganesha's Products Sustainable?

The following table summarizes the case study considering the Lowell Center Framework for making Sustainable Products, illustrating whether Ganesha is on its way to meeting many of the criteria or not.

Table 6.16: Sustainability measures of GANESHA

Measures	Significance
Is the product healthy for consumers?	Ganesha only processes post-consumer PET bottle waste that applies advanced technology for producing resins and pellets. Flakes, PSF, yarn, and other textile items need not require any chemicals, additives, adhesives/glues, fillers, or else. As a consequence, it delivers healthy products to versatile customers.
Is the production process safe for workers?	GANESHA has its own shared values on innovative products, result-oriented teamwork, uncompromising integrity, and mutual trust & respect for all. Technicians, operators, and workers enjoy a healthy and congenial work environment within the company functions and are used to receiving periodic health and safety training and all employees are treated respectfully with utmost care. At Ganesha, workers & technicians are not exposed to chemical toxins throughout the whole operation.
Is the product environmentally sound?	Being a mission-driven company, GANESHA is built on a circular economy model that combines economic, social, and environmental value creation. The company is solely responsible to keep a healthy environment without polluting with high-end drawing and crimping machines for the whole process. Since the company works with the circular economy principles, sustainability is at its core. In the connection, 20% of the energy consumption comes from renewable energy, with an aim to take it to 75% in the next 5 years through a zero liquid discharge facility. The ultra-modern technology uses only 2 liters of water while recycling 1 kg of PET bottle recycling, which is substantially lesser than the 5-6 liters of industry-standard usage.
Does production benefit local communities?	It is committed to focusing on inclusive growth and improving lives by contributing to society at large. For achieving its CSR objectives, the Company strives to benefit humanity through work in the area of **Education, Healthcare, and Hunger** Eradication by supporting the communities in which it lives and works.
Is the product economically viable?	Ganesha has a portfolio of a diverse range of products originating from PET bottle waste recycling with varied customer bases across the world that are continually buying its products. Therefore, all of its products are economically viable that generate repeat buyers from different parts of the world. As the company has been in existence for many years, it is in a fully stable position in the long-term perspective and keeps expanding its business to a new height.

6.8.4 Critical Analysis

GANESHA is the pioneer company that recycles discarded PET Bottles into valuable Polyester Staple Fiber (PSF) and Polyester Spun Yarn having wide arrays of applications. On every single stage of GANESHA's operations, a drive toward a circular economy is noticeable. One of the core objectives of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. Considering this GANESHA was selected as one of the cases because of its vision: "To become a Global Corporate citizen committed to recycle every PET bottle which is thrown into waste with world-class recycling facilities and to create wealth for our stakeholders through conducting business around social and environmental concerns".

It does not appear to be the case that profit is the final goal for GANESHA. It is a sustainable value creation-oriented company and this aspect appears mostly imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, GANESHA presently emphases collecting and processing discarded PET bottles into valuable Polyester Staple Fiber (PSF) and Polyester Spun Yarn having wide arrays of applications.

The basis of GANESHA business model is classified as the recyclers of discarded PET bottles that form the main part of the company's business The PET bottle wastes recovery program consists of collecting discarded PET bottles at end-of-life that are then recycled/upcycled into different products or used as inputs for another process.

GANESHA established itself as a strong brand that is associated with eco-friendly collection programs and products manufactured in cooperation with its valued suppliers and customers.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Wide collection networks across India
- Effective and efficient value chain actors
- Advanced technology helps make superior-quality products
- Wide product ranges for versatile applications
- Increasing corporate sustainability powered by the mounting environmental consciousness of customers

- Remarkable customer satisfaction
- Solid and long-term customer relationship

Key Barriers:

- Difficult to maintain demand and supply gap
- Probable limitations of using few non-recyclables in the discarded PET bottles such as labels and caps that are made of other types of plastic
- Comparatively low economies of scale

The circular business model of GANESHA appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on discarded PET bottle recovery, companies in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for resource recovery
- Use environmental-minded volunteers
- Make well-organized resources in diverse life cycle phases
- Design for reusability ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations
- Introduction of restrictive requirements in waste management is necessary
- Introduction of a circular public procurement on a wider scale
- Monitor implementation of circular economy legislation

The current business model of GANESHA has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. As a consequence, the business of GANESHA has been increasing exponentially in terms of value and volume, hence generating economic gain and environmental sustainability. Since, GANESHA is a successful company in this sub-continent, the scalability, and replicability of the business model are strongly possible in Bangladesh.

6.9 Bangladesh Petrochemical Company Ltd. (BPCL), Bangladesh

6.9.1 Overview

Founded in July 2012, Bangladesh Petrochemical Company Ltd. (BPCL) has emerged as the first waste PET bottle recycling project in Bangladesh that epitomizes the "recover & recycling" business model in which post-consumer PET bottles that used to be considered waste are revitalized for new usage. With a yearly production capacity of manufacturing 10,500 MT of recycled PET resin by using PET Bottle wastes, BPCL is more than a PET resin manufacturer. BPCL has a solid environmental commitment to lessening greenhouse gas emissions and a social commitment to improving the life of waste pickers. The goal of BPCL is to improve the environment, eradicate child labor and bring fairness to the whole recycling value chain.

BPCL's high-quality state-of-the-art European technology successfully transforms the post-consumer PET bottle waste into high-quality resins suitable for food-related and non-food-related usage ensuring contamination-free flakes/resin/PET sheets far exceeding minimum purity requirements for direct food contact. With a fully equipped quality testing laboratory that ensures quality products and provides test reports to its valued customers. As a result, customers can purchase BPCL products with confidence. BPCL's operation is ISO-certified and food-grade resin manufacturing plants are FDA approved.

BPCL is exceedingly devoted to adapting PET bottle waste into commercially viable products, using environmentally friendly recycling and manufacturing processes. It intends to produce sufficient revenue with a quick return on investment and to finance sustained growth and development of quality products through incessant R&D.

Since its inception, BPCL has been playing a pivotal role in the following noteworthy issues:

Import Substitute

Since the PET industry of Bangladesh was fully import-driven provided bottle makers the option to source PET resins locally; thus, helping the country.

Ready Market for its Products

Bangladesh imports approximately 142,000 MT of PET resin and demand is growing steadily by more than 20% a year. BPCL relishes a prepared and rising product by more than 20% a year to absorb its products.

Secure Funding

With the passing of time, BPCL has received equity and debt financing from various renowned foreign and local prominent investors such as DEFTA partners (USA), NFM Energy Singapore Pte, IDCOL, and Trust Bank Ltd.

The company closely works with the circular economy principles and development is based on the Triple Bottom Line Model where its continued commitment to the economic, social, and environmental development of the communities it operates. BPCL is closely working towards the development of the surrounding society and strives to minimize its environmental footprint, improving conditions in surrounding areas and hence providing a better way of life for all.

6.9.2 Applying Business Model Canvas to BPCL

This case study takes on the BPCL recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.9: BPCL (BANGLADESH) Business Model Canvas

Case Study on BPCL(Bangladesh)

<table>
<tr>
<td rowspan="2">Key Partners
• PET Bottle Collectors & Stockiest
• Brokers</td>
<td>Key Activities
Manufacturing PET Resin and PET Sheet from recycled PET Bottle Wastes</td>
<td rowspan="2">Value Proposition
Developed based on the Triple Bottle Line Model while continued commitment to the economic, social and environmental development of the communities it operates.</td>
<td>Customer Relationships
Strong bonding with the domestic customers as well as overseas customers</td>
<td rowspan="2">Customer Segments
• Food Industry
• Plastic Industry</td>
</tr>
<tr>
<td>Key Resources
• Professional Management
• Skilled Manpower
• European Machinery transforms the post-consumer bottles into high quality resins suitable for food graded and non- rated usage
• Fully equipped with quality testing laboratory</td>
<td>Channels
• Transport and logistics companies
• Network Marketing
• Internet Marketing</td>
</tr>
<tr>
<td colspan="2">Cost Structures
• General administrative cost
• Collection & Operational cost
• Machine Maintenance cost</td>
<td colspan="3">Revenue Stream
Selling of PET Resin and PET Sheet to domestic and overseas buyers.</td>
</tr>
</table>

Key partners

BPCL closely works with the value chain actors of postconsumer PET bottle waste who are engaged in sourcing, collecting, trading, and warehousing PET bottle waste and they are its key partners. Municipal collectors, scrap shops, transport companies, and communities are also considered to be the key partners of BPCL since they provide valuable services for the collection, sorting, warehousing, and processing of the material. Shippers and freight forwarders are other noteworthy key partners of BPCL for their noteworthy support and services. BPCL sometimes work with the stockiest, broker, middlemen, and musclemen to collect post-consumer PET wastes since they render valuable service no matter whether it is an ethical or unethical practice.

Key activities

By designing the recycling process, BPCL starts its collection program as well as its reprocessing process to produce PET flakes, resin, or PET Sheets. BPCL categorizes collection systems of post-consumer PET bottle waste through its own R&D facilities, workforce, and relevant technological know-how on material processing. For the smoother and hassle-free collection of waste, BPCL enjoys a holistic PET waste-collecting ability through a strong country-wide collection center in Bangladesh. To meet customer needs, BPCL is in the process of expanding its production facilities to produce PET flakes, PET resin, and PET sheets derived from post-consumer PET bottle waste, and storage capacity augmentation as well. PET plastic waste is crushed and baled at facilities and processed properly for producing PET flakes, PET resin, and PET Sheets based on specific demands from customers.

Key resources

Since its inception, BPCL's engineers, technicians, marketing, and R&D teams are engaged closely and these highly skilled professionals have been spearheading the company as a key resource of the company. On top of that, the headship of its highly educated management team helps accomplish the company's mission and vision to a height and further expansion of business. The process for reclaiming material from a circular economy perspective with an effective collection system spread across the country, a highly effective infra-red German sorting system enables it to manufacture contamination-free PET flakes, PET resin, and PET sheets with the latest European Technology available in the world. The quality testing laboratory of BPCL ensures superior quality products that provide test reports to customers for making a purchase decision.

Value proposition

BPCL's value proposition is to cooperate for the holistic collection of PET Bottle waste and further usage of PET waste typically by making value-added products such as PET flakes, PET resin, and PET sheets. Equipped with the latest infra-red sorting technology and the latest reprocessing technology, BPCL has set up its production and large storage facilities with a team of over 100 skilled members. BPCL has put pragmatic plans to exponentially increase the revenue and expand its business using desired innovation, the latest technology, premium products, capacity optimization, and exploring the foreign market. BPCL never compromises on quality and for this reason, it got ISO certification as well as got FDA approval.

Customer relationships

BPCL's product portfolio is limited to PET flakes, PET resin, and PET sheets and it has diversified customers. BPCL maintains a good relationship with its customers and thus has established a long-term bonding with them with a fully collaborative effort that enables them to renew the customer's order always and hence create new customers from those references. Regarding the working relationships with customers, the company engages its well-trained dedicated skills and thus partners with brand manufacturers to supply its goods for their operations as a secondary raw material and help towards accomplishing sustainability goals.

Channels

As stated earlier, BPCL has established a country-wide collection network with adequate supply sources with a robust channel for the collection, processing, distribution, and shipping functions. Their shipment takes place both home and overseas countries and thus BPCL used to maintain congenial relationships and connections with renowned transportation companies, and shippers & forwarders

Customer segments

As mentioned earlier BPCL produces varied value-added products such as PET Flakes, PET resin, and PET Sheets that are used as secondary raw materials for making various products. The diverse product portfolio of BPCL has the following applications:

- PET Flakes: To produce rPET Spun Yarn Products of various colors and types
- PET Resin: To produce PET bottles, PET pots & jars, etc.
- PET Sheet: To make egg trays, cookie trays, pastry & cake trays, etc.

The customers who produce cookies, biscuit, water bottle, and textile items are basically the customers of BPCL.

Cost structure

BPCL works with the circular economy principles aiming to collect maximum PET bottle waste through the country-wide network in Bangladesh to produce PET flakes, PET resin, and PET sheets. BPCL has established a nationwide network of PET waste dealers, brokers, traders, and contractors who work with waste pickers to source post-consumer PET bottle waste for the company. After sourcing PET bottle wastes, these are crushed and baled at collection points and then sent to manufacturing facilities for further treatment and production as stated earlier through the available latest technologies in a non-chemical process thus the cost incurs along with regular administrative, marketing, sales, and promotional cost.

Revenue streams

BPCL has been among the largest and only PET waste recyclers in Bangladesh to date for more than 10 years produces versatile products used in varied sectors ensuring a steady supply for distinguished applications.

BPCL's revenue originated from selling the following products to diverse industries;

- PET Flakes
- PET resin
- PET sheets

In the conventional value chain, the intermediaries obtain a high-profit margin by paying low prices to the scavengers. Sidestepping the intermediaries is a goal for many scavengers, but in the context of Bangladesh, it is close to impossible if the industry doesn't want it. BPCL is trying hard and intervening in the market to oust the middlemen from the value chain and buying directly from waste collectors at a fixed price in its hub.

6.9.3 Applying Lowell Center Framework for Sustainable Products to BPCL

In relation to level one, two, and three indicators, BPCL fully complies with the Lowell Framework. Founded in July 2012, Bangladesh Petrochemical Company Ltd. (BPCL), has emerged as the first waste PET bottle recycling plant in Bangladesh. BPCL has employed European technology that successfully transforms the post-consumer PET bottle waste into high-quality resins suitable for food-related and non-food-related usage ensuring contamination-free flakes/resin/PET sheets far exceeding minimum purity requirements for direct food contact. With a fully equipped quality testing laboratory that ensures quality products and provides test reports to its valued customers so that they can purchase BPCL products with confidence. BPCL's operation is ISO-certified, and food-grade resin manufacturing plants are FDA approved. BPCL is highly devoted to converting PET plastic wastes into commercially valuable products, exploiting environmentally friendly recycling and manufacturing methods. It intends to generate adequate revenue with a quick return on investment and to re-generate finance for continuous growth and development of superior quality products through incessant R&D.

Though the company has a positive intention for establishing a strong supply chain network it is struggling a lot while managing it smoothly as there exist, multiple actors, who used to take illegal chances in most cases. Therefore, business activities hamper a lot causing undue price escalation, demand and supply gap, inferior quality supplies, and many more. Thus, the supply chain is highly volatile for BPCL to run the business unhindered.

Table 6.17: Current Indicators related to Framework Level

Framework Level	Current Practicing Indicators
Level 1: Compliance/Conformance	BPCL was founded as a PET bottle waste recycling company by fully complying with Bangladesh's regulations and industry standards from a circular economy perspective it is an ISO-certified company and resins are approved by FDA.
Level 2: Facility Material Use & Performance	BPCL produces PET flakes/PET Resin and PET sheets from post-consumer PET Bottle waste with European Technology through continuous R&D and selling those produced items to various plastic companies and food industries.
Level 3: Facility Effects	Dedicated to converting waste plastic materials into commercially viable products, utilizing environmentally friendly recycling and manufacturing methods. Ensuring a congenial working environment with adequate safety and health measures.
Level 4: Supply Chain & Product	The supply chain is highly volatile and fragmented equipped with multiple actors that hamper the overall business activities from the viewpoint of waste sourcing, processing and finally selling to the ultimate customers.
Level 5: Sustainability Indicators	BPCL works with the circular economy principles and development is based on the Triple Bottom Line Model where it's a continued commitment to the economic, social, and environmental development as a whole.

BPCL works with the circular economy principles, and development is based on the Triple Bottom Line Model where its continued commitment to the economic, social, and environmental development of the communities it operates. BPCL has a solid environmental commitment to lessening greenhouse gas emissions and a social commitment to improving the life of waste pickers. The goal of BPCL is to improve the environment, eradicate child labor and bring fairness to the whole recycling value chain

6.9.3.1 Are BPCL's Products Sustainable?

The following table summarizes the case study considering the Lowell Center Framework for making Sustainable Products, illustrating whether BPL is on its way to meeting many of the criteria or not.

Table 6.18: Sustainability measures of BPCL

Measures	Significance
Is the product healthy for consumers?	Like Ganesha, India, BPCL only processes post-consumer PET bottle waste that applies advanced technology for producing resin, and pellets. Flakes, PET sheets, and need not require any chemicals, additives, adhesives/glues, fillers, or else. As a consequence, it delivers healthy products to the customers.
Is the production process safe for workers?	The goal of BPCL is to improve the environment, eradicate child labor and bring fairness to the whole recycling value chain. BPCL has its own shared values on innovative products, result-oriented teamwork, uncompromising integrity, and mutual trust & respect for all. At BPCL Technician, operators and workers enjoy a healthy and congenial work environment, and they are not exposed to chemical toxins throughout the whole operation.
Is the product environmentally sound?	Coping with current international and domestic laws & regulations, BPCL has committed to the protection and improvement of the environment that the organization subscribes to regarding ecological and environmental matters, including the rational and efficient use of resources. BPCL has defined pragmatic policies that lead it to the development of various projects for waste reduction, water conservation, and emissions reduction. The company is committed to taking action for lowering carbon footprint across all dimensions of its operation and hence reducing the direct and indirect impact on the environment brought by its business processes.
Does production benefit local communities?	In Bangladesh, scavengers inheritably have low incomes, mainly because the industry does not buy recyclables directly from them because its minimum volume demand is beyond what most scavengers can provide and because the materials still need to be stored, cleaned, and baled adding other labor costs for the purchasers. In the conventional value chain, the middlemen obtain a high-profit margin by paying low prices to the scavengers. Sidestepping the middlemen is a goal for many scavengers, but it is near impossible if the industry doesn't want it. BPCL will intervene in the market to break this trend, and purchase directly from scavengers at a fixed price in its hub and help them earn on a regular basis.

6.9.4 Critical Analysis

It has been observed in this study that Gemini is the prominent circular economy market creator in Bangladesh that gives a second life to million tons of post-consumer PET bottle waste. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. In this consideration, BPCL has been selected as one of the cases because of its goal: “to improve the environment, eradicate child labor and bring fairness to the supply chain of recycling”.

BPCL is not only a profit-focused company but also a sustainable value-creation organization and this aspect appears most imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. Keeping the circularity principle at the forefront of all its endeavors, BPCL presently focuses on collecting and processing post-consumer PET bottle wastes into valuable raw materials, and manufacturing new recyclable products in varied applications.

The basis of BCL’s business model is classified as a PET Bottle collection program through a collaborative approach that forms the main part of the company’s business. This approach helps find and implement effective solutions for the betterment of the environment and society as a whole. The PET Bottle waste collection program consists of collecting waste materials at end-of-life that are then recycled into different products such as PET Flakes, PET granules and PET sheet.

BPCL established itself as a strong brand in Bangladesh that is associated with eco-friendly collection programs and products are manufactured in cooperation with its numerous stakeholders.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Mobilizing the whole value chain across Bangladesh to bring circularity of waste
- Providing required training to every stakeholder in the value chain to create a successful circular economy model
- Striving diligently to ensure impartial circulation of resources at every stage of the value chain and the obtainability of feedstock
- Using state-of- the- art technology

- Providing high-quality multi-modal logistics facilities with timely service at affordable prices through a globalized network

Key Barriers:

- Sometimes non-availability of PET bottle wastes due to seasonal variation and syndicate issues could hamper business growth in the long term on a circular economy notion
- Probable limitations of amalgamation PVC content and imported particles with the PET bottle wastes along with few non-recyclables

The circular business model of BPCL appears to be replicable and transferable to a certain extent to any entity in Bangladesh and offers significant possibilities for positive ecological and economic benefits. Based on PET bottle waste recovery in terms of volume, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Cooperate with different stakeholders to find the finest solutions for resource recovery
- Use environmental-minded volunteers
- Make well-organized resources in diverse life cycle phases of various types of wastes
- Design for reusability ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations of different regions of the world
- Introduction of restrictive requirements in waste collection and processing is necessary
- Introduce on a wider scale a circular public procurement on regional considerations
- Monitor implementation of the circular economy legislation

The current business model of BPCL has been founded on circularity philosophies. Over the years, it has been evidenced to be financially successful and environmentally beneficial. Since BPCL handles only post-consumer PET Bottle wastes, the scalability and replicability of the business models are comparatively easier to implement. Even though, replicating the business model of BPCL's would require a long-term commitment and a wide waste collection network which is a high barrier for the new entry.

Despite all these, it would be better to decrease the waste generation, the processing of various wastes has significant benefits for society and the environment.

BPCL could use its vast network and experiences in offering closed-loop solutions as a standard to enhance its PET waste collection program. Such a program would ensure the final products made from recycled material are recyclable without any additional resources to establish such a system by BPCL as already functioning collection points could be used.

6.10 Royal Polyware Bangladesh Ltd. (RPL)

6.10.1 Overview

With an aim to build a profitable plastic recycling business in Bangladesh, Royal Polyware Ltd. (RPL) started its journey as a small recycler in the old town of Dhaka in the mid-20s under the headship of a Primary school headmaster along with nineteen other partners. With conventional and crude recycling technologies, the company started producing various household items from post-consumer plastic wastes of various types. As time passes on, the value and volume of business increased and the company could not maintain the pace of its production facility located in the old town of Dhaka south city corporation. Later the company moved to BSCIC, Keraniganj comparatively to a bigger place. The mission of RPL is to become the trusted, dominant, and leading manufacturer and seller of various food containers such as pickle jars, tiffin boxes, yogurt boxes, cookies boxes, biscuit boxes, itching sticks, backpack plates, spices boxes, etc., and sell to various customers across the country. Through a few second-hand types of machinery, RPL produces these diverse products from 100% recycled plastic waste.

RPL closely works with both the post-consumer and post-industrial sources to collect plastic waste for varied product manufacturing and those products are mainly being sold to the mass people who are not bothered about the quality.

RPL has gathered technicians, and salesmen to serve its clients from customer requirements, market-oriented analysis, product design, and manufacturing.

Since the company produces substandard products for varied applications at cheaper prices, products are used to generate great appeal from the consumer and small-scale manufacturers.

Since the company is not aware of social responsibility and environmental sustainability, it is not upholding any mission, vision, and objectives as well.

6.10.2 Applying Business Model Canvas to RPL

This case study takes on the RPL recycling activities on mixed type plastic waste, selected in the framework of the business model canvas. Each building block of the business model is described as follows:

Figure 6.10: ROYAL POLYWARE (BANGLADESH) Business Model Canvas

Case Study on Royal Polyware (Bangladesh)

<table>
<tr>
<td rowspan="2">Key Partners
• Wholesalers & Middle Dealers of scraps
• Retailer & whole sellers of household items sellers
• Food and Packaging Industry</td>
<td>Key Activities
Manufacture household items & food containers</td>
<td rowspan="2">Value Proposition
Producing cost effective, low priced & affordable household food containers for the mass people</td>
<td>Customer Relationships
Maintaining favorable relationship with the customers by providing cheaper products</td>
<td rowspan="2">Customer Segments
• Wholesalers and retailers of household items
• Packaging and Food industries</td>
</tr>
<tr>
<td>Key Resources
• Hardworking and Dedicated investors
• Good network</td>
<td>Channels
• Transport and logistics companies
• Network Marketing</td>
</tr>
<tr>
<td colspan="2">Cost Structures
Administrative and operational cost</td>
<td colspan="3">Revenue Stream
Selling of food containers and other household products</td>
</tr>
</table>

Key Partners

The core competencies of RPL are the collection, recycling, sourcing, and logistics of postindustrial and postconsumer plastic waste and for these, it has many key partners such as waste pickers, scrap dealers, traders, and sometimes small processors who supply reprocessed plastic waste to be used as secondary raw materials. For doing such RPL is partnering with the municipal collectors, itinerant scavengers, Investors, collectors, aggregators, supply chain actors, and recyclers as its key partners.

Key activities

RPL works on the concept of recycling varied plastic waste and then after producing various products such as pickle jars, tiffin boxes, yogurt boxes, cookies boxes, biscuit boxes, itching sticks, backpack plates, spices boxes, etc. that are mainly substandard and cheaper. Because of its cheaper price, RPL products have a wide market network across the country. The company deploys designated people for the collection and supply of required post-consumer plastic waste. After plastic waste collection and manual sorting and shredding of plastic waste, new products are produced for the market.

Key resources

RPL has cheaper second-hand technology, lesser operating cost, and cheaper workforces are the key resources to produce cheaper products for the mass people as well as for small and medium-scale product manufacturers. On the other hand, all partners of the company work together within the same platform and hence can save a significant amount by minimizing production costs. The production facility is strategically located in the periphery of the country's biggest recycling hub in old Dhaka which enables RPL for getting reprocessed plastic resin and flakes as secondary raw materials to produce various products.

Value proposition

Though the company produces various types of substandard products from postconsumer plastic wastes relatively at a reduced production cost and hence offers to the market, it creates certain value for the mass people, especially for those who lie on the bottom layer of society, penetrating the marketplace with those substandard products.

Customer relationship

RPL maintains outstanding relationships with all of its customers giving them a topmost priority by delivering cheaper products within their affordability and thus creating loyal customer groups who buy goods regularly.

Channel

As stated earlier, RPL is located in a strategically good location its collection and distribution channel are comparatively smoother to maximize its business activities positively. Since the company has established a wider collection network within old town areas by several actors with strategically well-located production & storage facilities it usually maintains a strong distribution channel. RPL used to maintain congenial relationships and connections with different truck drivers, rickshaw van pullers, and itinerant collectors.

Customer segment

RPL is the old town's leading manufacturer of various products such as pickle jars, tiffin boxes, yogurt boxes, cookie boxes, biscuit boxes, itching sticks, backpack plates, spices boxes, etc., and sells to various customers across the country. And these are sold to small & medium scale manufacturers, wholesale dealers, small traders, and consumers as well.

Cost structure

As mentioned earlier, all partners of the company work together in a single platform, RPL is used to reduce and save significant operational costs. Furthermore, the company employs cheaper manpower for operational and marketing purposes and thus saves production costs. However, the company invests a significant amount in the value chain which strengthens its value chain through the collection, segregating, processing, and production of new products from post-consumer- and post-industrial plastic waste, machinery, infrastructure, and logistics operation mostly.

Revenue stream

Revenue comes from selling various types of products as stated above to different customers. Thus, profit also varies based on product type, seasonal variation, cost of collection, cost of processing, etc.

6.10.3 Applying Lowell Center Framework for Sustainable Products to RPL

RPL started its journey as a small recycler in the old town of Dhaka in the mid-20s. The Company started producing various household items from post-consumer plastic wastes of various types with locally made or very old second-hand recycling technology. The mission of RPL is to become the trusted, dominant, and leading manufacturer and seller of various food containers such as pickle jars, tiffin boxes, yogurt boxes, cookies boxes, biscuit boxes, itching sticks, backpack plates, spices boxes, etc., and sells to various customers across the country. RPL produces these diverse products from 100% recycled plastic waste.

RPL closely works with both the post-consumer and post-industrial sources to collect plastic waste for varied product manufacturing and those products are mainly being sold to the mass people who are not bothered about the quality.

Since the company is not aware of social responsibility and environmental sustainability, it is not upholding any mission, vision, or objectives as well rather than focusing only on revenue generation by selling goods produced from plastic waste.

Table 6.19: Current Indicators related to Framework Level

Framework Level	Current practicing Indicators
Level 1: Compliance/Conformance	RPL started the plastic recycling business according to Bangladesh rules and regulations as other business establishment procedures.
Level 2: Facility Material Use & Performance	It produces various products such as pickle jars, tiffin boxes, yogurt boxes, cookie boxes, biscuit boxes, itching sticks, backpack plates, spices boxes, etc., and sells to various customers across the country.
Level 3: Facility Effects	Dedicated to converting waste plastic materials into commercially viable products mainly for the lower-class and lower-middle-class communities where environmental, safety, and health issues are highly neglected.
Level 4: Supply Chain & Product	Manage supply chain smoothly because of locational advantage as well as no prerequisites of quality plastic waste.
Level 5: Sustainability Indicators	Mainly focus on profit generation where sustainability and related things are highly ignored.

6.10.3.1 Are RPL's Products Sustainable?

The following table summarizes the case study considering the Lowell Center Framework for making Sustainable Products, illustrating whether RPL is on its way to meeting many of the criteria or not.

Table 6.20: Sustainability measures of RPL

Measures	Significance
Is the product healthy for consumers?	RPL processes various types of post-consumer Plastic waste that applies very old second-hand technology for producing various types of products in an unhealthy environment and thus it delivers substandard product ranges that are often unhealthy for the customers.
Is the production process safe for workers?	The company tries to give a healthy and safe work environment to its workers but could not do it because of some undue limitations such as space constraints, financial problems, etc.
Is the product environmentally sound?	According to the interview cited for the study, it has been discovered that the investors are not concerned about environmental issues but rather concerned about making money in the easiest way.
Does production benefit local communities?	They are not concerned with the overall betterment of the communities they operate the business.
Is the product economically viable?	Because of its cheaper price, RPL's products have strong customer demand for varied applications and thus it has created a strong customer base that buys its products regularly. Therefore, all of its products are economically viable until the consumers are not educated.

6.10.4 Critical Analysis

Royal Polyware Ltd. (RPL) started its journey as a small recycler in the old town of Dhaka in the mid-20s under the headship of a Primary school headmaster along with nineteen other partners. It has been explored in this study that RPL's operation is far away from attaining the circular economy. One of the aims of this study is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in Bangladesh. Considering this the selection of RPL may not be worthwhile. But the study has chosen this company to see how a company is performing with less or without any circularity principle.
RPL is a profit-focused company and this aspect appears most imperative when assessing the possibilities for probable replication and scalability of the business model in line with the circular economy principle. RPL, presently emphasizes collecting and processing various types of post-industrial and post-consumer plastic waste into various products of varied ranges.

The basis of RPL's business model is classified as a post-consumer plastic waste collection and processing program that forms the main part of the company's business. The waste recovery program consists of collecting plastic wastes at end-of-life that are then recycled/upcycled into different products or used as inputs for another process.
RPL has established a strong relationship with its customers who buy low-cost products.

Throughout the study, the following enablers and barriers have been identified.

Key Enablers:

- Strategically located
- Strong customer base
- Less product cost

Key Barriers:

- Low volume of products that can be recycled in a socially-accepted other different ways
- Probable limitations of using few non-recyclables
- Mixed plastic waste hard to sort and process
- Comparatively low economies of scale

The business model of RPL appears to be replicable and transferable fully or to a certain extent to any entity in Bangladesh and offers significant possibilities. But for attaining positive ecological and economic benefits it requires to re-modelled its business model. Based on resource recovery, companies in different sectors in Bangladesh can reflect on their specific context and product design.

Key Managerial Considerations:

- Replace crude recycling technology with the contemporary recycling technology
- Require large space for sorting, accumulating, and processing various types of plastic wastes
- Introducing the hot washing process in the plant
- Cooperate with different stakeholders to find the finest solutions for plastic waste collection
- Use environmental-minded collectors
- Make well-organized resources in diverse life cycle phases
- Design for reusability of products ensuring the lowest negative impact on the environment and human well-being

Key Considerations for Policy Makers:

- Ensure constant regulations
- Introduction of restrictive requirements in waste management is necessary
- Introduce on a wider scale a circular public procurement
- Monitor implementation of the circular economy legislation

The scalability and replicability of the RPL business model are easy to implement for an entity in Bangladesh since locally made crude technology allows for the processing of mixed types of plastic wastes that are widely available. RPL could use its good location and experiences in offering closed-loop solutions as a standard to enhance its collection program of various plastic wastes and adapt modern recycling technology in order to establish it as a sustainable plastic recycling company in Bangladesh.

6.11 Comparative Analysis & Findings from the business models of Plastic waste recycling companies

In Bangladesh, plastic waste processing is run mainly by small-scale factories that have been discussed in the finding and analysis part as originating from open-field interviews of the recyclers. Nevertheless, two cases of Bangladesh have been considered here with the eight renowned cases of the world for possible replication and scalability.

As mentioned earlier, the study has been conducted, based on data that is publicly and readily available within the case organizations with desk research conducted by the researchers complemented by targeted interviews with the case organizations considering the elements (e.g. customer segments, value proposition, channel, customer relationship, revenue stream, key resources, key partners, cost structures, environmental impact) of the business model canvas and the Lowell Center Framework for making sustainable products. Since the study has been conducted to facilitate an independent analysis of eight selected foreign organizations and two domestic organizations, and to identify new opportunities for Bangladesh, to change while assessing the prospect and opportunities for replication and scalability of the business from the circular economy perspective; not just only for comparison.

Therefore, this part of the research will try to address replicability and benchmarking options of the business models. The case study findings will help to discover additional gaps and to provide the required solution with the proper benchmark for establishing a viable plastic waste recycling industry in Bangladesh.

Table 6.21: Comparative Statement of Cases

BLOCKS	TERRACYCLE	BYFUSION	INTEGRICO	GEMINI	DAISAKU	SHINHUA	UNION	GANESHA	BPCL	ROYAL
Customer Segments	Perishable goods producers Retail Sector Municipalities NGOs & Individuals	Industries Individuals Municipalities Government	Government Individual companies Contractor Erectors	Manufacturers & Brand owners	Plastic industries	Retailers, wholesalers, companies	Plastic industries	Gov. Companies Engineers Individuals	Food Industry Plastic Industry	Wholesalers, retailers, packaging & food industries
Value Propositions	Recycle the unrecyclable	Recycle mixed plastic waste	Process hard to recycle plastic into durable	Creating sustainable infrastructure	Process PIR	Creating value from waste plastic	Process PIR	varied products from PET waste	Developed based on TBL Model	Low priced affordable products
Channels	Customers approach directly	Customer approaches directly, website, email	Customer approaches directly, website, email	Website, email, exhibition, seminar	Website, email, exhibition	Website, email, warehouse, logistics	Website, email, exhibition	logistics companies Website, email	Logistics Website Email exhibition	Logistics warehouse
Customer Relationships	Long term	Long term	Long term	Long term	Long term	Long term	Long term because of low price	Long term	long term	favorable
Revenue Streams	Selling materials	Selling materials	Selling materials	Selling products	Selling materials	Selling products	Selling products	Selling varied products	Selling PET resin & sheet	Selling products
Key Resources	Human, volunteers, technical knowhow, brand recognition	Patented technology, technical knowhow, R&D	Patented technology, technical knowhow, R&D	Worldwide presence with large facilities	Manpower Top machinery Lab facility	product R&D, Advanced technology	Wide network People Technology	Collection network & distribution centers	Professional mgt EU machinery Lab	Good network, hardworking investors
Key Activities	Design recycling process, organize collection, marketing & PR	Produces building materials	Produces construction materials	Plastic granules of different types	Plastic granules of different types	Household & logistic items	Plastic granules of different types	value-added product from PET	Produce PET Resin & Sheet	Household items
Key Partnerships	Recycling, freight & storage companies, school, charities &NGOs	Communities, corporations, Industries and governments	MRF, NRC, Brand owners, individuals, GOV	MRFs Brand owners & manufacturers	Plastic and Packaging industries	Municipal Collectors Government Companies	Plastic and Packaging industries	Collectors Stockiest Brokers	Collectors Stockiest Brokers	Wholesalers, retailers, brokers, companies
Cost Structure	Operational costs, people and subcontractors cost	Technology Operational costs Logistics People	Technology Operational costs Logistics People	R& D Cost Collection, Sorting & Reprocessing Technology	People Purchase Processing cost R & D	Collection, sorting, recycling & new product making cost	collection processing cost R&D Cost Technology	People Process R & D Technology	administrative cost Collection Operational cost	Administrative and operational cost

It has been observed from the above-mentioned comparisons that the business models of foreign companies generate more positive impacts considering economic gain and environmental sustainability. Of the two Bangladeshi companies Bangladesh Petrochemical Company Ltd. (BPCL) has been trying to accomplish sustainability goals and on the other and Royal Polyware Ltd. (RPL) is far away from this despite it having exponential growth from the perspective of products selling that are substandard mostly. Plastic recycling companies in other parts of the world such as the organizations' cases that have been analyzed here in the study TerraCycle, ByFusion, IntegriCo, Gemini, Daisaku, Shunhua, Union, and Ganesha are considered to be sustainable as they have rightly addressed technical, infrastructural and financial issues to create economic values and environmental sustainability from a circular economy perspective. On the other hand, a business model like BPCL in Bangladesh is facing infrastructural constraints with dependent on bank loans at high interest and hence somehow struggling to create desired economic values, and environmental sustainability. Considering the business case of RPL, the study found that the company is run by investors' funds and the company is not interested in availing of bank loans since it is producing substandard products with second-hand and locally made technology mainly for the bottom layers people and small-scale manufacturers. RPL does not care about environmental sustainability as well as social value creation. The locational advantage of collecting plastic waste for processing, cheap labor, and second-hand crude technology helped RPL to produce various types of products at a cheaper price, no matter these substandard. All the elements of the business model canvas and the Lowell Center Framework for sustainability where key partners, key activities, resources, cost structure, value propositions, revenue streams, customer segments, customer relationships, channels, environmental sustainability, social values, etc. were rightly managed by the foreign recycling companies. As a consequence, their business models are more viable, profitable, and sustainable where each element are correspondingly imperative for making the business model appealing and replicable.

6.11.1 Major Challenges of Recycling Companies in Bangladesh

It is tough to replicate scalable business models from other countries since the business procedures, ecosystem, ethos, tradition, and history varies country to country. Despite this reality, companies across different countries adopted different business model concepts internationally and became successful in the long run such as Ganesha from India, Shunhua from Taiwan, and Union from Thailand. Considering due to products, services, customer segments, and the ecosystem of the country, business models also differ and vary. From all ten business cases, open-field interviews with the supply chain actors, in-depth interviews, and literature reviews, the research identified the following challenges of plastic waste recycling companies in Bangladesh that are limiting growth and sustainability.

The key factors that came from business cases, open-field interviews with the supply chain actors, in-depth interviews, and literature reviews are described below:

Skilled Manpower

The case studies have revealed that skilled resources are the most indispensable requirements to execute any business. It has been identified from the case studies that Bangladesh is lagging far from the rest of the world regarding skilled manpower which has become one of the top challenges for the recycling industries in Bangladesh from the circular economy perspective. Since there exist many small-scale recyclers with a few medium-scale recycling companies, this sector has not been established like other sectors and thus, has failed to encounter the compulsory skills required for running those recycling companies coping with global standards and trends as well as to invite skilled resources comparing to conventional businesses. The lack of technical skills is one of the foremost hindrances to the growth and development of this sector. From the case analysis, it is clearly noticeable that significant skill gaps in the recycling sectors of Bangladesh compared to recycling companies in the world because of low salaries & wages, and lack of investment affordability on required training for their human resources. Therefore, experience/ knowledge sharing on technical know-how and training is required as a long-term priority to design, deploy and sustain business models.

Access to Finance

Recycling companies across the world usually invest a significant amount and are heavily dependent on required funding since continuous R& D, Technological evolvement, and cost of waste collection & reprocessing take place on a regular basis. Therefore, inadequate investment has been considered a crucial funding restraint, and access to finance is often considered to be one of the key challenges for any recycling company to be sustained. In Bangladesh, the dearth of proper investment prospects made it hard for accessing to finance since financial institutions are mainly interested to finance in established businesses with the expectancy of a quick return on investment at a high-interest rate. On the other hand, recycling companies in other parts of the world have the options available from alternative sources of funding as well as the easiest access to finance. In Bangladesh, traditional bankers used to assess the business model of plastic waste recycling companies are more focused on waste management goals and less profit-focused and thus discourage providing adequate funding which is a big challenge for the recycling companies to start/explore their respective businesses. In addition, most of the recyclers in Bangladesh are not interested to provide the required supporting papers to get investment due to their illiteracy, conservative mentality, and limited & skilled manpower. Despite having good recycling concepts or business ideas, many recycling businesses in Bangladesh cannot ensure the required funding since it has been treated as a dirty job by the mass people. The research revealed that small recyclers except BPCL established themselves as self-sufficient plastic waste recycling company in terms of sound financial competencies and are happy with their small earnings rather than thinking big.

Access to Market

Reaching customers & suppliers through market access is a big concern for plastic waste recycling in Bangladesh despite having good ideas often from probable replication, that cannot assure smooth access to the market for executing such a business compared to similar cases in the world. In Bangladesh, the plastic waste recycling business often fails to compete with the conventional business model due to:

- Wrong public perception of plastic waste
- Lack of contemporary recycling technology
- Dearth of knowledge about varied plastic waste types and their processing technology
- Lack of competitiveness and efficiency in the marketing and production phase
- Dearth of replication
- Substandard products originating from plastic waste

The issues stated above form complications for the recycling industries to reach out to the target market in Bangladesh. Market information about plastic wastes, their type, and reprocessing are other key aspects with minimum access to information in Bangladesh. Considering two cases from Bangladesh, it has been observed that like the cases of other countries, less information is available for mass people. Due to a lack of market information with demand and supply gaps, recycling companies face practical challenges. Therefore, it isn't easy to access the market for the recycling companies in Bangladesh which are easy for other countries recycling companies.

Technological Evolution, Product Innovation, and R & D

Case studies have identified that successful recycling companies across the world always rely on advanced recycling technology, product innovation, and incessant R% D. In the context of product design, product versatility, idea development, processing technology, business type, etc. we can see the clear distinction between Bangladesh and other parts of the world where the education, public awareness, ecosystem, and culture differ significantly. Addressing environmental and economic issues, many start-up ventures adopt concepts from the existing business models of successful recycling companies in the world. Considering technology adaption & evolution and R&D recycling companies of Bangladesh are far behind those of other countries which is a barrier to creating an environment for innovation. Since, recycling industries are mainly dominated by informal sector people that don't have the financial strength, education experience, and technological know-how to purchase advanced technology as well as just to follow the new technology invented by others. On the other hand, renowned companies are highly discouraged to enter into this business and hence investing in new technology because of the wrong perception of this sector. As a result, the recycling business in Bangladesh often cannot rightly address their technological demand and thus produce value-added products for the consumers despite Bangladesh's aggregate recycling percentage being higher than the global average.

Issues Related to the Environment

The ever-increasing environmental challenges are gradually becoming a crucial issue worldwide. Over the years, the world has been unhappily suffering from various environmental issues such as air pollution, water pollution, incessant natural disasters, etc. Considering these environmental issues, successful recycling companies across the world are continuously working on taking some innovative solutions through advanced technology, strong measures on the collection, sorting, hot water washing of plastic wastes, and infra-red technology that are visible through recycling practices of those companies like IntegriCo, ByFusion, TerraCycle, Gemini, Daisaku, Ganesha, Union, Shunhua. Together with Municipal Recycling Facilities (MRF), Government & Policymakers, these companies play substantial roles in considering environmental issues. Except for BPCL, no such big and renowned companies have entered into the plastic business in Bangladesh that can play a key role in the environmental issues like BPCL is trying to do at this moment while other small-scale recyclers are highly negligible in addressing environmental issues.

Infrastructure

Regarding infrastructure, the overseas countries are far away than Bangladesh where recycling activities are being done with narrow roads, space constraints, unstable utility supply, locational disadvantages, and many more. Poor recycling infrastructure and facilities are a big apprehension for Bangladesh for availing the success of viable and sustainable plastic waste recycling industry. In the absence of basic infrastructure, existing recycling companies are facing extreme challenges with inadequate working facilities that eventually discourage new entrants to enter this prospective sector. Also, the unstructured urbanization with the increase of the basic operational cost, rental cost, land procurement cost, bank interest rate, high volatile utility costs, etc. discouraged big and renowned investors to enter this business. In the absence of adequate roads and favorable connectivity, the re-processors are often failed to produce an anticipated output of products in terms of value and volume. Therefore, it is hard for recyclers to reach out to waste suppliers and buyers in remote areas for waste collection, sorting, reprocessing, and transporting within the stipulated date and time.

Quality Education and Training

As mentioned earlier plastic has varied types and applications and for this reason, there should be a correlation between quality education and the skilled resources available. Quality resources will not be generated without a quality education and technical training system. Therefore, quality education and technical background are very important as parallel to other factors for establishing a sustainable recycling business which is widely practiced among the successful recycling companies in the world. In Bangladesh where the recycling sector is mostly dominated by the small-scale informal sector, which cannot produce value-added products like the cases analyzed above owing to a lack of economic strength, and often cannot deliver anticipated outcomes due to the low-skilled workers and crude recycling technology. Practical training on plastic waste handling, reprocessing, and trading is required to encourage workers and employees to bring new, creative, imitative, and innovative ideas with probable answers to implement these. Therefore, the recycling companies who involved themselves in providing required training to their resources give more positive outcomes. The study has discovered that most successful recycling companies in the world whose members are sincere in terms of their specific job roles and responsibilities, dedicated to their ambition, providing their best to their associates, honest, and have integrity in the business through an appropriate working environment.

Human Development Index (HDI)

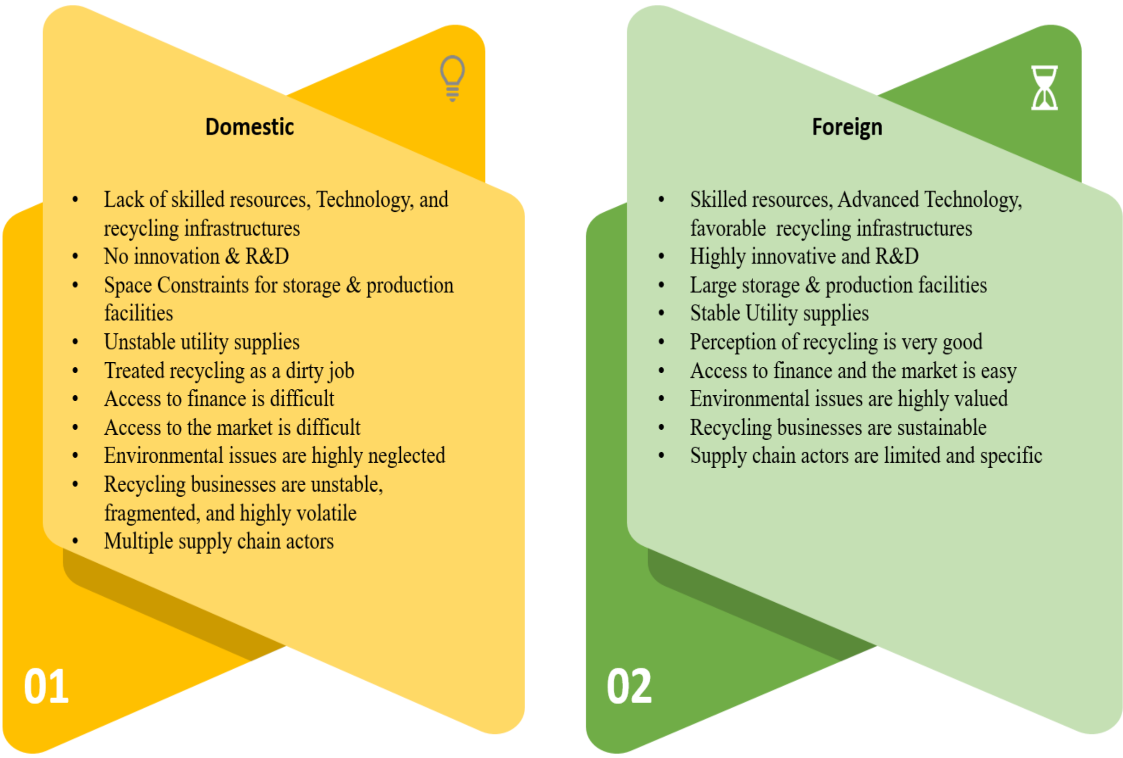
The case studies of different countries have discovered these successful companies are continuously taking numerous development initiatives like recycling education, healthcare, cleanliness, and poverty alleviation. As a consequence, people from the bottom of society can uplift their family life. For example, a significant portion of Ganesha's earnings goes directly to the healthcare, education, tree plantation, and social development activities that take place continuously across India. BPCL is very supportive of using the willpower of PET bottle collectors by providing training and fixation of price for a steady supply of PET waste as well as their stable earnings.

The below table displays the benchmarking of the aspects explicit to the recycling companies in Bangladesh, and other parts of the world.

Table 6.22: Benchmarking the factors explicit to domestic and overseas recycling companies

Factors	Foreign companies	Domestic companies
Skilled resources	Very good	Shortage
Access to finance	Easy	Difficult
Access to market	Easy	Difficult
Recycling Technology & Technological Evolution	Highly advanced and continuous evolution takes place	Crude technology (The case of BPCL is the exception)
Innovation & R& D	Highly innovative with continuous R&D	Mostly substandard and some cases imitative
Supply Chain actors	Very few and specific	Multiple actors
Environmental protection	Very good	negligible (Except BPCL)
Infrastructure (Road & Utilities)	Well-planned infrastructure and stable utility supplies	Narrow roads, space constraints, unstable utility supplies
Quality Education & Training	Widely available	Not affordable/available for all
Health & Vigorness	Very good	Low (Physical violence, child labor, drug abuse, corruption0
Perception on Recycling	Very good	Mostly treated as a dirty job

Figure 6.11: Synthesis of major findings from case studies



6.12 Lessons Learned for Making Sustainable Products

Cultivate Thoughtful Plan

Making sustainable products entails cautious care of economic competence and business facts such as the nature of business, its prospect & opportunities. The study has found that the biggest challenge for businesses is to manage their growth and development. After the inception of any business, the first few years it may not be able to grow at the desired level, because the business has to ensure that it has all its ducks in a row aligned with economic and environmental issues. Therefore, growing thoughtfully is the core issue in making sustainable products one should look into.

Start the Design Process with Environmentally-preferred Materials

The world economy is transforming from a linear to a circular economy. Therefore, environmental issues must be considered prior to starting designing process with environmentally preferred materials which is a newfangled and dissimilar means to formulate the design. Upon finding materials that fully meet green growth and safe criteria, then decide what products can be produced and offered to consumers for the common betterment.

Adaptation of advanced technology & continuous development of technology

Technological evolution plays a key role in all aspects of our lives. Without the proper technology, a business cannot yield anticipated outputs taking into consideration of product design, manufacturing, R&D, marketing, selling, and distribution. Therefore, for establishing a sustainable product, businesses must follow the global trend in technological viewpoints.

Closely work with the Product Manufacturer

Specialized machinery and technical know-how may be required to use greener materials. The manufacturing process, close connection, and tie-up with the product manufacturer will certainly help achieve its goal and it may eventually provide a competitive advantage despite taking time upfront.

Know about Material Composition for Making Products

For making sustainable products, various raw materials need to be sourced from numerous sources. If those raw materials are inferior or substandard fully or partially then the final products will be of inferior quality and hence could not create any positive impact on the environment and society as well. Therefore, prior to starting to make any product, one should get accustomed to his suppliers by providing detailed information about material structure according to required specifications. A periodic visit to suppliers is imperative to understand how raw materials are effectively used and managed.

Frequent Tests of Raw Materials and Products

For any business, it is tough to uphold quality standards and regulations in order to avoid the perception of contamination, date of expiry, product substandard quality, etc. Testing raw materials and finished products regularly helps assuring the quality of products meeting conditions for greener, safer, and improved products.

Seeking Prospects to Support Local Communities

From a circular economy perspective, communities and the environment are intertwined and we cannot do anything to avoid environmental and social issues. Therefore, we must consider it and see how businesses can stimulate the community with employment prospects and support ecological initiatives.

Chapter Summary

Through studying cases across the world as stated above, it can be ascertained that measuring sustainable production is a complex process. With the growing number of organizations, attempts to be sustainable, their measurement processes must change from easier compliance and regulatory-driven models of performance appraisal. In this study, all eight international companies studied employed all the levels of indicators. In the case of Bangladesh BPCL is on its way to accomplishing its journey toward sustainability despite having serious constraints related to the supply chain that is highly volatile and fragmented. On the other hand, RPL is mainly focusing on making money from recycling where environmental, social, and other related factors are highly ignored and thus it doesn't focus on sustainability.

The case studies mentioned above revealed that sustainable production indicators are beneficial for organizations, firms, community groups, government agencies, and many other stakeholders. All stakeholders need to measure and manage their respective accomplishments. NGOs, communities, organizations, policymakers, researchers, municipalities, and governments need to assess companies' performance meticulously to reward the leaders and determine how best to inspire the stragglers the improvement of their performance toward sustainability.

The purpose of the Lowell Center Framework is to deliver companies with a classification structure indicator and direction for evaluating their advancement toward sustainability. Sustainability indicators of industries stress one part of the sustainable

development equation i.e., environment over the others i.e., social and economic where social and economic parts include economic possibility, social impartiality, community development, and employee safety and health development. This chapter provides a detailed analysis of ten different cases from various regions of the world including two from Bangladesh applying Business Model Canvas (Alexander Osterwalder, 2010) and Lowell Center Framework for Sustainable Products (Sally Edward, 2010). The study discovered that skilled resources, advanced technology, continuous R& D, strong infrastructure, sound financial strength, favorable state policies, and a vibrant supply chain play key roles in the growth and development of plastic recycling companies which are widely practiced in the other part of the world. As a consequence, successful recycling companies are emerging. On the contrary, Bangladesh is lagging far in that successful journey towards attaining a circular economy because unregulated, unstructured, and unmonitored plastic recycling sector that has been described in this chapter. Therefore, this chapter addresses the possible replicability of the business models, and the overall findings will help to find further gaps and to provide anticipated solutions with the proper benchmark for establishing a feasible plastic waste recycling industry in Bangladesh.

CHAPTER 7: SUSTAINABLE PRODUCT STRATEGY

Outcomes of the specific objective 3

To formulate a sustainable product strategy from recycled plastic waste in Bangladesh

CHAPTER CONTENTS

This chapter of the study provides an outline of probable strategies to formulate a feasible recycled plastic market in Bangladesh. This chapter also provides recommendations for short term and long-term roadmaps.

7.0 Chapter Introduction

The study has found that plastic recycling is unstructured, unregulated, unauthorized, and unmonitored so it has been proven difficult and uneconomical. In addition, there is a dearth of information regarding plastic types, the composition of plastic wastes, disposal and reprocessing of plastic waste to achieve economic gain and environmental sustainability where western and other developing countries are clearly ahead of Bangladesh in handling plastic and plastic waste to extract ultimate benefit from it. This chapter of the study offers an outline of probable strategies to formulate a feasible recycled plastic industry in Bangladesh. This chapter also provides recommendations for short-term and long-term roadmaps.

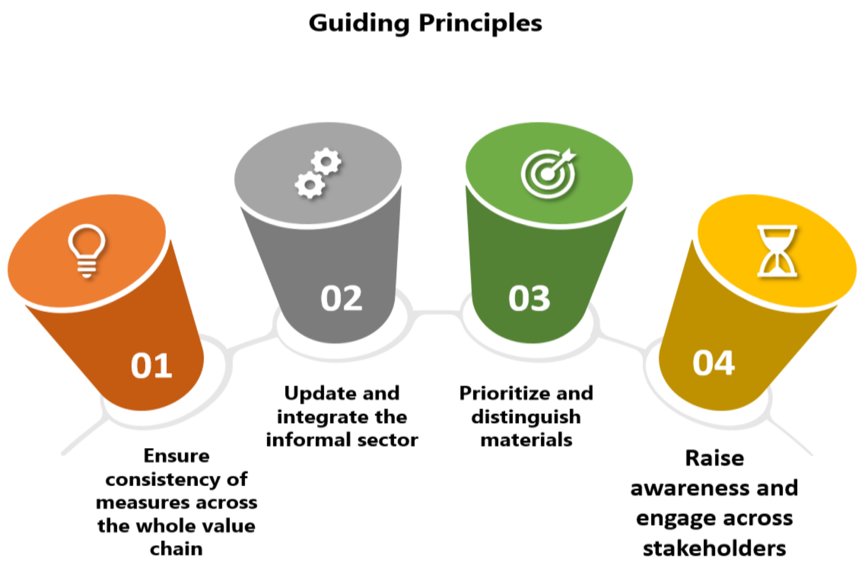
7.1 Guiding Principles

Below guiding principles are set out to stimulate positive results in the implementation of preferred strategies:

1. Ensure consistency of measures across the whole value chain

Strategic sequencing of measures is complex and should be aimed at sacking bottlenecks in order to maximize the impact of the investment. Interventions concentrating on merely a single actor of the value chain are uncertain to move the needle in improving material recovery. For example, interviews cited that 3R (Reuse, Reduce, Recycle) or source-sorting pilots in Bangladesh are unproductive mostly due to the absence of sorting and recycling infrastructure, where segregated waste is mixed up again when collected by municipal waste collectors or by informal waste pickers. Thus, the marginal benefits of implementing source-sorting at the household level will be maximized provided the measures are combined with investments to increase the capacity to sort and process collected waste.

Figure 7.1: Guiding Principles



2. Update and integrate the informal sector

Below guiding principles are set out to stimulate positive results in the implementation of preferred strategies adapted from the literature review:

In Bangladesh, the informal sector plays an enormous role in the collection and recycling of plastic waste. A significant volume of recyclable plastic waste is being collected by an informal network of waste-pickers, middle dealers, wholesale dealers, and recyclers. Additionally, waste pickers on the front collection of waste material are often exposed to uncongenial and filthy working conditions, with unsatisfactory income for their endeavors. Recycling zones are presently extremely dirty and do not have access to contemporary technology that could otherwise, increase resource recovery rates.

3. Prioritize and distinguish materials

Literature review reveals that all plastics are not created equal; some are easily recycled (e.g., PET, HDPE), and others are expensive to recycle (e.g., PE, mixed material). Thus, it is vital to develop a national valuation system to measure dissimilar plastic waste flows, distinguishing between various types of plastic, miscellaneous sources of plastic waste (e.g., urban/rural, municipal/industrial), and types of recycling processes (closed vs. open-loop recycling). In order to conduct this assessment, a transparent data collection mechanism must be put in place. Hence, a meaningful intervention is required to create a viable plastic recycling market in Bangladesh. Measures should provide stable and improved working conditions while leveraging their expertise to drive improvements in the quality and quantity of recyclables. In addition, waste and recycling markets can only be optimized through an integrated system. Therefore, a viable model must be inclusive of the informal sector and leverage their expertise.

4. Raise awareness and engage across stakeholders

The feasibility of solutions in plastic waste collection and recycling is more functional provided there are

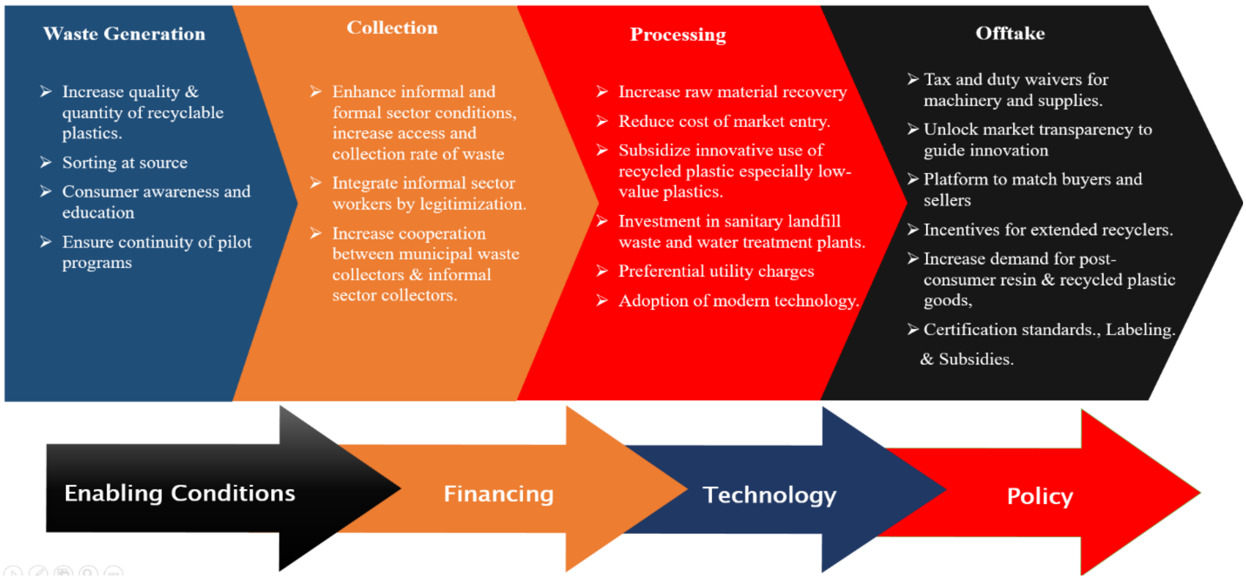
- complementary behavior changes by consumers
- strong political support by legislators and enforcers.

In addition, the businesses must be communicated, monitored, motivated, and enforced clearly for any intervention to pursue innovations that enable recycling and appropriate plastic waste management. However, more effort is required to involve consumers, improve enforcement at metropolitan cities and district levels, and institutionalize commitments by product manufacturers to decrease unnecessary plastic packaging, reduce waste, and increase plastic recycling rates.

7.2 Strategies for developing a viable Recycled Plastics Market ensuring sustainable products

This section offers strategies to develop a viable recycled plastics market in Bangladesh. Thus, a framework of these strategies is summarized in the below figure:

Figure 7.2: Strategies for developing a viable Recycled Plastics Market



Probable strategies can be characterized into the four stages of the value chain (waste generation, collection, processing, offtake) targeting to be consistent with the outline presented above and must be complemented by the right enabling conditions i.e., financing technology, and supporting policies and regulations.

7.2.1 Interventions by the Value Chain Phases

1. Plastic Waste Generation

Recap of Findings:

Low-value plastics and urban waste, absence of source segregation, and recycling are mainly restricted to high-value plastic waste.

The recycled plastics market in Bangladesh is mostly bottled up by inferior-quality feedstock. Contaminated, and co-mingled organic or inorganic materials can make re-processing costs uneconomical. In addition, generation of plastic waste is geographically disseminated and heterogeneous. Therefore, significant coordination effort is required to attain economies of scale.

Education and awareness, source-sorting, and product-oriented strategies can be taken into consideration to improve recycling rates along with quality feedstock that increases recyclability through improved design and material standards. In case of unavailability of a better design for specific types of plastic products (e.g., mixed, soiled, and tarnished plastics), measures to limit production and consumption, or preferable re-designing are suggested.

Figure 7.3: Strategies to improve the recyclability

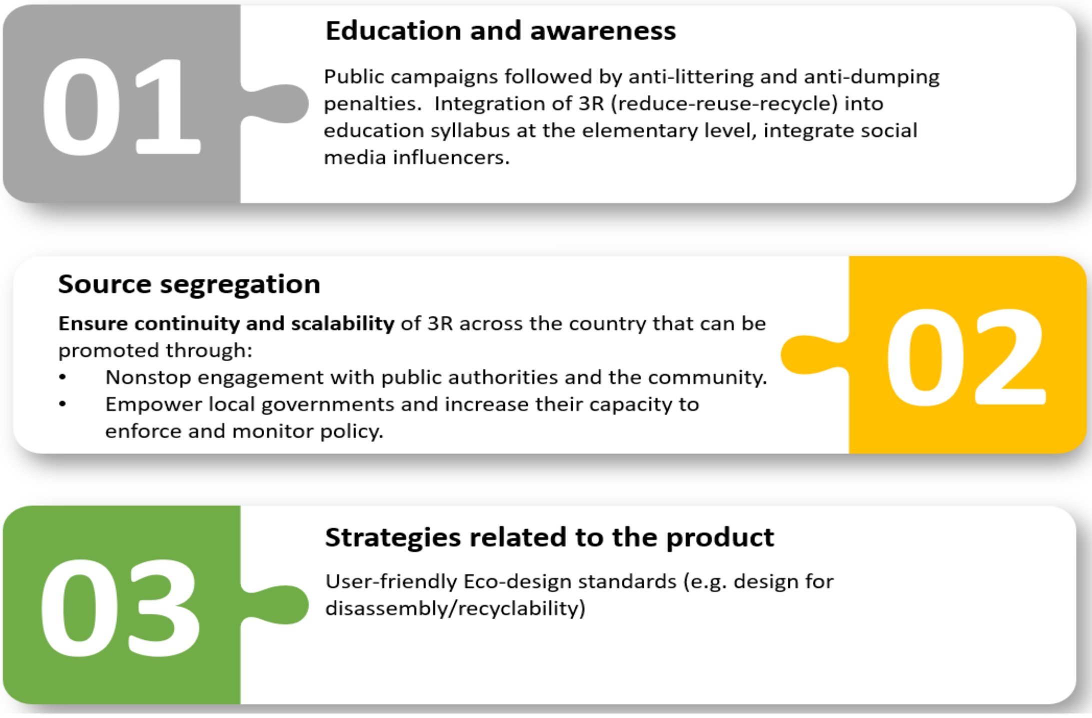


Table 7.1: Strategies to improve the recyclability of waste generation

Strategy	Description
Education and awareness	Public campaigns followed by anti-littering and anti-dumping penalties. Integration of 3R (reduce-reuse-recycle) into education syllabus at the elementary level, integrate social media influencers.
Source segregation	**Ensure continuity and scalability** of 3R across the country that can be promoted through: • Nonstop engagement with public authorities and the community. • Empower local governments and increase their capacity to enforce and monitor policy. A collective measure across the value chain while investing in recycling infrastructure and proper disposal of non-recyclable waste.
Strategies related to the product	User-friendly Eco-design standards (e.g., design for disassembly/recyclability)

2. Plastic Waste Collection

Recap of Findings:

a) Plastic waste collection for recycling relies mostly on the informal sector whereas formal collection is mostly underfunded and doesn't offer a unified solution.

b) Plastic waste collection for recycling is mainly limited to high-value plastics.

The study discovered that the informal sector is dominant in the collection of recyclable plastic waste in Bangladesh where waste management companies typically do not sort waste at source or transfer points but rather dispose of solid waste at the landfill. The predominance of the informal sector actors in the existing value chain limits the collection of recyclable waste in dense urban areas and is mainly limited to high-value plastics such as PET or HDPE bottles.

The informal sector is dominant in many countries. They focus on enhancing the work environment and increasing access to waste (with higher capacity & better prices). For example, in Brazil, a well-established cooperative union of independent waste pickers grants the "right to waste". This well-established cooperative union allows them to accumulate more volume directly from waste generation sources. Additionally, these cooperatives also issue and sell "reverse logistics credits" in order to guarantee that services have been delivered for the accountable dumping of waste and hence offer a means for businesses to accomplish their respective responsibilities under the National Solid Waste Policy. Such initiatives help to make informal sector waste collectors highly encouraged to amass low-value waste material increasing income for them. In addition, the implementation of producer responsibility laws facilitates the integration and deployment of skills in the informal sector. One such useful model for such initiatives would be Bangladesh's Waste Concern which establishes networks of informal sectors waste pickers, and composting plants providing training to waste pickers and processors in organic waste recycling, creating jobs for waste pickers and boosting their earnings.

Increasing the collection rate of recyclable plastic waste could incorporate measures to improve the formal collection, leverage the informal sector, and incentives to encourage proper disposal and collection for recycling in broader perspectives (Figure 7.4 & Table 7.2).

Figure 7.4: Strategies for the Collection of Recyclable Plastic Waste

Table 7.2: Strategies for the Collection of Recyclable Plastic Waste

Strategies	Description
Formal collection	• Increase user fee collection (flat monthly fee, fee-based on collection frequencies, or by weight & volume) • Privatize waste collection service across cities through an open tender process maintaining transparency • Set up the right collection points and recovery facilities at the community level that has clear sorting facilities • Informal sector integration considers outsourcing of collection work to waste picker cooperatives for reducing cost with efficiency optimization.
Informal collection (waste picker segment)	• Legitimize the profession of waste pickers by providing occupational identity cards, clarifying 'right-to-waste', etc. • Establish waste picker cooperatives, microenterprises, collectives, or foundations to increase revenue and bargaining power along with human rights support. • Talent hunt and development by providing required training and technical support on better collection, sorting, value addition, responsible waste handling, etc.
Incentives for product return (for producer/consumers)	• Deposit return schemes (e.g., reverse vending machines) can be incorporated into the western world. • Producers take-back responsibilities such as extended producer responsibility laws (EPR)

3. Processing (Recyclers)

Recap of Findings:

a) Formal: High market entry cost, demand-supply gaps, barriers to securing the high-quality supply of feedstock, high operational cost.

b) Informal: Low efficiency because of substandard crude technology, environmentally polluting mostly.

In Bangladesh, the formal recyclers are on an uneven playing field with an absence of access to dependable market information (existing companies, product types, customers), face high compliance costs. Additionally, they have limited access to superior-quality feedstock (have to rely on musclemen, personal connections to get feedstock). Although informal recyclers have been operating their business for many years, they are highly polluting. They do not offer innovative solutions and modern technology to handle plastic waste. Furthermore, most of the actors in this sector are price takers in the overall plastics market in Bangladesh. As a consequence, they have to compete with low and volatile virgin plastics prices.

The recommended solution in this section is to emphasize "democratizing" the market to invite new entrants and inspire innovation by ensuring the implementation of proper waste and aquatic treatment infrastructure.

Figure 7.5: Strategies to increase the viability of Plastics Recyclers

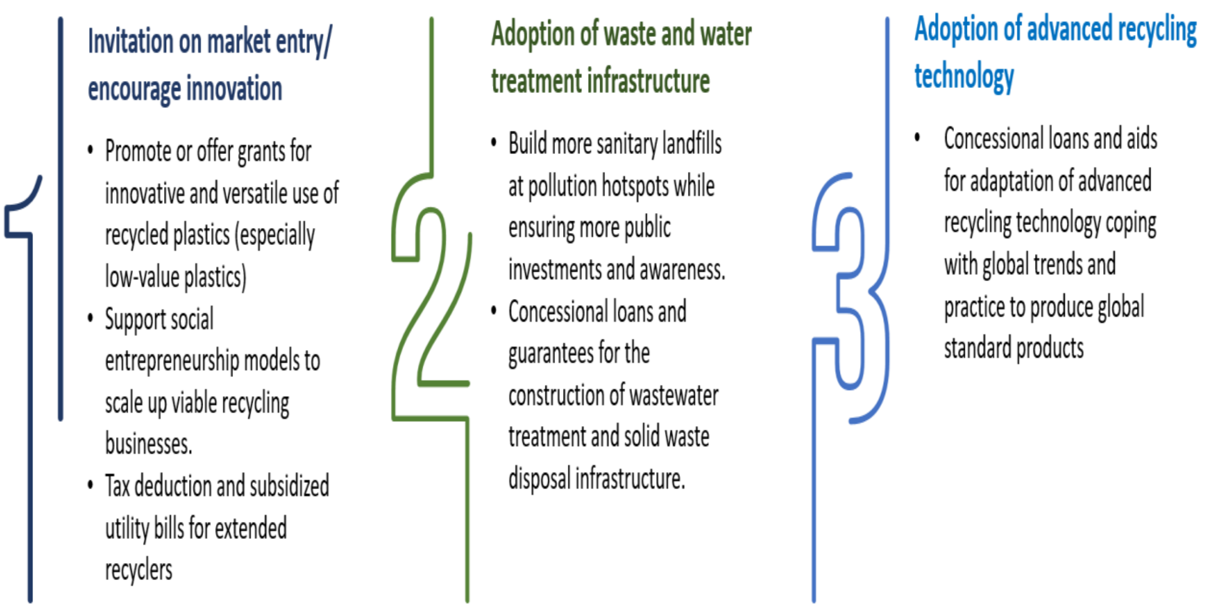


Table 7.3: Strategies to increase the viability of Plastics Recyclers

Strategies	Description
Invitation on market entry/ encourage innovation	• Promote or offer grants for innovative and versatile use of recycled plastics (especially low-value plastics) • Support social entrepreneurship models to scale up viable recycling businesses. • Tax deduction and subsidized utility bills for extended recyclers
Adoption of waste and water treatment infrastructure	• Build more sanitary landfills at pollution hotspots while ensuring more public investments and awareness. • Concessional loans and guarantees for the construction of wastewater treatment and solid waste disposal infrastructure.
Adoption of advanced recycling technology	• Concessional loans and aids for adaptation of advanced recycling technology coping with global trends and practice to produce global standard products.

4.Offtake

Recap of Findings:

a) Purchasers lack an adequate supply of cost-effective and superior-quality post-consumer resin

b) Lack of access and transparency owing to limiting the export potential of recycled plastics products

c) Concerns over the superior-quality of recycled plastics weaken demand

The study found that the prevailing recycled plastics market in Bangladesh is constrained by a lack of adequate information and access to an open market of recycled plastics buyers. Additionally, there is also high volatility in the availability and standard-quality of recycled plastics which leads to a ‘reputational deficit’ for recycled plastics products, henceforth hindering plastic product manufacturers from switching to recycled plastics. Market transparency, information, and knowledge-sharing strategies will help to democratize the market for recycled plastics.

Therefore, the suggested solutions in this segment are to

- increase transparency of information on buyers, sellers, and products in the market.
- encourage switching to recycled plastics by providing market incentives
- stimulate demand through education and awareness campaigns

- impose policies and standards to assure quality
- stimulate demand for recycled plastics (Table 7.4).

Figure 7.6: Strategies to improve offtake of recyclable plastic wastes

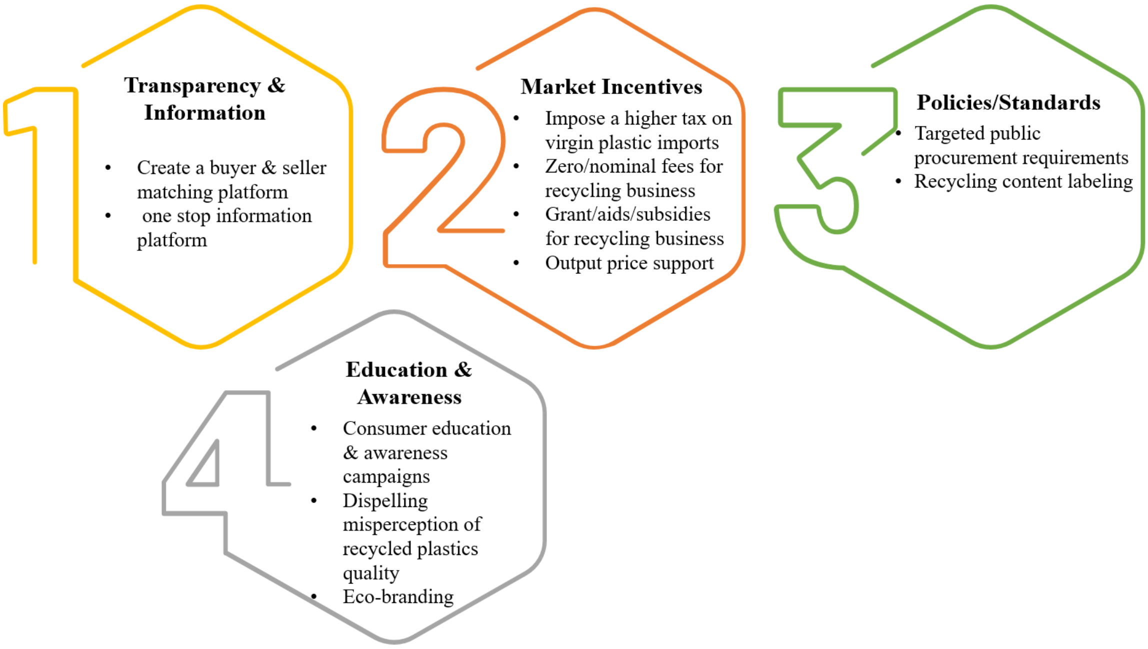


Table 7.4: Strategies to Improve Offtake of Recyclable Plastics Waste

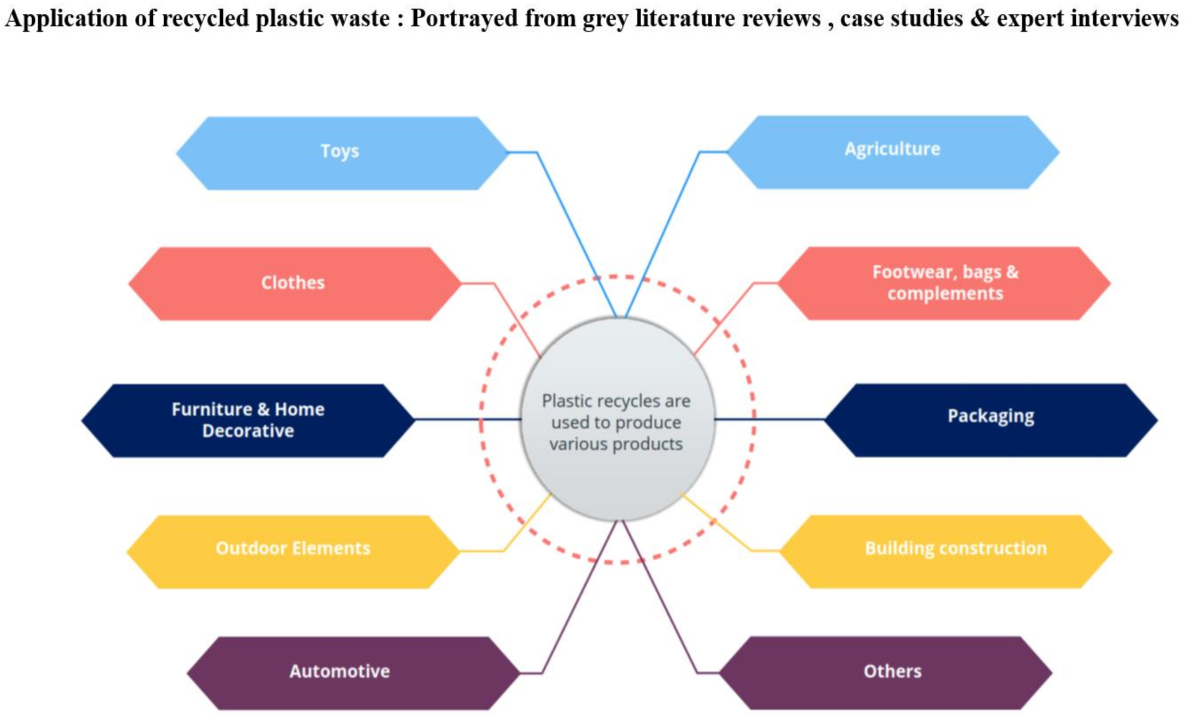
Strategy	Description
Transparency and information	• Create and establish a solid platform to match buyers and sellers. • Create and establish a one-stop information portal on policies and regulations related to plastic waste and scrap, and plastic recycling businesses.
Market incentives	• Impose comparatively higher taxes on the use of virgin plastics over recycled plastics or differentiated value-added taxes for recycled plastics or plastic products. • Zero or nominal fees for recycling business permit applications as well as running a recycling business. • Grants/aids/subsidies to reduce the legal cost of starting a recycling business, and fulfilling Environmental Impact Assessments along with the undue interference of the musclemen. • Output-price support such as minimum revenue contracts for recyclers to inspire investment in processing technology.
Policy/standards	Introduction of recycled content standards ▪ Targeted public procurement requirements ▪ Recycled content labeling
Education and awareness to stimulate demand	• Consumer education and awareness campaigns, emphasizing the environmental benefits of recycled plastics • Dispelling misperception of quality of recycled plastics (particular for non-food grade items) • Eco-branding: Products using recycled material to be branded as 'green or eco' instead of 'recycled content' which may have a more negative connotation

The study has found that numerous value-added products can be made from recycled waste plastics some of which have listed below as applicable to Bangladesh:

Table 7.5: Application & features of Plastic Recycles

	Recycled granules	Waste Bin/Pole	Plastic Pipe, Construction net, Pavement block	Polyester Yarn, padding, PET Flakes	Plastic Block	Plastic Lumber
Features	Lightweight	Light weight, easy to move and handle, washable, cheaper, long-lasting, can be used in the park, street curbside etc.	Quality as similar to the pipe made from virgin raw materials but the price is cheaper, and can widely be used construction and agriculture sector	Environment friendly, energy consumption, reduces the production cost	Required no glues lightweight, cheaper, energy-saving, thermal insulation, can be processed with all types of plastic waste	Weather resistance, cheaper, replace wood, can be easily used as park a bench, restaurant table-chair, and other user-friendly furniture making
Target Market	Secondary market, Industries	Municipalities/Government/Individuals/communities	Individuals, industries, government	Textile, comforter, garments industry, Pet Bottlers, etc.	Municipalities/Government, Industries, Individuals	Individual, Furniture and design industry

Figure 7.7: Application of Recycled Plastic Waste



7.2.2 Enabling Conditions

Considering fundamental initiatives and investments to develop a feasible plastic waste recycling industry in Bangladesh, the followings are three important considerations:

A) Financing

B) Available innovative technology &expertise and

C) Policy and regulatory environment.

A. Financial Aspect

Considering the financial aspect to develop a feasible plastic recycling industry in Bangladesh, the development of a functional, integrated waste management system is deeply intertwined.

To improve the cost structure for the recycling sector by increasing access to high-quality feedstock, and reducing the cost of processing proper funding is imperative. Funding mechanisms are necessary to enhance the incentive structure of the plastic recycling value chain. To exemplify, the imposition of Extended Producer Responsibility Laws that impose producer fees affects the waste management cost for problematic multi-layer packaging. User collection fees change consumers' behavior in waste generation and sorting at the source.

The below table and figure show various financing options for plastic management and recycling, and key insights from the literature and interviews conducted.

Figure 7.8: Sources of Capital

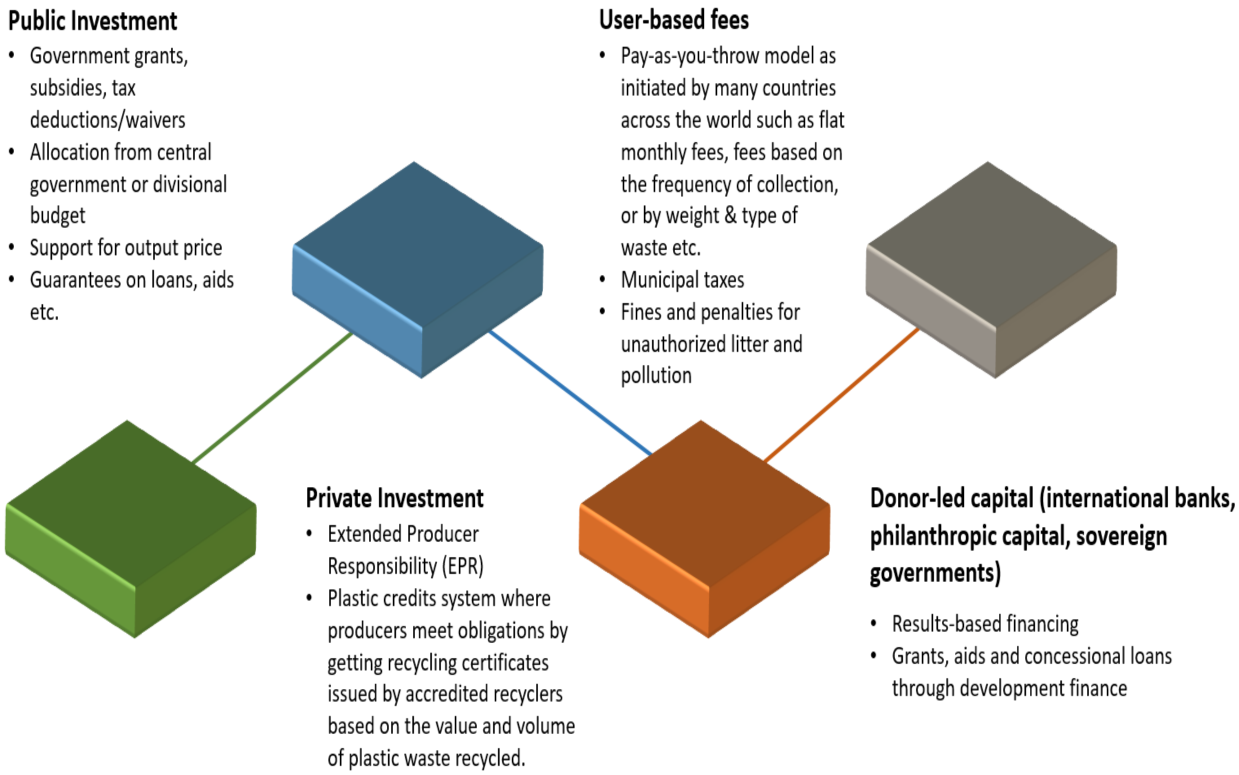


Table 7.6: Sources of Capital

Source of Capital	Examples
Public Investment	• Government grants, subsidies, tax deductions/waivers • Allocation from central government or divisional budget • Support for output price • Guarantees on loans, aids etc.
Private Investment	• Extended Producer Responsibility (EPR) • Plastic credits system where producers meet obligations by getting recycling certificates issued by accredited recyclers based on the value and volume of plastic waste recycled.
User-based fees	• Pay-as-you-throw model as initiated by many countries across the world such as flat monthly fees, fees based on the frequency of collection, or by weight & type of waste, etc. • Municipal taxes. • Fines and penalties for unauthorized litter and pollution
Donor-led capital (international banks, philanthropic capital, sovereign governments)	• Results-based financing • Grants, aids, and concessional loans through development finance

In Bangladesh, funding for several projects centered on green growth (e.g., 3R Project) comes from international donors, and those external funding may reduce government incentives to ensure continuity in pilot projects funded by donors. Hence, the successful implementation of such projects is critical while engaging the public sector in regard to obtaining both monetary and political buy-in.

B. Technological Aspect

Investments in upgrading plastic recycling technologies can increase material recovery rates, increase the recycling capacity of low-value plastics (e.g., multi-layered flexible/mixed/contaminated plastics), and increase recycling process efficiency (i.e., increase water and energy efficiency).

In Bangladesh, modern and innovative technological adoption in the plastic recycling sector is at a low grade of advancement where waste management, sorting, and reprocessing rely predominantly on manual labor from the informal sector that collects, sort, and transport recyclable feedstock down the value chain. In terms of recycling, all recyclers apply conventional mechanical recycling technology, as opposed to chemical recycling able to break down more complex, hard-to-recycle plastics and low-value plastics into basic polymers. Considering this, long-term investments into more advanced recycling and information technology can unlock additional prospects and possibilities to re-process more complex materials and thus would increase efficiency and coordination among various actors involved in the whole value chain.

In terms of discovering the economic value of investing in various technologies is beyond the scope of this paper. Yet, Bangladesh may get the advantage from increasing acceptance of digital waste management, which taps into tracking waste flows, refining knowledge sharing as a tool to raise public awareness in the medium term, In the long-term perspective, investments into more advanced and innovative technologies such as optical sorting, metal detector, NIR, baling, de-polymerization, pyrolysis, etc. can unlock the ultimate potential to recycle more complex plastic waste flows.

C. Policy and Regulatory Backup

Stakeholders

In Bangladesh, the master plan development for a viable recycled plastics industry could fall under the domain of four main ministries: 1) Ministry of Environment 2) Ministry of Industry and Trade 3) Ministry of Health 4) Ministry of Economic &Finance, and Ministry of Local Government.

Encompassing both its economic and environmental considerations is summarized in the below table considering the related functions of these ministries to the development of a viable recycled plastic sector. Henceforth, periodic cross-agency dialogues should be conducted between these ministries and other related ministries in the growth and development of a recycled plastics market.

Table 7.7: Support function of different Ministries

Function	Relevant Ministries
Planning, goal-setting, communication, and implementation of the roadmap	Ministry of Planning Ministry of Finance
Fiscal incentives to develop market	Ministry of Commerce & Ministry of Industry
Ensuring effective management of residual waste, mitigation of environmental and health risks	Ministry of local government, Ministry of Environment & Forest and Ministry of Health & Family welfare

Implementation and enforcement support must be complemented by local and municipal agencies, waste management companies, BPGMEA that play key roles such as monitoring quality, managing, and implementing plastic waste management policies pursuant to rules and regulations issued by relevant ministries for establishing a viable recycling market.

7.2.3 Policy Gaps and Possible Paths

The government has unveiled noteworthy attention while enacting various laws from a legislative perspective and coped with globally acceptable standards to promote the green revolution in Bangladesh. Despite this, there exist momentous gaps that deter the prospective development of a feasible plastic recycling market.

Amid policy gaps described in the literature reviews, open field interviews with the value chain actors and experts' interviews are lacking capacities to execute and monitor targets and lack access to data. The below table summarizes the prospect and opportunities to strengthen the policy and regulatory environment.

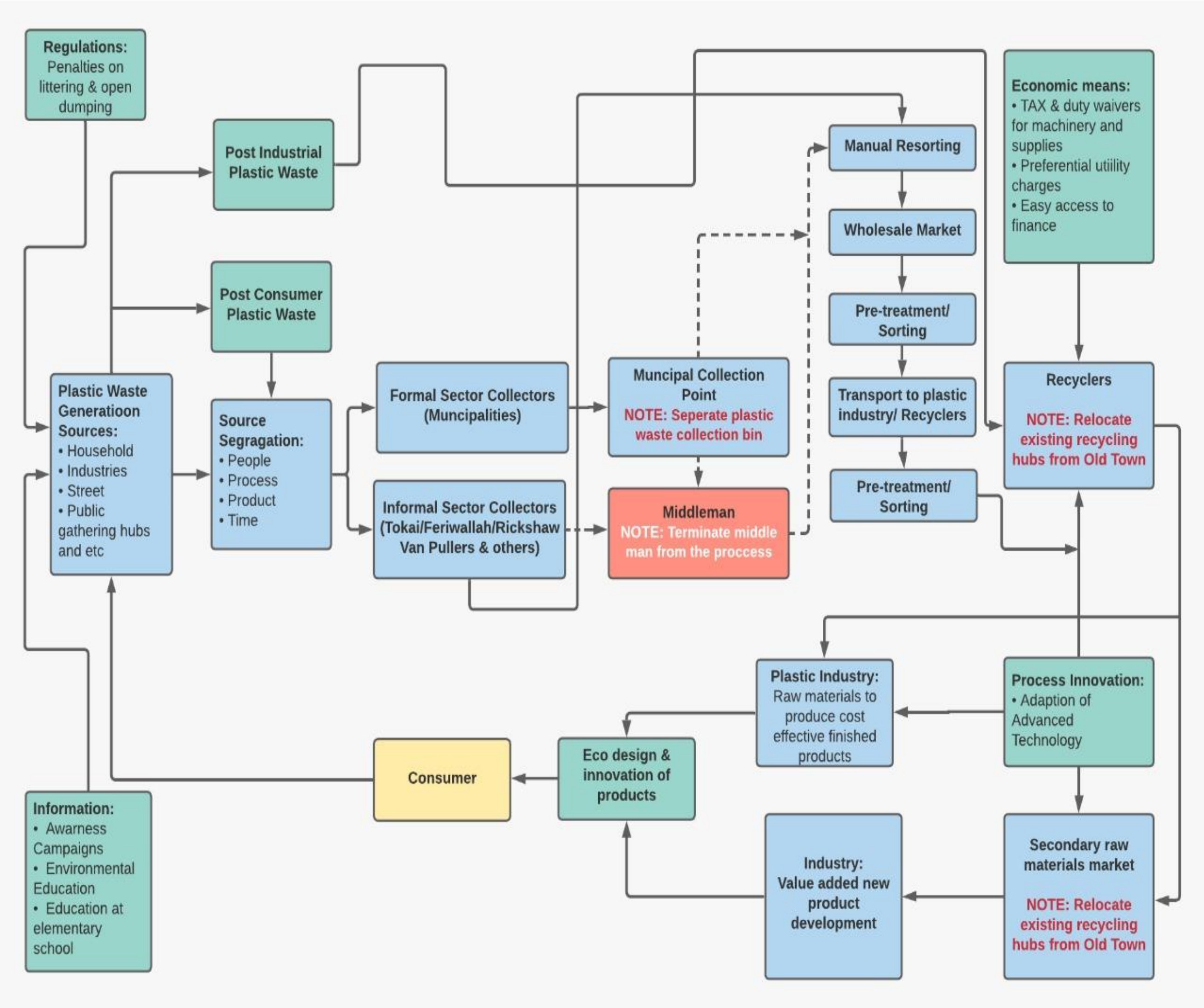
Figure 7.9: Potential Regulatory and Policy Pathways

Table 7.7: Potential Regulatory and Policy Pathways

Strategy	**Description**
Transparent and vigorous data-access	• Regular data collection, analysis, and evaluation of plastic and plastic waste.
legislation clarity	• Clarify clear definitions of plastic wastes by types. • A well-defined user-friendly and accessible platform with easier information on laws and policies related to plastic, plastic waste, and recycling.
Product standards	• Eco-products certification • Minimum recycled content • Circular design guidelines • Certification for use of recycled plastic in food/medical applications
Economic instruments	• Incentives and technical support for the recycling industry. • Duty and tax waiver for recycling companies. • Favorable utility charges.
Other	• Incentivize brand manufacturers to make long-term commitments to the use of recycled plastics. • Green public procurement. • Records for brand manufacturers addressing plastic waste issues.

Based on the findings from open-field interviews, case studies, literature reviews, and expert interviews, the following framework for viable and sustainable recycling industry in Bangladesh has developed by this study.

Figure 7.10: Proposed plastic recycling value chain framework for Bangladesh



7.3 Recommendations & Roadmap

Measures of Evaluation

Various recommended strategies presented above are evaluated considering two broad criteria to develop a roadmap for sustainable product strategies from plastic waste for Bangladesh.

Short and Mid-Term Roadmap

The study recommends three main precedence directed by the prior analysis, to be addressed for the short and medium-term roadmap to develop a feasible plastic waste recycling market in Bangladesh described below table:

Table 7.8: Short-term and midterm Roadmap

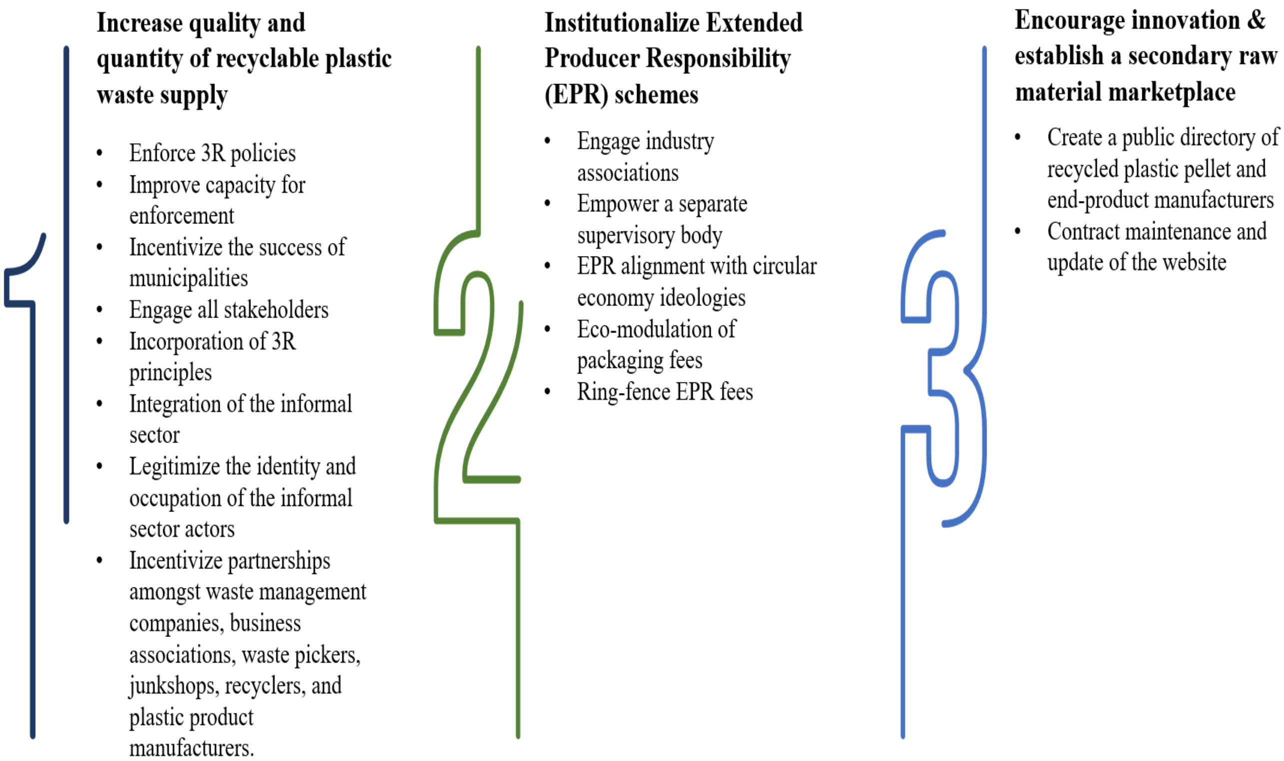
Precedence	Actions
Increase quality and quantity of recyclable plastic waste supply: Consumers, municipal authorities, waste management companies, business associations, and informal sector actors are the main stakeholders.	The main bottleneck for a steady supply of high-quality, accessible, recyclable plastic waste to a viable plastic recycling market. Hence, the below actions are recommended **Enforce 3R policies in the practical field** that have already been crafted at the state level. **Improve capacity for enforcement** across the country, by talent-hunt with capacity-building workshops engaging expert organizations. **Incentivize** the success of municipalities for the performance and continuity of waste management activities. **Engage** the private sector and civil society to perform extensive community engagement activities. **Incorporation of 3R** principles into the national education curriculum elementary level. **Integration of the informal sector** to improve the collection, sorting, and processing efficiency. **Legitimize** the identity and occupation of the informal sector actors through empowerment, and cooperative initiatives. **Incentivize** partnerships amongst waste management companies, business associations, waste pickers, junkshops, recyclers, and plastic product manufacturers. The above-mentioned actions must be spearheaded by the government with the association of municipalities and local governments as enforcement authorities and can be supported by the private sector bodies.

Precedence	Actions
Institutionalize Extended Producer Responsibility (EPR) schemes for plastic packaging to help fund investments in recycling infrastructure: Ministry of Environment, Ministry of Finance, Ministry of Commerce, and industry are the main stakeholders.	Though enacted by the law, the EPR scheme for plastic packaging, through voluntary private sector collaboration, has not yet been introduced and institutionalized through legislation in Bangladesh. Thus, a legislative framework for EPR schemes for plastic packaging must be institutionalized as Bangladesh has a window of opportunity for green growth. **Incorporate EPR into the legislated structure** with clear roles and responsibilities defined in legislation. **Engage** industry associations in defining the scope and charges contained within EPR in the Law of Environment. **Empower** a separate supervisory body to set up a transparent and robust public database covering comprehensive information to track quantities of packaged goods since manufacturers must pay according to quantities produced and distributed. **EPR alignment with circular economy ideologies**, incentivizing circular design such as design for reusability and recyclability. **Eco-modulation** of packaging fees, determined by recyclability and recycled content quantity. **Ring-fence EPR fees** to fund public investment in sanitary landfills, major recycling infrastructure, and program costs.

Precedence	Actions
Encourage innovation and establish a transparent secondary raw material marketplace by matching recyclers with business opportunities. Ministry of Industry and Trade, industry representatives (e.g. Chamber of Commerce), Bangladesh Plastics Goods Manufacturers and Exporters Association (BPGMEA) are the main stakeholders.	By improving supply-side conditions with economic viability, more recycling businesses will enter the market and scale. Because of the entrance of more players into the market, a transparent one-stop platform will be created to aggregate suppliers, manufacturers, and consumers that guide the innovation of recycled plastic products to transmit policies and regulatory changes with regard to the recycled plastics market. **Create a public directory** of recycled plastic pellet and end-product manufacturers, with information on products, and the contact information of various manufacturers and stakeholders. Contract maintenance and regular update of the website and database maintaining transparency.

Precedence	Actions
Institutionalize Extended Producer Responsibility (EPR) schemes for plastic packaging to help fund investments in recycling infrastructure: Ministry of Environment, Ministry of Finance, Ministry of Commerce, and industry are the main stakeholders.	Though enacted by the law, the EPR scheme for plastic packaging, through voluntary private sector collaboration, has not yet been introduced and institutionalized through legislation in Bangladesh. Thus, a legislative framework for EPR schemes for plastic packaging must be institutionalized as Bangladesh has a window of opportunity for green growth. **Incorporate EPR into the legislated structure** with clear roles and responsibilities defined in legislation. **Engage** industry associations in defining the scope and charges contained within EPR in the Law of Environment. **Empower** a separate supervisory body to set up a transparent and robust public database covering comprehensive information to track quantities of packaged goods since manufacturers must pay according to quantities produced and distributed. **EPR alignment with circular economy ideologies**, incentivizing circular design such as design for reusability and recyclability. **Eco-modulation** of packaging fees, determined by recyclability and recycled content quantity. **Ring-fence EPR fees** to fund public investment in sanitary landfills, major recycling infrastructure, and program costs.

Figure 7.11: Short and Medium-Term Roadmap



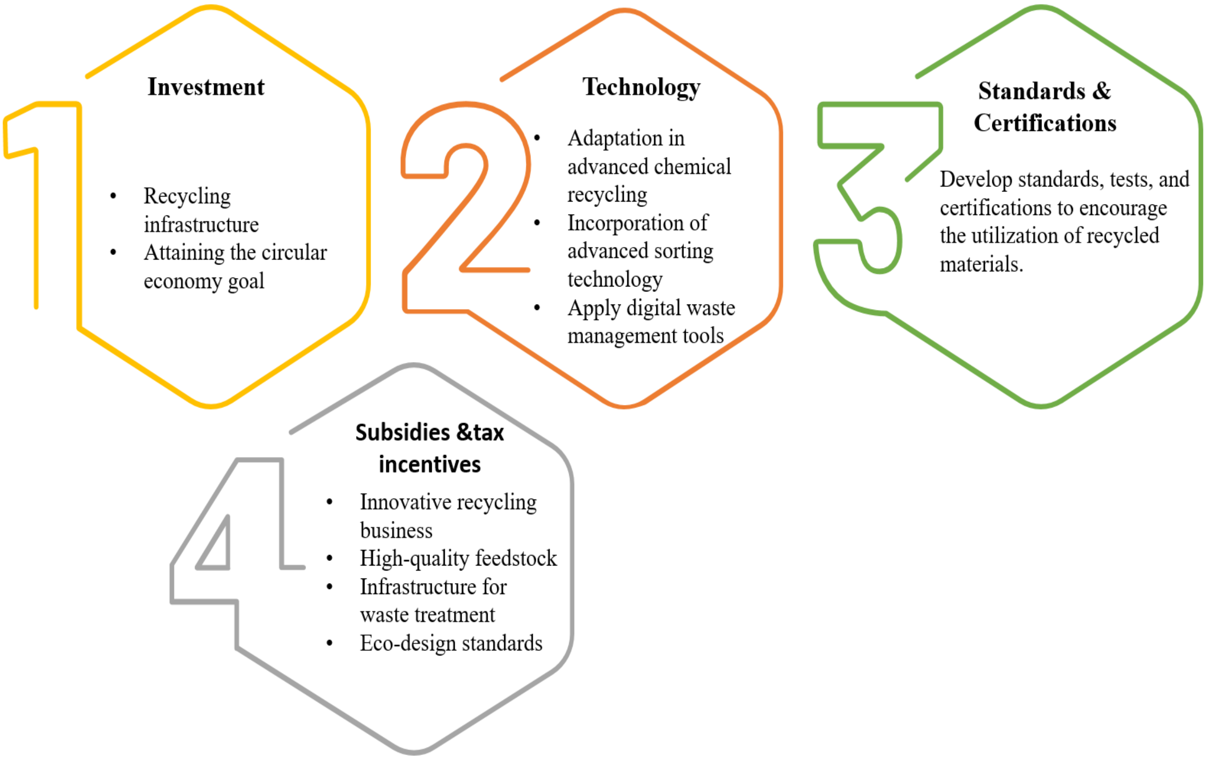
Long Term Measures

The three-precedence cited above will take place the direction for measures and investments on short-term and mid-term basis that have a higher impact and establishing a transparent market would aid modernization and investment in the plastic waste recycling sector, although there should have a long time to impact.

Considering longer-term measures, emphasis must be given to capacity where governments and businesses must consider investments to attain circular economy principles.

In terms of Technological aspects, progressions in chemical recycling and innovative sorting technologies (e.g., NIR, particle detector, optical sorting, etc.) will significantly increase recycling output while allowing the plastic waste recycling sector to be capable to reprocess more complex resources as well as mixed plastics. Additionally, digital plastic waste processing devices (devices that leverage the Internet of Things (IoT), and data analytics) are a “Future Possibility” for this industry. Modern digital plastic waste treatment technologies, devices, and tools, such as GPS-enabled tracking devices for vehicles or image recognition devices could be the remarkable options for improving collection and recycling rates.

Figure 7.12: Long-term measures



Apart from these, standards and certifications could also be helped as vital market-oriented techniques to increase the quality of recycling processes and recycled plastic products. The study has found that the Sustainable Packaging Coalition and How2Recycle programs in the US created and developed standard certification to inspire the use of recycled materials.

In the future, innovative recycling businesses could be accelerated by tax incentives and subsidies, especially when the building blocks are in place (i.e., superior feedstock, and strong waste treatment infrastructure). In this connection, tax incentives and subsidies could be outlined to inspire the implementation of eco-design standards and advanced recycling technology such as closed-loop recycling.

Chapter Summary

The supremacy of the informal sector actors, which mostly apply substandard technology along with a lack of adequate infrastructure and waste treatment methods, has yielded disadvantageous economic and environmental consequences. For example, in the Old Town's recycling hub (the main hub for plastics scrap collection, sorting, and recycling in Bangladesh), 30-35% of plastics wastes used to collect for recycling, and a million liters of wastewater from washing is discharged daily into open landfills, municipal's drains, and canals with inappropriate treatment. Hence, proper investments into reforming and assimilating the informal sector with the mainstream economy will not only increase environmental competence but also reduce waste leakage into the environment and largely augment economic gain. Henceforth, favorable rules and strategies for supporting this sector could ease regulatory pressure, while extinguishing economic losses and environmental risks. Beyond these, global trends toward acquiring anticipated sustainability and resource efficiency beckon an outstanding economic prospect to build a feasible plastics recycling sector. Based on above mentioned findings from interviews with value chain actors, expert interviews, and literature this chapter depicted strategies to build a feasible plastic recycling sector in Bangladesh where policymakers, researchers, students, industry experts, social activists, donors, and businesses are the intended audiences.

CHAPTER 8: BENCHMARKING, CONTRIBUTIONS, LIMITATIONS & CONCLUSION

CHAPTER CONTENTS

This chapter provides benchmarking, contribution, limitations, conclusion, and scope for the future researchers

8.0 BENCHMARKING, CONTRIBUTIONS, LIMITATIONS & CONCLUSION

8.1 Benchmarking the factors explicit to prior research and the outcomes of this study

The contemporary studies on the Recycling of Plastic Waste and its Sustainable Product Strategy for Bangladesh are insufficient. Besides this, the contemporary studies gave conflicting or inconclusive results to some extent. The below table displays the benchmarking of the aspects explicit to the study outcomes and previous studies on plastic waste recycling.

Table 8.1: Benchmarking the factors explicit to prior research and the outcomes of this study

Factors	**Prior Research Insights**	**Study Outcomes**
The transition from the prevailing linear to the circular economy	Highlighted in a few studies but was not reflected in the number of studies covering each value chain stage.	The study covered each value chain stage and suggested rethinking the design, manufacture, and use of recycled plastic products from a circular economy notion.
Plastic Recycling Value Chain	Current policy and research have mainly focused on end-of-life neglecting the other important phases of the value chain.	The study has emphasized the entire value chain and developed a feasible solution on how the value chain phases may impact end-of-life possibilities for reuse, recycling, and reproduction.
Minimizing Knowledge Gap	Limited attention has been given to opportunities for the	To minimize the knowledge gap on plastic and plastic waste

	prevention of plastic waste, redesign, and new product development despite the fact that these aspects are often regarded as the most desirable in the circular-economy notion.	recycling the study has found policy gaps and recommended feasible solutions regarding waste prevention, redesign, and new product development.
Legislation	Except for a few studies, most of the studies have given attention to the end-of-life phase (e.g., waste management legislation) and paid little attention to the other phases.	The study has focused equal attention in all stages of the value chain which has been elaborately described in the previous chapters.
Circular Business Model	Most of the studies have focused (except a few) on plastic recycling, leaving out other aspects of the circular plastic economy.	The study strongly emphasized the Circular Business Model. The case study methods and expert interviews have helped discover sustainable product strategy on a circular economy principle.
Sustainable Product Strategy	Prior studies have mainly focused on recycling and reducing the amount of plastic consumed, ignoring the strategy formulation of making sustainable products from recycled plastic.	Strong attention has been given to all aspects such as recycling, reducing, reusing as well as sustainable product strategy in this study as depicted in the earlier chapters.

8.2 Contributions of the Study

The circular plastic economy has gained huge attention all over the world, but there is still an imbalance in the number of studies that address challenges and opportunities. The most commonly identified challenges are the contaminated plastic waste and composite polymers/materials in various plastic goods and packing and the absence of a holistic approach across the value chain. The study discovered that the specific problems are triggered by systems and behavior in other phases of the value chain, such as composite product design or scarce sorting of plastic waste, possibly yielding adulteration in the process of plastic waste recycling. Considering these challenges, proposed solutions towards circularity could be design-integration for recycling, the inclusion of recycled materials in the production process, demand augmentation for recyclable materials, and raising fruitful investment in the development of recycling technologies and infrastructure along with the establishment of the technology systems that assimilate mechanical and chemical recycling technologies. The above-mentioned solutions could meaningfully contribute to the transition towards a circular economy from the prevailing linear economy by keeping plastic resources within the controlled consumption and production system. However, this conversion will not likely to be materialized without continuous Research and Development. Further research in every stage and a holistic collaboration across the value chain could be attained through suitable mapping the implications, identifying the root causes where these occur in the value chain, and sponsoring stakeholders' involvement and collaboration.

A set of specific impacts in this study has been defined that will be indispensable to assure the achievement, exclusivity, and urgency of the study rationale. In this connection, the indicators would have been developed to measure both the impact and contribution of the study for various stakeholders.

Table 8.2: Contributions of the study

Contribution	Indicators	Stakeholders
Improvement of the current state of the plastic recycling value chain	The emergence of New Companies/New Job creation. Actors involved in the Informal sectors who now work individually and in unsafe conditions can be drawn into the mainstream economy	Waste pickers/Dealers/ Traders/Brokers Plastic producers /converters, waste managers equipment firms, consumers, public bodies
Advancement of plastic packaging recovery	Reduction of landfilled and incinerated waste / Reduction of associated adverse environmental impact	Local administration, plastic manufacturers, plastic converters, citizens
Improved plastic waste quality	Separation of plastic waste into the optimal fractions to be subsequently recovered (PET, rigid PE, PE film, rigid PP, PP film, and plastic mixes). The volume of quality materials achieved through the process will be used as an indicator	Plastic producers /converters, waste managers equipment firms, consumers
Production optimization of recycled goods	Sorts and typologies of secondary products developed from recycled plastic	Recycling firms and manufacturers
Encourage recovery over plastic landfilling and incineration	Alignment with the waste hierarchy established in the Waste Framework	Waste managers, consumers/citizens, public administration representatives
Creation of new business opportunities in plastic sector	Increased number of manufactured eco-innovative solutions	Producers, converters, waste management, equipment, software, etc.
New Product Strategy	Creation of new and sustainable products	Researchers, academics, businessmen
Economic gain and environmental sustainability	Will create a new gateway to excel in positive social impact	Waste managers, consumers/citizens, public administration representatives
Knowledge enhancement on plastic recycling	New research on plastic reprocessing, new business idea generation	Practitioners, policymakers, commoners, and academics
Impact on Tourism	Tourists come to see enjoyable places and a healthy environment and hence will attract new tourists.	Actors involved in the tourism sectors
Impact on Health	People can eat, breathe and live in a healthy environment to have a high life expectancy rate.	All the countrymen live in Bangladesh

This study attempts to inspire plastic recycling by giving an overview of the surplus plastic waste of Bangladesh: what is in the millions of tons of plastic waste that is brought daily to scrap shops and recyclers? Where does it end up? And, especially, what can be done with it? This study will be interesting for state authorities, policymakers, municipalities, circular economy entrepreneurs, businesses, researchers, and students as empirical, practical, and methodological contributions.

Empirical contribution

Researchers and scholars may get new avenues for the next step of plastic waste recycling research which ultimately may expedite the research atmosphere. Through this study, novice and seasoned researchers will innovate new and unique uses for plastic recycling.

Practical contributions

In case of practical contributions, this study will be helpful to the business fraternity, and circular economy entrepreneurs for pragmatic business growth, the government may formulate policy, and business associations may streamline the functions of plastic recycling to reach up-to-the-mark product manufacturing.

Methodological contributions

This study mainly pinpointed the case study which is unique in the context of plastic recycling in Bangladesh. Here mainly this case study method explored the insights of plastic recycling functions and its potential for strategy formulations. In addition, the study attempted to investigate the actors involved in the existing recycling process deeply in Bangladesh. Henceforth, the study is indicative and provides an opportunity for concerned stakeholders to formulate strategies in this field.

8.3 Limitations

1. The Open-field interviews of the study mainly cover Dhaka Metropolitan City, although there are a few references to the recycling activities in another part of the country.
2. Considering the scope, this particular study is focused on residential, commercial, and industrial waste, not on hazardous, or medical waste.

3. The study is limited to Dhaka Metropolitan City as the yearlong field visit were exploratory.
4. This is a descriptive report, and not exhaustive that aim to deliver an overall understanding of the plastic recycling sector of Bangladesh with recommendation for a viable plastic waste recycling industry in Bangladesh.
5. In Bangladesh, plastic waste recycling value chain actors are often found in the bottom layer of society and are considered embarrassing and shameful in Bangladesh. As waste collection and processing are mainly done informally, the real number of waste pickers, processors, waste types, and incomes may be higher or lower than what is mirrored in this study.
6. During the open-field interviews, waste pickers, traders and recyclers were mostly unwilling to answer on data, accounts, and recycling treatment that causes fear of rivalry, loss of income, and harassment that one would likely face many issues like pollution or else.
7. This study has not considered the value chain of organic waste.

8.4 Conclusion

The study pens the epilogue to this report, in such an unprecedented crisis of seismic extents where the world has plunged through COVID-19 pandemic consequence with the existing Russia-Ukraine geopolitical unrest, and leading businesses moving towards an ambiguous destiny. As a consequence, economic activity is getting slowed down by the issues like behavioral and mental shifts that happen throughout the crisis and have direct or indirect implications on businessmen, policymakers, state authorities, households, and individuals. Despite all these uncertainties, there is hope for the plastic recycling sector in Bangladesh since oil price has been increasing exponentially which rises the appeal of recycled plastics, which prevails in this ever-increasing contemporary world.

The study found that the informal sector plays a prominent role in the plastic waste recycling value chain where the plastic waste recycling industry is mainly supported by informal waste pickers, informal waste traders, and re-processors that possess heterogeneous income. Since the informal sector has been in the plastic recycling value chain with its own initiatives and arrangements, they do have lots of limitations such as lack of funds, space, infrastructures, applicable technology & preferential utility supplies, etc. the sector is not growing or establishing coping with the global trend and eventually yielding substandard secondary raw materials and finished goods as well.

It has been observed that a vibrant plastic recycling industry already exists in Bangladesh and it needs to scale up and increase its effectiveness from the socio-economic and environmental standpoints. In consideration of the prevailing situations, the recyclers must work very closely with the value chain actors at all stages to discard the technical, psychological, economic, and environmental obstacles. If government stimulus reaches this neglected informal group, this sector will be established like other potential sectors; otherwise, it will be struggling to survive. Since there is a demand for recycled plastic waste, the informal sector has the opportunity to grow if jobless people adopt waste-picking as a means of their respective existence. This highly potential sector could likely be crumpled, if waste pickers, junkshops, and small recyclers are not reckoned as indispensable services and operations. Therefore, state authorities need to develop favorable frameworks with efficient implementation endeavors for this promising industry to flourish, inspiring eco-design, source-separated collection, and the inclusion of recycled plastic granules/flakes/resin/pellets as secondary raw materials in product manufacturing as well as producing value-added new products from those. Lastly, striking pressure from civil society and consumers pushes brand manufacturers to increase recycled plastic contents in their respective packaging applications since manufacturing companies are concerned about losing market share where citizen movement, engagement, and awareness regarding environmental issues are sufficient to force product manufacturers to act accordingly.

Lastly, renowned companies that have sound financial strength, the ability to absorb shocks, and the ability to adopt contemporary digital technology & tools should adopt this opportunity to develop or create products and thus reach and connect with consumers from a circular economy perspective that enables to establish a viable and sustainable plastic recycling industry in Bangladesh.

8.4.1 Scope for future Researchers

The world is moving towards a linear to a circular economy. This transition will not happen without further research in each phase and collaboration across the value chain, to prevent implications both within each phase, and also affecting other phases. This study calls for additional research into design, pure waste streams, processing, new product strategy and modified consumer behavior. Future research should take a holistic approach to the transition to circular. This can be done by mapping of the implications, identifying where in the value chain these occur, and promoting stakeholder involvement and collaboration.

1. Medical waste recycling process in Bangladesh
2. Potential upcoming researcher may enhance their research on a single polymer-waste like only PET waste, LDP waste, HDPE waste PP waste, mixed-plastic waste, and so on.
3. Some researchers may carry on research based on plastic-rubber waste composite recycling.
4. This study mainly focuses on mechanical recycling of plastic waste but future researchers may handle research on chemical recycling.

References

Adrian Merrington, "Plastic Recycling," Management, Recycling and Reuse of Waste Composites, 2010, 2011, https://wwwsciencedirect com.ezpprod1.hul.harvard.edu/topics/engineering/plastic-recycling.

Agenda, I. (2016, January). The new plastics economy rethinking the future of plastics. In The World Economic Forum: Geneva, Switzerland (Vol. 36).

Akter, N., & Hossain, M. I. (2016) Investigating the nature of plastic recycling supply chain: Bangladesh perspective. Du journal of marketing, 1.

Alexy, P., Anklam, E., Emans, T., Furfari, A., Galgani, F., Hanke, G., ... & Sokull Kluettgen, B. (2020). Managing the analytical challenges related to micro-and nano plastics in the environment and food: filling the knowledge gaps. Food Additives & Contaminants: Part A, 37(1), 1-10.

Alstrup, Thomas (2012): Materials flow and Stakeholders in Danish Plastic Industry. European Union

American Chemistry Council (ACC). Chemistry and Sustainability. https://www.americanchemistry.com/chemistry-in-america/chemistry-sustainability

ARA office, Wienna, February 2011. (www.ara.at)

ARA System (2011): Power Point Presentation and personal information received at meeting,

ASTM Plastics Committee Releases Major Revisions to Resin Identification Code (RIC) Standard | Www.Astm.Org, https://wwwastmorg.ezpprod1.hul.harvard.edu/newsroom/astm plastics-committee-releases-major-revisions resin identification-code-ric-standard.NetPlusMaterials - Bureo," n.d., https://bureo.co/pages/bureo-collection. https://www.greentoys.com/pages/our-story

Avolio, R., Spina, F., Gentile, G., Cocca, M., Avella, M., Carfagna, C., ... & Errico, M. E. (2019). Recycling polyethylene-rich plastic waste from landfill reclamation: Toward an enhanced landfill-mining approach. Polymers, 11(2), 208.

BCC Publishing, 2022. Plastics Recycling: Global Markets. May 2022. PlS031D. BCC Publishing.

BCC (2022) The global market for recycled plastics is expected to grow from $28.7 billion in 2022 to $37.3 billion by 2027 with a compound annual growth rate (CAGR) of 5.3% for the period of 2022-2027. BCC Publishing

Becker, L. (2018). Methodological proposals for the study of consumer experience. Qualitative Market Research: An International Journal.

Benzies, K. M., Premji, S., Hayden, K. A., & Serrett, K. (2006). State-of-the-evidence reviews: advantages and challenges of including grey literature. Worldviews on Evidence-Based Nursing, 3(2), 55-61.

Bilitewski, B. (2011): Mechanical Treatment: Unit Processes, in: Christensen, T. H. (red.) (2011): Solid Waste Technology and Management, Vol. 2, Blackwell Publishing Inc.

Bishop, G., Styles, D., & Lens, P. N. (2020). Recycling of European plastic is a pathway for plastic debris in the ocean. Environment International, 142, 105893.

Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. Journal of industrial and production engineering, 33(5), 308-320.

Boesen, S., Bey, N., & Niero, M. (2019). Environmental sustainability of liquid food packaging: is there a gap between Danish consumers' perception and learnings from life cycle assessment? Journal of cleaner production, 210, 1193-1206.

British Plastic Federation (BPF). Plastic Recycling. https://www.bpf.co.uk/

Brouwer, M. T., van Velzen, E. U. T., Augustinus, A., Soethoudt, H., De Meester, S., & Ragaert, K. (2018). Predictive model for the Dutch post-consumer plastic packaging recycling system and implications for the circular economy. Waste management, 71, 62-85.

Bryman, A. (2008), Social Research Methods, (3rd ed.) Oxford: Oxford University Press.

Bucknall, D. G. (2020). Plastics as a materials system in a circular economy. Philosophical Transactions of the Royal Society A, 378(2176), 20190268.

Burgess, M., Holmes, H., Sharmina, M., & Shaver, M. P. (2021). The future of UK plastics recycling: one bin to rule them all. Resources, Conservation and Recycling, 164, 105191.

Burrell, G., & Morgan, G. (2017). Sociological paradigms and organizational analysis: Elements of the sociology of corporate life. Routledge.

Calleja, D. (2019). Why the “New Plastics Economy” must be a circular economy. Field Actions Science Reports. The journal of field actions, (Special Issue 19), 22-27.

Camilleri, M. A. (2020). European environment policy for the circular economy: Implications for business and industry stakeholders. Sustainable Development, 28(6), 1804-1812.

Christensen, T. (Ed.). (2011). Solid waste technology and management. John Wiley & Sons.

Civancik-Uslu, D., Puig, R., Voigt, S., Walter, D., & Fullana-i-Palmer, P. (2019). Improving the production chain with LCA and eco-design: application to cosmetic packaging. Resources, Conservation and Recycling, 151, 104475.

Clare Goldsberry, 2016. ByFusion promises to reduce plastic in the ocean by making building blocks. Plastics Today, August 15, 2016

Clare Goldsberry, 2020. "Solid Growth Projected for Recycled Plastics Market." Plastic today

Conservancy, O., & Alliance, T. F. S. (2019). Plastics Policy Playbook: Strategies for a Plastic-Free Ocean. Ocean Conservancy: Washington, DC, USA.

Cooper, D. R., & Schindler, P. S. (2014). Business Research Methods. © The McGraw− Hill Companies. *New York*.

COWI, 2013, Plastic ZERO - Assessment of Relevant Recycling Technologies, Aalborg University

Creswell, J. W. (2015). An Introduction to Mixed Methods Research. Thousand Oaks, CA: Sage. Social and Behavioral Sciences Research Consortium

Curtzwiler, G. W., Schweitzer, M., Li, Y., Jiang, S., & Vorst, K. L. (2019). Mixed post-consumer recycled polyolefins as a property tuning material for virgin polypropylene. Journal of Cleaner Production, 239, 117978.

Dahlbo, H., Poliakova, V., Mylläri, V., Sahimaa, O., & Anderson, R. (2018). Recycling potential of post-consumer plastic packaging waste in Finland. Waste management, 71, 52-61.

DeCarlo, M. (2018). Scientific inquiry in social work. Open Social Work Education.

Delta Membrane, (2020). Virgin plastic is the direct resin produced from a petrochemical feedstock, such as natural gas or crude oil. "Virgin Plastic or Recycled Plastic – What Is Best Suited for the Waterproof Membrane Industry? - Delta Membranes.

Dijkstra, H., van Beukering, P., Brouwer, R., 2020. Business models and sustainable plastic management: a systematic review of the literature. J. Clean. Prod. 258

Dunkle, M. N., Pijcke, P., Winniford, W. L., Ruitenbeek, M., & Bellos, G. (2021). Method development and evaluation of pyrolysis oils from mixed waste plastic by GC-VUV. Journal of Chromatography A, 1637, 461837.

Edge, J. B. (2017). Becoming a reflexive researcher: a developmental approach to research methodology AU-Attia, Mariam. Open Rev Educ Res, 4(1), 33-45.

Eisenhardt, K. M., & Graebner, M. E. (1989). Theory building from case study research. Academy of Management Review, 14(4), 532-550.

Enayetullah, I., Sinha, A. M. M., & Khan, S. S. A. (2005). Urban solid waste management scenario of Bangladesh: problems and prospects. Waste Concern.

Enayetullah, I., &Hashimi, Q. 2006. Community based solid waste management through public-private community partnerships: experience of waste concern in Bangladesh, 3 R Asia Conference, Tokyo, Japan

Eriksen, M. K., Christiansen, J. D., Daugaard, A. E., & Astrup, T. F. (2019). Closing the loop for PET, PE and PP waste from households: Influence of material properties and product design for plastic recycling. Waste management, 96, 75-85.

Eriksen, M. K., Pivnenko, K., Faraca, G., Boldrin, A., & Astrup, T. F. (2020). Dynamic material flow analysis of PET, PE, and PP flows in Europe: evaluation of the potential for circular economy. Environmental science & technology, 54(24), 16166-16175.

Eu commission. (2019). Annex to the communication from the commission to the European parliament, the European council, the council, the European economic and social committee and the committee of the regions the European green deal.EU

European Commission. (2020). Circular economy action plan. For a Cleaner and More Competitive Europe. EU

Faraca, G., & Astrup, T. (2019). Plastic waste from recycling centers: Characterisation and evaluation of plastic recyclability. Waste Management, 95, 388-398.

Farace, D. J., & Schöpfel, J. (2010). Grey literature in library and information studies. KG Saur.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. Qualitative inquiry, 12(2), 219-245.

Foschi, E., Zanni, S., & Bonoli, A. (2020). Combining eco-design and LCA as decision-making process to prevent plastics in packaging application. Sustainability, 12(22), 9738.

Frechtling, J., Sharp, J., & Sharp, L. (1998). User-Friendly Handbook for Mixed Method Evaluations. DIANE Publishing.

Fred N. Kerlinger (1986), Foundations of Behavioral Research, 3d ed. (New York: Holt, Rinehart & Winston, p. 279

Gall, M., Schweighuber, A., Buchberger, W., & W. Lang, R. (2020). Plastic bottle cap recycling—characterization of recyclates composition and opportunities for design for circularity. Sustainability, 12(24), 10378.

Gasde, J., Woidasky, J., Moesslein, J., & Lang-Koetz, C. (2020). Plastics recycling with tracer-based-sorting: Challenges of a potential radical technology. Sustainability, 13(1), 258.

Getor, R. Y., Mishra, N., & Ramudhin, A. (2020). The role of technological innovation in plastic production within a circular economy framework. Resources, Conservation and Recycling, 163, 105094.

Grand View Research (2022). "Plastic Market Size Worth $811.57 Billion By 2030 | CAGR: 3.7%," https://www.grandviewresearch.com/press-release/global-plastics-market-analysis

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.

Hahladakis, J. N., & Iacovidou, E. (2018). Closing the loop on plastic packaging materials: What is quality and how does it affect their circularity? Science of the Total Environment, 630, 1394-1400.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives presents in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. Journal of hazardous materials, 344, 179-199.

Hammersley, M. (1990), Reading Ethnographic Research: A Critical Guide, London: Longmans.

Hammersley, M. (1992), What is Wrong with Ethnography: Methodological Explanations, London: Rutledge. Lawrence Neuman, W. (2003), Research Methods: Qualitative and Quantitative Approaches (5th ed.), New York: Pearson Education, Inc.

Hawken, P ,2010. The Ecology of Commerce: A Declaration of Sustainability. NY: HarperCollins, 1993, pg. 210

Heron, J. (1996) Co-operative Inquiry: Research into the Human Condition. London: Sage.

Higgins, J. P., & Altman, D. G. (2008). Assessing risk of bias in included studies. Cochrane handbook for systematic reviews of interventions: Cochrane book series, 187-241.

Hopewell et al (2009), Harper (2006), Merrington (2011), Conceptos Plasticos website, UBQ materials website, Frost and Sullivan (2019), BCG (2019), Agilyx website, Recycling of Polymers: A Review (2014)

Horodytska, O., Cabanes, A., & Fullana, A. (2020). Non-intentionally added substances (NIAS) in recycled plastics. Chemosphere, 251, 126373.

Hossain, P. M. N. (2016). The Prospects and Challenges of Plastic Industries in Bangladesh. BPGMEA

Hundertmar, K. T., Mayer, M., McNelly, C., Simons, T. S., & Witte, C. How plastics waste recycling could transform the chemical Industry, 2018. McKinsey and Company.

Available online: https://www. McKinney. com/industries/chemicals/our-insights/how-plastics-waste-recycling-could-transform-the-chemical-industry (accessed on 14 November 2021).

Iacovidou, E., Velenturf, A. P., & Purnell, P. (2019). Quality of resources: a typology for supporting transitions towards resource efficiency using the single-use plastic bottle as an example. Science of the total environment, 647, 441-448.

Ijaz Hossain, 2019. International Experience and Strategies to Improve Plastic Recycling in Bangladesh. Souvenir of 14th Bangladesh International Plastic, Packaging and Printing Industrial Fair, 2019

IUT (IUT Ingenieurgemeinschaft Innovative Umwelttechnik GmbH) (2012): Personal communication. 2012.

Jabareen, Y. (2009). Building a conceptual framework: philosophy, definitions, and procedure. International journal of qualitative methods, 8(4), 49-62.

Janis McKenzie (2020), Grey Literature: What it is and how to find it, Library, Simon Fraser University, Canada

JICA- Japan International Cooperation Agency, (2005), the Study on Solid Waste Management in Dhaka City by Dhaka City Corporation

Johansen, M. R., Christensen, T. B., Ramos, T. M., & Syberg, K. (2022). A review of the plastic value chain from a circular economy perspective. Journal of Environmental Management, 302, 113975.

Kabir, M. H., Ismail, M., & Jashimuddin, M. (2013). Status of Solid Waste Recycling at Sholokbahar Ward in Chittagong, Bangladesh. Journal of Environmental Science and Natural Resources, 6(2), 7-11.

King, G., Keohane, R. O., & Verba, S. (2021). Designing social inquiry: Scientific inference in qualitative research. Princeton university press.

Klemeˇs, J.J., Fan, Y. van, Jiang, P., 2021. Plastics: friends or foes? The circularity and plastic waste footprint. Energy Sources, Part A Recovery, Util. Environ. Eff. 43 (13), 1549–1565.

Kowszyk, Y., & Maher, R. (2018). Case studies on Circular Economy models and integration of Sustainable Development Goals in business strategies in the EU and LAC. EU-LAC Foundation.

Kranzinger L, Pomberger R, Schwabl D, Flachberger H, Bauer M, Lehner M, & Hofer W (2018). Output-oriented analysis of the wet mechanical processing of polyolefin-rich waste for feedstock recycling. Waste Management & Research, 36 (5), 445-453.

Kranzinger, L., Schopf, K., Pomberger, R., & Punesch, E. (2017). Case study: Is the 'catch-all-plastics bin'useful in unlocking the hidden resource potential in the residual waste collection system? Waste Management & Research, 35(2), 155-162.

Lacy, P., Spindler, W., & McAndrew, C. (2019). Plastic is a global problem. It's also a global opportunity. In World Economic Forum. Retrieved October (Vol. 2, p. 2019).

Le Blevennec, K., Jepsen, D., Rödig, L., Vanderreydt, I., & Wirth, O. (2018). For Better Not Worse: Applying Eco-design Principles to Plastics in the Circular Economy. ECOS, VITO and ÖKOPOL. Belgium, Brussels.

Lemnek, S. (1998), Qualitative Sozialiforschang Bond 1: Methodologie; Bond 2: Method und Techniken, Munich: Psychologie Verlags Union.

López de Dicastillo, C., Velásquez, E., Rojas, A., Guarda, A., & Galotto, M. J. (2020). The use of nano additives within recycled polymers for food packaging: Properties, recyclability, and safety. Comprehensive Reviews in Food Science and Food Safety, 19(4), 1760-1776.

M. Hanif and A. Momen (2020). A Review of Plastic Scrap Dealers & Recyclers in Dhaka City. International Conference on Management of Innovation and Sustainability: Vision 2041. Institute of Business Administration (IBA), University of Dhaka.

M. Hanif and A. Momen, (2018). Post-consumer PET Bottle Collection and Recycling Practice in Bangladesh: Is it worth it? International Conference on Business, Economics, Education and Social Sciences (ICBEESS, 2018), East West University, Bangladesh

M. Hanif and A. Momen, (2017). Insights into plastic litter collection and recycling practices in Bangladesh: A qualitative study. 1st International Conference on Business and Management 2017, ICBM, BRAC University, Bangladesh

MacArthur, E. (2013). Towards the circular economy. Journal of Industrial Ecology, 2(1), 23-44.

MacArthur, E. (2014, January). Towards the circular economy: Accelerating the scale-up across global supply chains. In World Economic Forum.

Mariam Attia & Julian Edge (2017) Becoming a reflexive researcher: a developmental approach to research methodology, Open Review of Educational Research, 4:1, 33 45, DOI

Mark, L. O., Cendejas, M. C., & Hermans, I. (2020). The use of heterogeneous catalysis in the chemical valorization of plastic waste. ChemSusChem, 13(22), 5808-5836.

Masmoudi, F., Alix, S., Buet, S., Mehri, A., Bessadok, A., Jaziri, M., & Ammar, E. (2020). Design and characterization of a new food packaging material by recycling blends virgin and recovered polyethylene terephthalate. Polymer Engineering & Science, 60(2), 250-256.

Mason, M. (2010, August). Sample size and saturation in PhD studies using qualitative interviews. In Forum qualitative Sozialiforschang/Forum: qualitative social research (Vol. 11, No. 3).

McKinsey, 2019. Recycling and the Future of the Plastics Industry | McKinsey," accessed

McNamara, C. (1999). General guidelines for conducting interviews.

McQuarrie, E. F. (1991). The customer visit: qualitative research for business-to-business marketers. Marketing Research, 3(1), 15-28.

Mehnaz, Aditi (2020). Export Potential of Recycled Plastic: A Study on Bangladesh. Asian Social Science; Vol. 16, No. 3; 2020 ISSN 1911-2017 E-ISSN 1911-2025 Published by Canadian Center of Science and Education

Metabolic, 2020. What Are Systems Thinking?" Metabolic (blog), https://www.metabolic.nl/about/our-approach/.

Meys, R., Frick, F., Westhues, S., Sternberg, A., Klankermayer, J., & Bardow, A. (2020). Towards a circular economy for plastic packaging wastes–the environmental potential of chemical recycling. Resources, Conservation and Recycling, 162, 105010.

Miles, M. B. & Huberman, A. M. (1994) "Qualitative data analysis", Sage: Thousand Oaks, CA.

Milios, L., Holm Christensen, L., McKinnon, D., Christensen, C., Rasch, M.K., Hallstrøm Eriksen, M., 2018. Plastic recycling in the Nordics: a value chain market analysis. Waste Management. 76, 180–189.

Mishler, E. G. (1990) "Validation in inquiry-guided research: The role of exemplars in narrative studies", Harvard Educational Review, Vol.60, pp. 415–441.

Moazzem, K. G. (2016). Plastic Waste Management in Bangladesh, in search of an effective operational framework. BPGMEA Members Directory, Bangladesh Plastic Goods Manufacturers and Exporters Association. (2016). International Plastic Summit 2016.

Mosaddeque Hossain, 2018. Salient Feature of Recycling Plastic: Process & Prospectus. Souvenir of 13th Bangladesh International Plastic, Packaging and Printing Industrial Fair,2018. BPGMEA

Mumladze, T., Yousef, S., Tatariants, M., Kriūkienė, R., Makarevicius, V., Lukošiūtė, S. I., ... & Denafas, G. (2018). Sustainable approach to recycling of multilayer flexible packaging using switchable hydrophilicity solvents. Green Chemistry, 20(15), 3604-3618.

National Geographic (2018). "Revolution in Plastic Recycling," June 2018, National Geographic

Neuman, W. L. (2014). Basics of social research. Pearson/Allyn and Bacon.

Nielsen, T.D., Hasselbalch, J., Holmberg, K., Stripple, J., 2020. Politics and the Plastic Crisis: A Review throughout the Plastic Life Cycle. In: Wiley Interdisciplinary Reviews: Energy and Environment. John Wiley and Sons Ltd.

Nicholas, W. (2011). Research methods: the basics. Published in the USA and Canada by Routledge, New York.

Núñez-Cacho, P., Leyva-Díaz, J. C., Sánchez-Molina, J., & Van der Gun, R. (2020). Plastics and sustainable purchase decisions in a circular economy: The case of Dutch food industry. PloS one, 15(9), e0239949.

OECD, 2001 "Extended Producer Responsibility" OECD

OECD, (2022). Global plastic waste set to almost triple by 2060. https://www.oecd.org/newsroom/global-plastic-waste-set-to-almost-triple-by-2060.htm

OECD (2017). Systems approaches to public sector challenges: Working with change. OECD.

Olivier de Weck, Daniel Roos, and Christopher Magee, 2011. Engineering Systems: Meeting Human Needs in a Complex Technological World. MIT Press

Osterwalder, A., & Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1). John Wiley & Sons.

Oulton. M (2021). Plastics: Confusion Around Recycling. Czapp, May 19, 2021. https://www.czapp.com/analyst-insights/

Papadopoulou, A., Hecht, K., & Buller, R. (2019). Enzymatic PET degradation. Chimia, 73(9), 743-743.

PlasticsEurope. (2019). The Circular Economy for Plastics—A European
Overview. Technical report.

PlasticsEurope, E. P. R. O. (2019). Plastics—the facts 2019. An analysis of European plastics production, demand and waste data. PlasticEurope https://www. plasticseurope. org/en/resources/publications/1804-plastics-facts-2019.

Plastics Europe Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

Plastics Europe Market Research Group (PEMRG), 2020. Plastics- the Facts 2020.

Plastic Recyclers Europe (2016) – Plastics recyclers Europe 20 years later & the way forward making more from plastics waste.

Polysterusa (2020), Recycling Basics-Reuse, Reduce, Recycle

Qureshi, M. S., Oasmaa, A., Pihkola, H., Deviatkin, I., Tenhunen, A., Mannila, J., ... & Laine-Ylijoki, J. (2020). Pyrolysis of plastic waste: Opportunities and challenges. Journal of Analytical and Applied Pyrolysis, 152, 104804.

Rachel Macarthur, 2019. "European Council Sets out 30% Recycled Content Target for Plastic Bottles," European Council

Rashid, M. H. O. Sustainable Municipal Solid Waste Management in Dhaka City: Challenges and Issues. Journal of Bangladesh Institute of Planners ISSN, 2075, 9363.

Recycling International, 2012. Bangladesh Plastics Industry to hit US$ 4 Billion by 2020. https://recyclinginternational.com/plastics/bangladesh-plastics-industry-to-hit-us-4-billion-by-2020/6738/

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 (16)

Remi Jaligot., Wilson, D. C., Cheeseman, C. R., Shaker, B., & Stretz, J. (2016). Applying value chain analysis to informal sector recycling: A case study of the Zabaleen. Resources, Conservation and Recycling, 114, 80-91.

Research and Markets 2022. Recycled Plastics market by Type (PET, PE, PP, PVC, PS), Source (Bottles, Films, Fibers, Foams), End-Use Industry (Packaging, Textile, Building & Construction, Automotive, Electrical& Electronics) and Region-Global Forecast to 2026. Business Wire

Robaina, M., Murillo, K., Rocha, E., & Villar, J. (2020). Circular economy in plastic waste-Efficiency analysis of European countries. Science of the total environment, 730, 139038.

Robertson, D. (2019). Regional: Promoting Action on Plastic Pollution from Source to Sea in Asia and the Pacific-Enhancing Knowledge and Creating Enabling Environments for Reducing Marine Plastic Pollution (Subproject 1).

Robson, C. (2002). Real-world research: A resource for social scientists and practitioner-researchers. Wiley-Blackwell.

Rogoff, M. J. (2013). Solid waste recycling and processing: planning of solid waste recycling facilities and programs. Elsevier.

S. Edwards. (2009). A New Way of Thinking: The Lowell Center for Sustainable Products. Lowell Center for Sustainable Production, University of Massachusetts Lowell, https://www. uml. edu/docs/A% 20New% 20Way% 20of% 20Thinking_tcm18-229911. pdf (data dostępu: 5.03. 2018).

Santagata, C., Iaquaniello, G., Salladini, A., Agostini, E., Capocelli, M., & De Falco, M. (2020). Production of low-density poly-ethylene (LDPE) from chemical recycling of plastic waste: process analysis. Journal of cleaner production, 253, 119837.

Sarfraz, J., Gulin-Sarfraz, T., Nilsen-Nygaard, J., & Pettersen, M. K. (2020). Nanocomposites for food packaging applications: An overview. Nanomaterials, *11*(1), 10.

Saunders, M., et al. (2019). Research Methods for Business Students. (8th ed.). London, UK: Pearson Education.

Schyns, Z. O., & Shaver, M. P. (2021). Mechanical recycling of packaging plastics: A review. Macromolecular rapid communications, 42(3), 2000415.

Seawright, J., & Gerring, J. (2008). Case selection techniques in case study research: A menu of qualitative and quantitative options. Political research quarterly, 61(2), 294-308.

Serajul & Mahmudul (2014). Need Assessment to set up Bangladesh Institute of Plastic Engineering & Technology (BIPET). Souvenir of 9th Bangladesh International Plastic, Packaging and Printing Industrial Fair, 2014. BPGMEA

Serajul & Mahmudul (2016). Current State with Facing Challenges by entrepreneurs & future prospect of plastic Sector in Bangladesh. International Plastic Summit,2016, Bangabandhu International Conference Centre (BICC). BPGMEA

Serajul & Mahmudul (2018). Rethinking the future of plastics for enhancing the plastic economy. Souvenir of 13th Bangladesh International Plastic, Packaging and Printing Industrial Fair, 2018. BPGMEA

Serajul & Mahmudul (2019). Refurnishing the usability of plastics: making circularity and resource efficiency a reality. Souvenir of 14th Bangladesh International Plastic, Packaging and Printing Industrial Fair, 2019. BPGMEA

Shimo, M. H. U. (2015). Plastic Recycling in Bangladesh, what needs to be done? ARCADA

Silverman, D. (2003), Interpreting Qualitative Data, (3rd ed.) London: Sage

Strauss, A., & Corbin, J. (1990). Basics of qualitative research: Grounded theory procedures and techniques. Sage Publications, Inc.

Sultana, N. (2019). Plastic Recycling in Bangladesh. Advance in Environmental Waste Management & Recycling, 2(1), 1-4.

Sustainable Brands (2019), Ourworldindata.org, internal PWC Report to World Bank (2019)

Sustainable Brands, 2021 "How to Pursue Sustainability during COVID-19: A Tactical Guide for Brand Professionals," n.d., https://sustainablebrands.com/read/walking-the-talk/how-to pursue-sustainability-during-covid-19-a-tactical-guide-for-brandprofessionals.

SYSTEMIQ (2022). Reshaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe." SYSTEMIQ

Tallentire, C. W., & Steubing, B. (2020). The environmental benefits of improving packaging waste collection in Europe. Waste Management, 103, 426-436.

Technavio (2020). "Global Recycled Plastics Market 2020-2024 | Rising Demand for Recycled Plastics from the Packaging Industry to Boost Market Growth | Technavio,"

The Associations of Plastic Recyclers (APR). https://plasticsrecycling.org/about

Thomas, R. and Hardy, C. (2011) 'Reframing resistance to organizational change', Scandinavian Journal of Management, Vol. 27, pp. 322–31.

Tom Hesselink (2019). The Plastic Recycling Opportunity. KPMG

Tons Emans, 2012, Making Plastics More Sustainable, Plastics Recyclers Europe

TOMRA, 2020. Plastic Value Chain. TOMRA leads e-book. www.tomra.com/recycling.

Tournier, V., Topham, C. M., Gilles, A., David, B., Folgoas, C., Moya-Leclair, E., ... & Marty, A. (2020). An engineered PET depolymerase to break down and recycle plastic bottles. Nature, 580(7802), 216-219.

UNDP, (2019). Recycling Value Chain Analysis (RVCA) in Teknaf and Ukhia sustainable solutions to solid waste project, cox's Bazar, Bangladesh. January 2019

Van Eygen, E., Laner, D., & Fellner, J. (2018). Circular economy of plastic packaging: Current practice and perspectives in Austria. Waste management, 72, 55-64.

Vieitez, E. R., Eder, P., Villanueva, A., & Saveyn, H. (2011). End-of-waste criteria for glass cullet: technical proposals. JRC Scientific and Technical Reports.

Veleva, V., & Ellenbecker, M. (2000). A proposal for measuring business sustainability: addressing shortcomings in existing frameworks. Greener Management International, (31), 101-120.

Vollmer, I., Jenks, M. J., Roelands, M. C., White, R. J., van Harmelen, T., de Wild, P., ... & Weckhuysen, B. M. (2020). Beyond mechanical recycling: Giving new life to plastic waste. Angewandte Chemie International Edition, 59(36), 15402-15423.

Wagner, S., & Schlummer, M. (2020). Legacy additives in a circular economy of plastics: Current dilemma, policy analysis, and emerging countermeasures. Resources, Conservation and Recycling, 158, 104800.

Waste Concern (2005). Waste is resource.

Waste Concern (2014). Waste DB 2014. http://article.sciencepublishinggroup.com/pdf/10.11648.j.ijepp.20170502.11.pdf

Waste Concern (2015). Municipal solid waste management system: a study on Dhaka north and South City corporations. Bangladesh Inst. Plan, 2075, 9363.

Wbcsd, B. C. G. (2018). The new big circle.

WEF Circulars (2018). "Banyan Nation | Banyan Nation Better Plastic WEF Circulars 2018," WEF Publication

Woldemar d'Ambrières (2019). "Plastics Recycling Worldwide: Current Overview and Desirable Changes," Field Actions Science, Reports. The Journal of Field Actions, no. Special Issue 19 (March 1, 2019): 12–21.

Woldemar d'Ambrières, W. (2019). Plastics recycling worldwide: current overview and desirable changes. Field Actions Science Reports. The journal of field actions, (Special Issue 19), 12-21.

World Bank (2018) Growth Estimates of Global Plastics Market vs. Recycled Plastics Market. World Bank

World Bank (2021). Meeting Bangladesh's Plastic Challenge through a Multisectoral approach. Published on December 23, 2021.

World Bank (2021). "Towards a Multisectoral Action Plan for Sustainable Plastic Management in Bangladesh." Washington, DC. The World Bank Group.

WWF (2019) "Legal Framework Study of Extended Producer Responsibility," WWF

Yin Robert, K. (1994). Case study research: Design and methods. Sage publications.

Yin, Robert K (2009). Case Study Research. Design and Methods. Los Angeles, London, New Delhi, Singapore, and Washington, DC. Sage Publications.

Zikmund, W. G., Babin, B. J., Carr, J. C & Griffin, M. (2010) "Business Research Methods", 8th Edition, International Edition, South-Western, Cengage Learning.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2020). The New Plastics Economy Global Commitment 2020 Progress Report.

APPENDICES

1) Questionnaire to Waste Pickers

Questionnaire submitted to waste pickers in order to study the current position of waste plastic collectors and the strength of the recycling industry in Bangladesh.

General Information

Name & Address	
Length of Job/Business:	**Employer:**
Registered/Non Registered:	
Employee Profile: Permanent / Casual: Salary/Month: Wages/per day/hr.: Profile (who, where are from, age etc.)	
Additional Facilities availed (if any): Housing, financial assistance, other benefits	
Main type of trading materials:	
Source of Waste: Households, Public places like park, market, mosques, curbside , industries, offices ,bulk generators, Other scrap dealers etc.	

Type of Scraps used to purchase

Purchase Information			
	Material	**Material Types**	**KG/Day**
1	Plastic	• Plastic Film • PET Bottle • Plastic Jar, bottle • UPVC • Other plastic	
2	Paper		
3	Glass		
4	Metal		
5	Others		

1. Who do you sell the recyclables to?
   - Wholesale markets /Middleman /Recyclers
   - Other large single material type of dealers
   - Directly to manufacturers
2. What is the average daily collection of plastic waste? (in kg)
3. What is the price/kg of plastic wastes of different types that you buy?
4. What is the price/kg of plastic wastes of different types that you sell?
5. What are the methods used to collect plastic waste?
6. What are the sources and methods used to clean the collected plastic waste?
7. What are the methods used to identify and sort collected plastic waste?
8. What challenges and problems do you face in the business?
9. What are the new trends you have observed in this type of business over the years?
10. Other observations

2) Questionnaire to Plastic Scrap Dealers (Wholesale/Middle Dealers)

Questionnaire submitted to middle dealers/wholesale Dealers in order to study the current position of waste plastic trading and the strength of the recycling industry in Bangladesh.

General Information

Name & Address	
Length of Business:	**Owned /Rented:** **Rent/Month:**
Registered/Non Registered:	**Number of Employees**
Employee Profile: -Number of permanent workers: Salary/Person: -Number of casual workers: Wages/Person per day/hr.: -Profile of workers (who, where are they from, age group, number of men and women	
Facilities provided to the staff (if any): Housing, financial assistance, other benefits	
Main type of trading materials:	
Source of Waste: Waste Pickers, municipal collectors, bulk generators, Other scrap dealers etc.	

Type of Scraps used to purchase

Purchase Information			
	Material	**Material Types**	**KG/Day**
1	Plastic	• Plastic Film • PET Bottle • Plastic Jar, bottle • UPVC • Other plastic	
2	Paper		
3	Glass		
4	Metal		
5	Others		

1. Who do you sell the recyclables to?
   - Wholesale markets /Middleman /Recyclers
   - Other large single material type of dealers
   - Directly to manufacturers
2. What is the average daily collection of plastic waste? (in kg)
3. What is the price/kg of plastic wastes of different types that you buy?
4. What is the price/kg of plastic wastes of different types that you sell?
5. What are the methods used to collect plastic waste?
6. What are the sources and methods used to clean the collected plastic waste?
7. What are the methods used to identify and sort collected plastic waste?
8. What are the sorted types of collected plastic waste?
9. Do you have any type of machinery to process the waste (baling, etc.)
10. Other details on infrastructure available (vehicle, own or rented space etc.)
11. What challenges and problems do you face in the business?
12. Are there any seasonal variations in work and how does this reflect in the business in terms of number of employees, type of material in demand, etc.
13. What are the new trends you have observed in this type of business over the years?

13. Other observations

3) Questionnaire to Recyclers

Questionnaire submitted to plastic waste recyclers in order to study the current position of plastic collection and the strength of the recycling industry in Bangladesh

General Information

Name & Address	
Length of Business:	**Owned /Rented:** **Rent/Month:**
Registered/Non Registered:	**Number of Employees:**
Employee Profile: Number of permanent workers: Salary/Person: Number of casual workers: Wages/Person per Day/Hour: Profile of workers (who, where are they from, age group, number of men and women:	
Facilities provided to the staff (if any): Accommodation, financial assistance, other benefits	

1. What type of plastic waste do you source for reprocessing?
2. What are the products manufactured?
3. What are the technologies used to recycle collected plastic waste?
4. Is it a value-added process or do you manufacture a product for the end-user?
5. What is the average daily recycling capacity? (In kg)
6. How do you source plastic waste for recycling?
7. What is the average daily collection of plastic waste? (In kg)
8. What is the price/kg of plastic waste of different types that you buy?
9. What are the major steps involved in the process of recycling?
10. What are the sorted types of collected plastic waste?
11. What are the basic parameters searched for recycling materials?
12. What are the methods used to identify and sort collected plastic waste?
13. What is the average energy utilization per month?
14. What are the current recycled products?
15. What is the price/kg of plastic recyclates of different types that you sell?
16. What is the assurance of the quality of recycled products?
17. What are the common processing problems?
18. What is your monthly consumption of plastic scrap?
19. What is your yearly consumption of plastic scrap?
20. What are the challenges faced by you in sourcing the raw material?

4) Interview Questions (Interviewees from Key Persons of Plastic Industries)

1. Do you have in-house plastic scrap recycling facilities?
2. How do you process plastic scrap as generated from your own industry?
3. Do you source plastic scraps from outside? If so, how do source and process these scraps?
4. What types of plastic scraps do you usually source from outside?
5. Do you use locally sourced recycled plastic pellets?
6. What types of recycled plastic pellets do you usually source locally?
7. Do you import recycled plastic pellets regularly?
8. What types of recycled plastic pellets do you usually import from abroad?
9. According to you, how do you differentiate the quality of locally recycled plastic waste pellets and imported recycled plastic wastes?
10. What about the consumers' perception about the finished products which are usually made from recycled plastic pellets and virgin pellets?
11. Considering the present trend and practice, what's the future of the plastic waste recycling business in Bangladesh for sustainability index?
12. How would we improve plastic waste recycling in Bangladesh coping with global trends and practices?
13. What do you think about the future trend of the plastic waste recycling business in the global context?
14. Since you are a large conglomerate in the plastic field, do you have any future plans to set up a large-scale commercial plastic waste recycling plant?

5) Interview Questions- Experts

1. Considering the present trend and practice, what's the future of the plastic waste recycling business in Bangladesh for sustainability index?
2. How would we improve plastic waste recycling in Bangladesh by coping with global trends and practices?
3. What do you think about the future trend of the plastic waste recycling business in the global context?
4. How could we mix up virgin and recycled plastic resin to minimize production costs? In doing so, will it degrade the quality of the final products as produced?
5. According to you, how technology plays an important role to get the utmost result from plastic waste?

6) List of Participants for the In-depth interviews

SL	Person interviewed	Position	Name of the Organization	Country	Interview Focused on
1	Sayad Hossain Chowdhury	COO	Allplast Bangladesh Ltd. RFL Group	Bangladesh	The current state of plastic recycling & Future Possibilities
2	MD Zashim Uddin, MD, Bengal Group President, BPGMEA	MD	Bengal Plastic Ltd. Bengal Group	Bangladesh	The current state of plastic recycling & Future Possibilities
3	Chowdhury Hasan Tariq	Sr.GM	Akij Plastics Ltd. Akij Group	Bangladesh	The current state of plastic recycling & Future Possibilities
4	Khadem Mahmud Yusuf	MD &CEO	Bangladesh Petrochemical Co. Ltd	Bangladesh	The current state of PET Bottle Recycling and Future Possibilities
5	Md. Sujauddin Zafar	Director	Luna Plastic Industry Ltd.	Bangladesh	The current state of plastic recycling & Future Possibilities
6	Salahuddin Mahmud	MD & CEO	Famous Plus Industries Ltd.	Bangladesh	The current state of plastic recycling & Future Possibilities
7	Shamim Ahmed	President	BPGMEA	Bangladesh	The current state of plastic recycling & Future Possibilities
8	Md. Shahidullah	Sr. Deputy Secretary	BPGMEA	Bangladesh	The current state of plastic recycling & Future Possibilities
9	Altaf Hossain	Executive Engineer	Plastic Division (BITAC)	Bangladesh	Plastic Processing Technology
10	Abul Kashem Titu	Proprietor	Mafia Engineering	Bangladesh	Plastic Processing Technology
11	Md. Hasim Hasnat	Packaging Development Manager	Unilever Bangladesh	Multinational Organization	EPR
12	Engr. Semab Faheem	Freelance Consultant	EX COO, BPCL	Bangladesh	PET Bottle Recycling
13	Professor DR. Haripada Bhattacharjee	Professor, FBS, DU	Professor, DU & Consultant and Trainer BPGMEA	Bangladesh	Export Potential of Recycled Plastic

14	Chaiyudh Sripraipran	Consultant	INACT Corporation	Thailand	Recycling Machinery
15	Daniel Szymanek	Area Sales Manager	NGR	Austria	Recycling technology
16	David LO	Marketing Manager	POLYSTAR	Taiwan	Recycling Technology
17	Robin Yang	Head of Sales	ATLAS TW	Taiwan	Recycling Technology
18	Joanna Liang	Sales Manager	KOWIN	Taiwan	Recycling technology
19	KK Cheung	Manager	KRAS	Taiwan	Recycling Technology
20	S.S CHIA	Director	CHESO	Singapore	Plastic Machinery
21	Shunsuke Kobayashi	Sales Manager	DAISAKU	Japan	Waste plastic recycling procedures
22	Lawrence Lin	Sales Manager	Chen Yu Plastic Machinery	Taiwan	Plastic Machinery
23	Jennifer Chen	Sales Manager	SSK Machinery Co	Taiwan	Plastic Machinery
24	Piyush Jain	Sales & Marketing Manager	GEMINI	Belgium	Plastic waste collection, sorting & reprocessing
25	B.P Sultania	Joint President	GANESHA	India	PET bottle collection, processing, and new product making
26	S. M Sajid	MD	MH Polymers	India	Plastic waste collection, processing & Recycling
27	VN Srinivasan	Business Manager, Polymers	SABIC, KSA	KSA	Virgin and recycled raw materials
28	Dharmes Oraon	AVP, Polyethylene	Reliance	India	Virgin and recycled raw materials
29	Alex Lee	Manager, Polymer	Petronas	Malaysia	Virgin and recycled raw materials
30	Alex Sungtaik Chung	Manager, Polyolefin	Hanwha	South Korea	Virgin and recycled raw materials
31	S.Y KIM	Manager, PE	SK Global	South Korea	Virgin and recycled raw materials
32	Kalpesh Jani	Global Technical Manager	EMERAUD	UAE	Virgin and recycled raw materials

7) Interview Questions (Case Organizations)

Customer Segments

- Who are the customers for which value is being created?

Value Proposition

- What is the product/service bundle offered to the focus customer segments? What is the value delivered to the customer?
- How does the value proposition incorporate elements of circular economy?
- How do these elements of circular economy drive or enhance the value created for customers?

Channels

- Through which channels are customers reached?
- What are the 'reverse' channels for product take-back or end-of-life product/material recovery? (If relevant)

Customer Relationship

- What types of customer relationships are used to serve each customer segment?

Revenue Streams

- For what value are customers paying? How are they paying?

Key Resources

- What are the key resources required for delivering the value proposition; operating channels; maintaining customer relationships; and capturing revenue streams?
- What key resources are required to enable a circular economy within the business model?

Key Activities

- What are the key activities required for delivering the value proposition; operating channels; maintaining customer relationships, and capturing revenue streams?
- What additional activities are required to enable a circular economy within the business model?

Key Partners

- Who are the key partners and suppliers who provide key assets and/or enable key activities to be performed (Including those that relate to the implementation of circular economy elements)?

Cost structure

- What are the most important costs inherent to the business model?
- How do circular economy elements have an impact on costs?

8) The Lowell Center Framework for Sustainable Products (Sally Edward, 2009)

Measures	Significance
Healthy for consumers	• It avoids harmful chemicals for the consumers and the surrounding environment. • It is safe for the consumers.
Safe for workers	• The workplace is well-designed, safe, clean, and well-ventilated, with good air quality, free of exposure to toxins, and equipped for fire safety and other dangers. • Periodic and adequate health and safety training for the workers. • Reasonable working hours and not excessive. • If workers stay in dormitories, then they must be clean, and workers have sufficient food with potable water and sanitation. • Fair treatment is mandatory with respect and dignity and no physical punishment, verbal abuse, force, discrimination, or harassment. • Avoid child or forced labor. • Workers have the right to collective bargaining and freedom of association. • Skills and ideas are well utilized and input is valued. • Communication is encouraged among workers and management.
Environmentally Sound	• Chemical and material inputs/outputs are safe and hazard-free. • Product is resource efficient in production and use. • Waste is prevented/reduced/recycled in the product lifecycle. • Product and packaging are durable and capable of reusing, recycling, repairing, or composting. • Product is designed for disassembly; it can be taken apart and remanufactured. • Renewable resources are utilized in production and consumption.
Beneficial to local communities	• The work design is supportive of family life that can help their families without government assistance. • The work design promotes equity and fairness in the community free from age or gender discrimination. • A certain profit amount accrues to the local community to be used for public improvements. • The work design promotes community participation considering production and labor practices.
Economically viable	• The product is responsive to market requirements with market-oriented innovation. • The firm is stable in terms of ownership and philosophy. • Reinvest options in the facility to improve the capacity for further production. • The product is priced as economically viable. • The firm is recognized for its corporate social responsibility: this