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Research Report

Status Report on Plastic Collection and Recycling Sector of Nepal

August 2023

Executive Summary

Background and Context

This research report serves as a cornerstone of the ReValue project. Orchestrated by German non-profit NIDISI gGmbH, ReValue embarks on a mission to reimagine the handling of low-value plastic waste (LVP) from a liability to a sustainable resource. The project specifically targets the use of this plastic waste as a valuable additive in road construction in Nepal, leveraging a proprietary technology known as the *ReValue Method*, a collaborative development involving the Fraunhofer Institute, the University of Kassel, and EcoPals.

This report aims to thoroughly examine and illuminate the current landscape of plastic waste management in Nepal, enabling an overview of the market and identifying critical challenges. This research is vital for the development of a new supply chain for the collection and processing of low-value plastic waste, using it in road construction under the *ReValue Method*.

The study seeks to provide a detailed qualitative analysis of the plastic waste management market in Nepal, from macroeconomic and supply chain perspectives to the processing and eventual repurposing or disposal of plastic waste. It will go beyond the direct handling of waste to consider macroeconomic factors and the political climate, which significantly influence waste management policies, funding, and public awareness.

Furthermore, the report will conduct an in-depth examination of the supply chains involved in plastic waste management, identifying key stakeholders, including local governments and private entities, and their roles and impact on the process.

The culmination of the research will be a comprehensive assessment of the technologies used in plastic waste management in Nepal. This assessment aims to evaluate the feasibility of integrating new machinery in recycling centers and to provide insights into the decision-making process regarding the selection and use of these technologies.

Key Findings

Macro-Economic Analysis: Nepal's growing plastic waste problem is accentuated by the projection to generate approximately 988.7 tons of plastic waste daily by 2023. The increase in waste generation is particularly prominent in urban centers due to various socioeconomic factors. The vast amount of uncollected MLP and PP film plastics presents one of the major environmental challenges and at the same time an untapped resource for initiatives like *Plastic Roads* under the *ReValue Method*, suggesting an economic incentive for plastic waste collection and recycling. Given the anticipated increase in waste, there's a favorable condition for the establishment of a robust collection and recycling infrastructure, especially in central and south-eastern Nepal, which could serve as strategic locations for plastic recovery and recycling efforts.

Supply Chain Analysis: Municipalities, being obliged with the implementation of waste management infrastructure, are currently overwhelmed with waste management, leading to fragmented systems and inefficiencies. A significant portion of plastic waste is uncollected and unrecycled, while a noteworthy amount is illegally exported to India for recycling. A significant need to enhance the recycling infrastructure in Nepal to manage waste domestically was identified, thereby reducing transport costs and environmental impact. The ReValue project could catalyze this development by introducing Plastic Credits to incentivize the collection of LVP, both in urban and remote regions. Investments in machinery for industrial processing and manufacturing within Nepal could improve market efficiency and predictability, fostering better investment climates.

Political Framework Analysis: The decentralization of waste management responsibilities to local governments has revealed inadequacies in technical support and execution. Even though steps toward the right direct are

taken, current regulations lack detailed guidelines and incentives, which hampers effective waste management and recycling efforts. The gap in the legal and regulatory framework could be addressed by innovative solutions such as *Plastic Roads* and Plastic Credits. Additionally, the development and enforcement of a robust legal framework would provide direction and stability, facilitating the implementation of effective waste management strategies and supporting technological and systemic advancements.

Stakeholder Analysis: Diverse stakeholders, from informal waste workers to government bodies, have varying roles and influences within the waste management ecosystem. Their interests range from economic to environmental, and their joint involvement is crucial to the system's functionality. For the ReValue project to succeed, it is imperative to forge strategic alliances that align with stakeholders' economic and environmental interests. Emphasizing mutual benefits and sustainability standards is essential. There is a particular need to strengthen the roles and bargaining power of informal waste workers and to engage government bodies for policy support, ensuring the project aligns with national waste management strategies.

Technological Analysis: The reliance on manual labor and the minimal use of technology in Nepal's waste management indicate a significant lag. The use of advanced machinery is limited, and manual segregation prevails. To manage increasing waste volumes and enhance recycling efficiency, Nepal must invest in technologies such as automatic sorting systems, shredders, and balers. These investments, however, should be made within a framework that ensures technological suitability for local conditions, easy maintenance, and integration with the existing waste management infrastructure. The adoption of these technologies will also be essential to facilitate the establishment of a supply chain for *Plastic Roads* under the *ReValue Method* and other recycling applications.

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List of abbreviations

ADB	Asian Development Bank
CBS	Central Bureau of Statistics
CCAC	Climate & Clean Air Coalition
CSR	Corporate Social Responsibility
EOL	End of Life
EXI	Export Initiative Environmental Protection
FMCG	Fast-Moving Consumer Goods
GPS	Global Positioning System
GIS	Geographic Information System
GSM	Global System for Mobile Communication
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LVP	Low-Value Plastic
MLP	Multi-Layer Plastic
MSW	Municipal Solid Waste
NEFEJ	Nepal Forum of Environmental Journalists
NHSRP	National Housing and Settlements Resilience Platform
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride
PWRS	Plastic Waste Reduction Standard
RAI	Rural Access Index
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

Introduction

Background

This research report is a constituent of the ReValue initiative, generously sponsored by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The funding for this project spans from the start of 2022 until the end of 2023, through the Export Initiative Environmental Protection (EXI).

The ReValue project, helmed by NIDISI gGmbH, embarks on a visionary path of redefining the perception of unavoidable plastic waste from a disposal issue to a viable resource. NIDISI's ReValue aims to actively address the global plastic crisis by reimagining low-value plastic waste, which is currently deemed worthless, and reintegrating it into the value-added cycle.

In more concrete terms, the ReValue project aspires to harness previously non-recyclable (low-value) plastic waste as a valuable additive in road construction in Nepal. The proprietary *ReValue Method*, a collaborative development involving the Fraunhofer Institute, the University of Kassel, and EcoPals, has the potential to transform millions of tons of non-recyclable plastic waste while enhancing road durability. This innovative *ReValue Method* employs *EcoFlakes*, a product which has already been efficaciously implemented by the subsidiary EcoPals GmbH in Europe, on test routes in Potsdam, Vorarlberg, Kiel, and Aschaffenburg. In the spring of 2021, the first prototype road was constructed in Nepal. In recognition of these accomplishments, NIDISI ReValue was bestowed with the FAIRWandler Prize 2020, the Plastic Revolution Award, and the ifok Innovation Prize 2021.

To extend the successful implementation of the *ReValue Method* to Nepal, post the initial pilot run, multiple facets necessitate further exploration. These encompass the local recycling market; the technical deployment of the *ReValue Method* within the Nepalese context; and the prospective financing mechanism through Plastic Credits. Complementing these research priorities, the establishment of local recycling centers, adhering to the Verra Plastic Waste Reduction Standard (PWRS) certified Plastic Credits concept, will be experimented within the scope of the project.

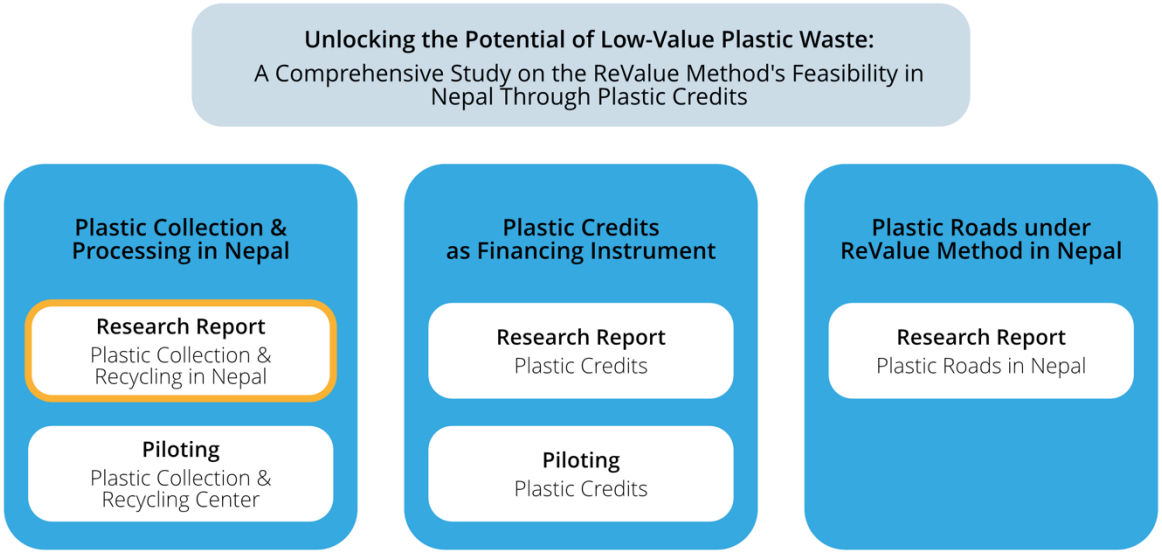

Figure 1: Visualization of ReValue Feasibility Research 2022-2023

In light of this, the present report sheds light on the current status of plastic waste management in Nepal. In the process of constructing the first pilot route in Nepal, several challenges surfaced. Among these, the collection and preparation of materials for road construction using the *ReValue Method* stood out as a primary hurdle. To elaborate further, the scenario in Nepal currently shows a distinct gap: low-value plastic waste, often considered a significant environmental concern, is neither being systematically gathered by any institutional mechanism nor is there adequate machinery that can handle such tasks.

Addressing this issue necessitates the development of an entirely new supply chain dedicated to producing EcoFlakes. Establishing such a system is no trivial task, especially when considering the optimal routes for collection, the kind of machinery required for processing, and the methods for quality control to ensure the produced EcoFlakes meet the desired standards. Moreover, ensuring that this new supply chain harmoniously integrates with Nepal's existing waste management and road construction infrastructure is crucial.

To build an efficient and effective supply chain, it's vital first to acquire a comprehensive understanding of Nepal's present state of plastic waste management. Such knowledge will offer insights into the current challenges, stakeholder dynamics, and potential points of integration, all of which will guide the effective setup of the new system.

About NIDISI

NIDISI is a non-profit, steward-owned organization building social enterprises in Nepal and Germany. NIDISI aims to reduce social inequalities by developing integrated and financially autonomous structures. Innovation is at the heart of the designs created to propose ecological solutions to resolve burning social issues that can be reproduced on a large scale. NIDISI is active in the field of drinking water treatment, youth education, plastic recycling infrastructure, development of biodegradable menstrual pads and menstrual hygiene education.

In 2018, together with the community of Devgau Village (Nepal), NIDISI successfully established a social business providing drinkable water to the population living in the area. Since then, this enterprise has filtered and sold 1.8 million liters of water, making it a sustainable and independent entity led by the villagers.

In 2021, NIDISI built the first pilot *Plastic Road* in Gaindakot (Nepal), substituting bitumen, a crude oil-based substance, with upcycled low-value plastics. Since 2021, NIDISI has invested in Nepali plastic waste infrastructure and has already recycled 60t in its pre-implementation phase to specifically reintroduce low-value plastic waste into the value chain.

Since 2015, through the educational project, more than 30 children of unprivileged backgrounds received long-term support in the form of sponsorship for school-related expenses, mentorship, and personal development assistance.

In the field of Women Empowerment, NIDISI is setting up a social business named Sparśa. This Nepali non-profit organization will manufacture and sell compostable menstrual pads made from locally obtained banana fibers. By offering compostable alternative, Sparśa can decrease the negative environmental impact caused by the consumption of plastic-made conventional menstrual products. The profits generated by Sparśa will finance menstrual awareness campaigns in Nepal and women's rights advocacy. Since 2019, NIDISI has reached over 6,000 participants with its menstrual awareness workshops.

NIDISI has been active in Nepal for more than seven years and has built a vast network among domestic NGOs, INGOs, public institutions, and activists. Among others, NIDISI was awarded the 'ifok - Innovation Award 2021', Plastic Revolution Award (2020), FAIRWandler Award, Filippas Engel Award (2022), and Start Social '22 scholarship.

Objectives

This research aims to provide an in-depth qualitative overview of the entire market of plastic waste management in Nepal, beginning with a macroeconomic perspective and supply chain analysis exploring its collection, progressing through the various stages of its processing, and culminating in its repurposing into new products or its final disposal.

In providing a holistic understanding, the study will not only focus on the direct handling of the waste but will also delve into broader macroeconomic factors and the prevailing political environment in Nepal that influence waste management. These considerations are critical as they often play a pivotal role in shaping policies, determining funding, and driving public awareness on the subject.

Further enriching the study, a meticulous examination of the supply chains involved in waste management will be undertaken. Alongside this, it's crucial to pinpoint and understand the roles of key stakeholders, from local municipalities to private sector participants, and ascertain their influence and responsibilities in the process.

Concluding the research, a detailed evaluation of the existing technologies used within the realm of waste management and recycling in Nepal will be conducted. The objective behind this is twofold: firstly, to assess the viability and effectiveness of incorporating additional machinery within the recycling centers; and secondly, to gain nuanced insights into the decision-making process surrounding the selection and implementation of these machines. Such insights can be instrumental in offering recommendations for optimizing waste management and recycling endeavors in Nepal moving forward.

Based on the aforementioned considerations, the subsequent research report is divided into five chapters, each dedicated to analyzing distinct focal points. The research will delve into the following key questions:

1. Macro-economic Analysis:
    a. What is the volume of plastic waste generation in Nepal?
    b. What are collection rates of different polymer types of waste plastics, and which are predominantly collected?
2. Supply Chain Analysis:
    a. How does Nepal handle and process its plastic waste?
    b. What are End-of-Life (EOL) and recycling destinations of different polymer types of waste plastics?
3. Political Framework Analysis:
    a. What legal and regulatory mechanisms govern plastic waste management in Nepal?
4. Stakeholder Analysis:
    a. Who are the primary stakeholders in Nepal's plastic waste management sector, and what are their respective interests?
    b. Who could be potential partners in establishing a supply chain for the *ReValue Method*?
5. Technological Analysis:
    a. What technologies or machinery are in current use for plastic waste management in Nepal?
    b. What potential enhancements can be made to machinery for general plastic waste management, and specifically for the treatment of low-value plastic waste?

Methodology

The research methodology adopted in this study is multi-faceted, aiming to provide a comprehensive understanding of the subject matter. It encompasses a blend of rigorous literature reviews, explorative fieldwork to capture ground realities, structured and semi-structured interviews with relevant stakeholders, observational studies to derive firsthand insights, and validation processes sourced from multiple avenues to ensure data

reliability through cross-referencing. Data collection efforts spanned from February 2022 to December 2022, and subsequent updates were incorporated through desk research in August 2023.

Each chapter of this study is meticulously structured to address distinct facets of the research. To ensure a comprehensive understanding, a concise methodological overview is provided at the onset of every chapter, detailing the specific approach adopted for that particular segment. This not only ensures methodological transparency but also aids readers in navigating the research framework with precision.

However, like all research undertakings, this study is not without its limitations. It's essential to highlight a few critical points. First, while the research greatly benefited from the invaluable support and insights of Nepali colleagues, it's pivotal to note that the primary investigator has limited prior exposure to Nepal, both in terms of cultural nuances and regional specifics. Such unfamiliarity poses inherent challenges, particularly concerning potential cultural misunderstandings and language-related constraints, which could have influenced the data collection and interpretation process. Furthermore, the available literature, which formed the bedrock of the foundational research, was limited in scope and, in many cases, dated. This scarcity necessitated an even more rigorous validation phase to ensure that the conclusions drawn align with the current realities of the subject at hand.

Macro-Economic Analysis

In the context of a rapidly globalizing world, the environmental impact of plastic waste has taken center stage. With plastic's longevity and potential for pollution, understanding the intricacies of its disposal and management becomes paramount. Nepal, nestled in the Himalayas, is no exception to this global challenge. To start into the topic of plastic waste management in Nepal, this chapter delves deeply into the macroeconomic dimensions of plastic waste generation and collection in the nation, setting the foundation for a comprehensive analysis. The leading research questions of this first chapter are therefore:

1. What is the volume of plastic waste generation in Nepal?
2. What are collection rates of different polymer types of waste plastics, and which are predominantly collected?

The challenge of accurately gauging the current state of plastic waste management in Nepal is magnified by a notable scarcity of contemporary and region-specific data. To provide a foundation for this research, two primary methodologies were employed:

Literature Reviews: An extensive review of available literature, including past studies, official reports, and academic papers, was undertaken. While these offer a historical perspective, they might not capture the current dynamics.

Primary Data from Field Visits: To augment the literature review and to gain a clearer understanding of the present situation, field visits were conducted in Kathmandu and Pokhara. These visits offered insights into waste collection methodologies, types of plastics being discarded, and the current waste management practices at hand.

It's imperative to note that the findings of this research are not exhaustive. Given Nepal's vast geographic and cultural diversity, the results, which are heavily reliant on observations from two urban centers, might not be representative of the entire nation. Additionally, due to the lack of up-to-date centralized data, these findings are best approached as initial insights or foundational data, requiring further in-depth study for a comprehensive understanding.

Volume of plastic waste generation in Nepal

Volume Estimates for 2023

Drawing from data in three seminal studies on waste management in Nepal (ADB, 2013; Pathak, 2017; World Bank, 2020), combined with the most recent population statistics and plastic waste proportions (ranging between 12% and 16%), the following plastic waste generation figures for Nepal in 2023 are projected:

Daily	988.7 tons
Annual	360,875 tons
Daily/Capita	0.09887 kg

Figure 2: Volume of Plastic Waste Generation in Nepal

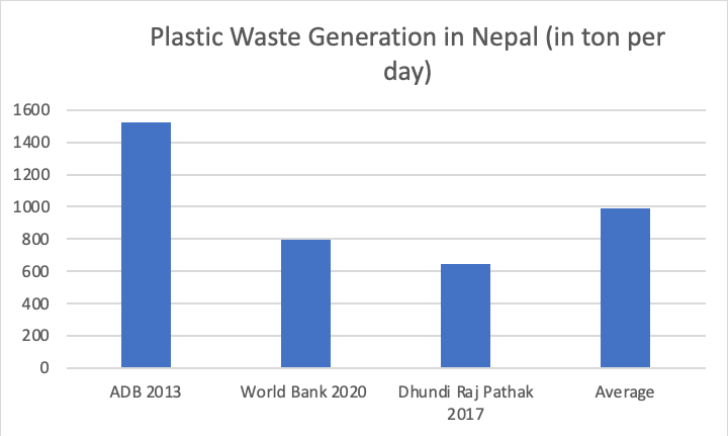

Figure 3: Plastic Waste Generation in Nepal based on World Bank (2020), Pathak (2017), ADB (2013)

Foundational Data Sources

The Asian Development Bank's 2013 report, "Solid Waste Management in Nepal: Current Status and Policy Recommendations," stands out in its depth. Covering 58 municipalities, it assessed 3,233 households, 627 institutions (educational and corporate), and 627 commercial establishments during 2011 to 2012, representing approximately 17% of Nepal's total population. According to this study, the average MSW generation amounted to 317g per person daily in 2011-12.

To provide a contemporary perspective, findings from the World Bank (2020) and Pathak (2017) were integrated, adjusting for the population growth until 2023. This synthesis led to the estimation of 988.7 tons of plastic waste generated daily in 2023.

Anticipating the Future

The ubiquity of plastics indicates that consumption in Nepal, in line with global trends, will unlikely decline in the immediate future. With the population projected to grow—from 30.82 million to an estimated 33.39 million by 2030 (United Nations, 2022) — it is anticipated that plastic waste generation will increase by approximately 8.34%. Taking this rate into consideration, the projected plastic waste generation for 2030 would be approximately 390,982 tons annually. Additionally, the global trend towards urbanization serves as another influential factor (Ritchie & Roser, 2018), expected to boost per capita plastic usage, further impacting Nepal's overall plastic consumption (Kaza et al, 2018).

A Detailed Look at Waste Composition

Regarding the general waste composition by sources of waste generation, the ADB report (2013) provides a granular breakdown:

Households: The primary contributors, accounting for 50%-75% of the total MSW.

- Plastics: 12%
- Organic: 68%
- Paper products: 9%

Institutional Waste: Emanating from entities like schools and offices.

- Plastics: 21%
- Organic: 22%
- Paper products: 45%

Commercial Waste: Originating from establishments such as shops, hotels, and restaurants.

- Plastics: 22%
- Organic: 43%
- Paper products: 23%

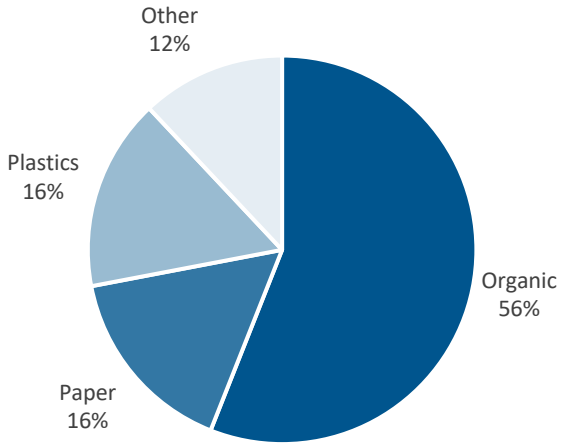

Figure 4: Municipal Solid Waste Composition based on ADB (2013)

Overall, MSW in Nepal primarily consists of organic materials at 56%, followed by plastics at 16%, and paper products at 16% (see Figure 4). The significant presence of organic or wet waste can complicate segregation efforts, especially in regions without established waste separation protocols, which is the case for many municipalities in Nepal. Especially in mountain areas waste segregation between dry, wet and organic waste on household level is not executed (World Bank, 2021).

Polymer Composition Analysis

Looking into the composition of plastic waste by different polymer types, representative and robust data is lacking for Nepal. Nevertheless, for a deeper understanding of the plastic types, a detailed study on Municipal Solid Waste in Lalitpur Metropolitan City proves insightful (Chitrakar, 2023). In this context, plastics formed 20.40% of MSW. Among the analyzed plastic types:

HDPE :	41.55%	PET :	7.17%
LDEP :	17.30%	PVC :	7.13%
PP :	16.62%	PS :	3.77%

In comparison with global metrics, there are distinct variations. For instance, the global averages stand at: LDPE (20.0%), PP (19.3%), HDPE (14.0%), and others, (Geyer, Jambeck, & Law, 2017) highlighting unique consumption patterns in Nepal, with especially high rates of HDPE.

A Geographical Perspective on plastic waste generation in Nepal

From a geographical standpoint, Nepal can be divided into three distinct regions: the Mountain region, the Hilly region, and the Terai region. Each of these regions exhibits unique characteristics in terms of topography, population size, culture, lifestyle, infrastructure development, and economy. These variations also impact municipal plastic waste generation. Cities like Kathmandu (including Lalitpur, located in the Kathmandu Valley), Pokhara, Birgunj, and Biratnagar are some of the largest urban centers thus much of the plastic waste will be generated in those parts of the country. They are all located either in the central or south-eastern part.

Secondly, tourism plays a major role in plastic waste generation. This is due to tourist consuming more plastic per capita than Nepali locals due to higher mobility amongst other factor (UNEP, 2023). The major touristic centers are in central Nepal including Kathmandu, Chitwan, Lumbini, Pokhara and the Annapurna Area (see **red dots** in Figure 6).

There is empirical evidence that higher incomes are also positively correlated with waste generation in Nepal (ADB, 2013). The highest incomes are generated in central Nepal und eastern Terai region (**green circles** in Figure 6). Hence, higher per capita plastic waste generation in these regions can be assumed.

Based on the findings of ADB (2013) on the relation between waste generation and economic development, a closer look at the national road network in Nepal is warranted. Examining the major roads (**orange** in Figure 6) shows that large parts of the country, which encompass almost the whole middle-northwest of central Nepal and the middle-northeast part – excluding the south that is connecting through the east-west high – are very disconnected from the major road network. According to Rural Access Index (RAI) in 2015, 10.3 million rural residents live without a road within 2 kilometers that is in good or fair condition (World Bank, 2016). Against this background, it can be derived that fewer goods, including plastic products, are delivered and thus accumulated in these regions due to lower economic development and higher costs of transportation. Conversely, regions located near the major road network are likely to accumulate more plastic waste (indicated in **blue** in Figure 6).

Accounting for the geographical nuances, it's evident that while localized plastic waste generation might appear fragmented due to the absence of efficient waste management infrastructure, a broader national overview reveals a significant concentration of plastic waste in specific regions of the country. By weighing in on factors

such as population density, income levels, tourism, and road infrastructure, it emerges that the epicenters of plastic waste generation are predominantly in central Nepal and its southern territories, with metropolitan hubs like Kathmandu and Pokhara leading the list. Furthermore, cities like Bharatpur, Birgunj, and Birtanagar have emerged as significant hotspots in the analysis (highlighted by **markers 1-3** in Figure 6).

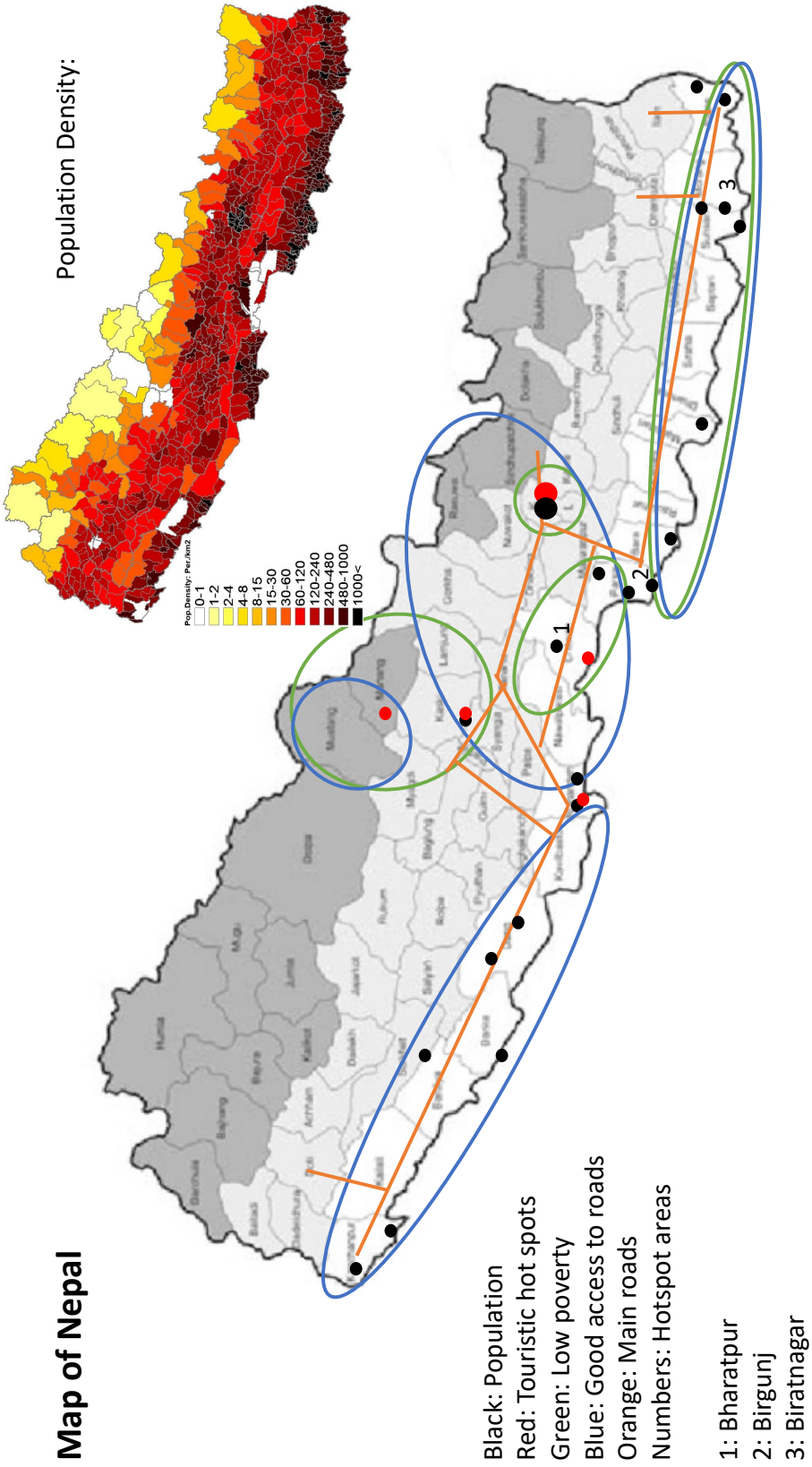

Figure 6: Geographical Perspective on plastic waste generation in Nepal

Collection of waste plastics by polymer types

Given the current absence of comprehensive data regarding the collection rates of plastic waste in Nepal, especially when categorized by polymer types, a qualitative research approach was adopted. This entailed conducting in-depth interviews with waste management workers at major aggregation points in Nepal's two largest cities – Kathmandu and Pokhara.

Between November 2nd and 10th, 2022, nine waste management workers were interviewed at the Teku Transfer Station in Kathmandu. This was followed by interviews with seven workers in Pokhara between November 13th and 20th, 2022 — three at the Pokhara Dumpsite and four at the Transfer Station. The emphasis on engaging with informal waste management workers arose from two key observations:

1. Literature indicated that recyclable recovery in many municipalities predominantly occurs through the informal sector due to the absence of formal reuse and recycling systems (ADB, 2013).
2. Informal waste workers possess hands-on knowledge about the segregation of recyclables and reusable goods, making them invaluable primary sources of information.

Based on the interviews:

- All 16 respondents confirmed significant collection of HDPE (rigid), PET, LDPE (both rigid and flexible), and PP (rigid) in both Kathmandu and Pokhara.
- 15 respondents indicated that flexible PP is only minimally collected and only when pristine.
- Unanimously, the 16 respondents reported that multi-layered plastics (MLP) are either not collected or are collected in insignificant amounts.

Further corroboration for these findings emerged from discussions with two managers overseeing segregation centers and transfer stations, as well as consultations with two UNDP-affiliated researchers.

The collected data implies that in metropolitan areas like Kathmandu and Pokhara, there is a significant emphasis on collecting HDPE (rigid), PET, LDPE (both rigid and flexible), and PP (rigid). Conversely, MLP and PP film are largely neglected. It is inferred that the demand for PET, HDPE (rigid), LDPE (rigid/flexible), and PP (rigid) is substantial enough to offset the expenses tied to their collection and subsequent recycling in these locations. The low or negligible collection of MLP and PP film can be attributed to the elevated costs of their collection and processing, which often outweigh their market value. Henceforth, the term *low-value plastics* (LVP) will be used to describe plastics that aren't economically feasible for collection or recycling.

Supply Chain Analysis

Building on the foundation established in the preceding chapter, where the volume of plastic waste generation and collection practices were discussed, this chapter delves deeper into the life cycle of plastic waste in Nepal. The primary aim is to elucidate the value chains of both plastic waste and its recyclable derivatives. Key questions this chapter seeks to address include:

1. How does Nepal handle and process its plastic waste?
2. What are EOL and recycling destinations of different polymer types of waste plastics?

To comprehensively address the aforementioned questions, the findings will be divided into four distinct sections:

(1) **Overview of the Plastic Waste Management Process**: A detailed look at the journey of plastic waste from its inception to the eventual recycling or disposal.
(2) **Collection and Segregation**: Highlighting the nuances of waste collection in both urban settings, like Kathmandu, and rural towns.
(3) **Recycling Pathways**: Analyzing the trajectory of segregate-recyclable plastic waste, its challenges, and opportunities.
(4) **Disposal Mechanisms**: Understanding the fate of non-recyclable plastics, with a special emphasis on low-value plastics.

The ultimate goal is to capture and document the foundational material streams of plastic waste in Nepal.

The research methodology is twofold: explorative and descriptive. The explorative approach ensures an unbiased understanding of Nepal's multifaceted system, minimizing preconceived notions. On the other hand, the descriptive facet focuses on narrating the observed data and information. All gathered information underwent group discussions to construct a cohesive picture, with open-ended questions subsequently verified during interviews.

Field visits spanned the entire value chain, incorporating dialogues with various market stakeholders. A total of 24 participants were interviewed, encompassing 16 waste collectors across four segregation centers and representatives from seven recycling firms. This rich pool of primary data was then utilized to chart out material value chains and their interconnectedness. In tandem, literature reviews and expert interviews further informed and validated the findings presented in subsequent sections.

Overview of the Plastic Waste Management Process

When looking at plastics waste management and recycling as well as the principles of the circular economy form a general perspective, we find the following basic process steps of system of both and in between linear or more circular plastics system: Generation, Collection & Segregation, End-of-Life (Disposal), Processing & Manufacturing (Recycling).

First, there is the ***generation of plastic waste.*** Plastic waste is generated both by consumers and in the industrial sector when a plastic product is disposed of. Typically, this waste is then collected by the producer until it is picked up and processed by larger waste disposal companies or local waste management firms.

Collection and Segregation: The plastic waste is collected by waste disposal companies or local waste management firms from the entities responsible for producing it. Depending on the region, the waste may have already been pre-sorted by the producer. However, some of the plastic waste may still be mixed with other

materials. Plastic waste and other valuable wastes are then segregated by different waste categories, plastic polymer types, and material grades. Valuable and circularly usable materials are sold for further recycling. The remaining materials, along with contaminated or low-value plastics, are sent to their final disposal with or without energy recovery.

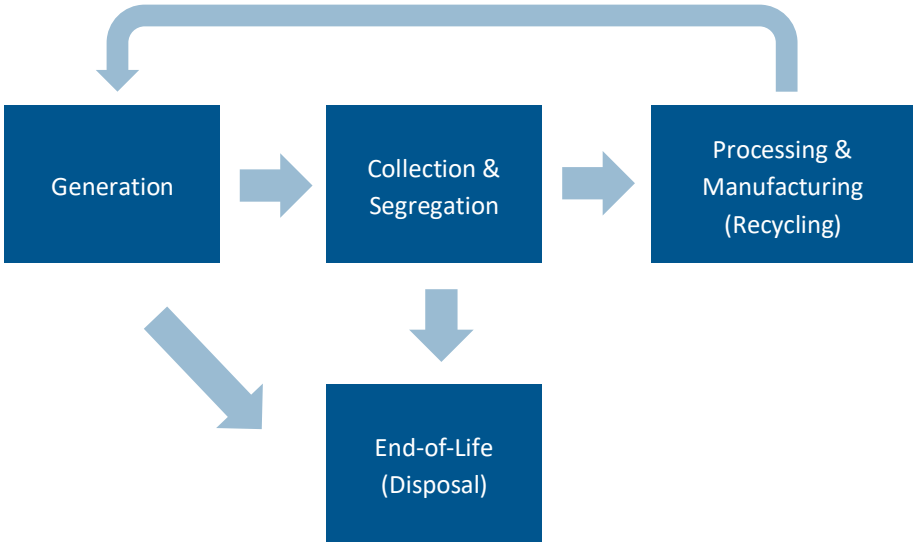

Figure 7: Plastic Waste Management Cycle

Processing and Manufacturing: Segregated waste plastics are then further processed. Depending on the material and reuse, this can involve further sorting, cleaning, shredding, and granulating into recyclate (mechanical recycling). Alternatively, chemical recycling is also an option, in which the plastic is broken down into its chemical components, from which various new products can be made. With mechanical recycling, the produced plastic granules are typically manufactured into new plastic products through injection molding or an extrusion process.

End-of-Life / Disposal: Plastic waste that is not suitable for recycling is disposed of after segregation. This can be in the form of proper disposal in landfills or by incineration. Especially plastic waste, due to its high calorific value, is suitable for energy recovery or co-processing, in which the energy generated during the combustion process is utilized. Unfortunately, improper disposal also occurs, in which the plastic waste is disposed of in poorly managed or illegal dumpsites, waterways, or through open burning.

After examining the generation of plastic waste in Nepal in the previous chapter, the next three subsections will investigate how the generated plastic waste is collected, segregated, and recycled or disposed of.

Collection and Segregation

First, it is important to distinguish between collection and segregation. Collection in this report refers to the service of picking up waste from waste producers such as households and industries, and then bringing it to segregation or disposal destinations. Segregation describes the process of identifying, sorting, dividing, and classifying waste in an effort to recover recyclable materials.

Who is handling collection in Nepal?

According to the Solid Waste Management Act (2011), the collection process is the responsibility of the respective municipalities in Nepal. They can either conduct waste collection themselves and employ their own staff, or it may be contracted to private waste management companies. A significant portion of current collection activities is attributed to the private sector. Occasionally, when outsourcing to private waste management companies, the provision of vehicles for waste disposal and the assumption of additional costs are covered by

the municipality (CBS, 2020). To cover the costs of waste collection, a fee might be taken from waste producers such as households and industries. These terms and possibilities for levying fees are also determined by the municipality. Overall, collection efficiency stands at 62% in Nepal (CBS, 2020). This means, according to interviews with municipalities, 38% of the overall waste in Nepal remains uncollected or is handled by informal structures. The exact collection efficiency for plastic waste remains undefined.

Segregation mechanism and its parameters

The process of segregation of plastic waste presents the mechanism for a general differentiation between higher value plastics that get collected for recycling and lower value plastic which are not recycled and hence not added back to a circular system, thereby reproducing a linear logic of consumption. There are two crucial factors for this: The sales value for the segregated material and the cost of segregation.

The sales value is dependent on five major factors. (1) Recyclability of different plastic polymer types, (2) the supply of plastic waste and underlying consumption pattern, (3) the demand of segregated plastics by producing industries, (4) the spatial concentration of supply with the resulting segregation and transport efficiency and (5) the international prices of crude oil as a substitute for plastic manufacture affecting demand.

Regarding the recyclability of different polymer types, special attention should be given to low-value plastics (sometimes also called non-recyclable plastics), which can be utilized for the *ReValue Method* in road construction. This includes Multi-Layer-Plastics (MLP), other composite materials, PP, or even contaminated plastics. Due to their physical characteristics, they are hard or even impossible to use in a circular manner, and processing, if at all possible, is only feasible at high costs, which are typically not economical. As a result, there is no demand for these plastics and their segregation unless a functioning EPR system is in place that subsidizes its recycling or recovery. Currently, in Nepal, this is not the case, and these LVP wastes are, as already identified in the previous chapter, rarely collected and seldom subjected to proper disposal.

The costs of segregation are dependent on factors such as (1) the general price level, including labor costs, (2) waste composition during collection, (3) waste cleanliness, (4) plastic polymer type and size of waste materials, and (5) quality requirements for the segregated materials.

Who is handling segregation in Nepal?

Generally, the segregation of waste according to the Solid Waste Management Act of 2011 is also the responsibility of the Municipalities. However, since they often handle this obligation differently and frequently lack technical competencies in waste management, segregation occurs very fragmentarily at different levels and locations of the plastic waste chain. It is often observed that after collection, segregation can either take place at landfills, transfer stations, on waste collection vehicles, or specific segregation centers. Before collection, pre-segregation on household or industry level is practiced in some areas.

In general, segregation is conducted to a very large extent by the informal sector. Informal waste collectors are usually paid on a merit basis for the plastic they collect. These waste collectors are often vulnerable and marginalized. The collected plastics are then further sold to aggregation points.

To a lesser extent, segregation is also practiced by Nepali municipalities themselves or through staff employed by municipalities for collection to gain some extra money through segregation and selling valuable materials.

Local context plays a big role in both segregation and collection.

Overall, the local context plays a crucial role in both collection and segregation. According to an analysis of the information provided by municipalities, the collection efficiency ranges between 70% and 90% in major towns, while it falls below 50% in smaller towns in Nepal (CBS, 2020). Similarly, the size of the towns affects the total amount and geographical concentration of plastic waste. Higher total amounts increase market opportunities

for segregators. Higher geographical concentration decreases the cost of segregation per unit. Finally, the efficiency and coordination of the collection systems vary among local contexts. The more efficient the system is, the lower are the cost of segregation, the more material can be recovered.

Further explanation will be provided on the nature and diversity of collection systems based on two examples in the following: the capital of Nepal, Kathmandu, and a rural town of the hilly region called Tansen.

Example of Kathmandu Plastic Waste Management System

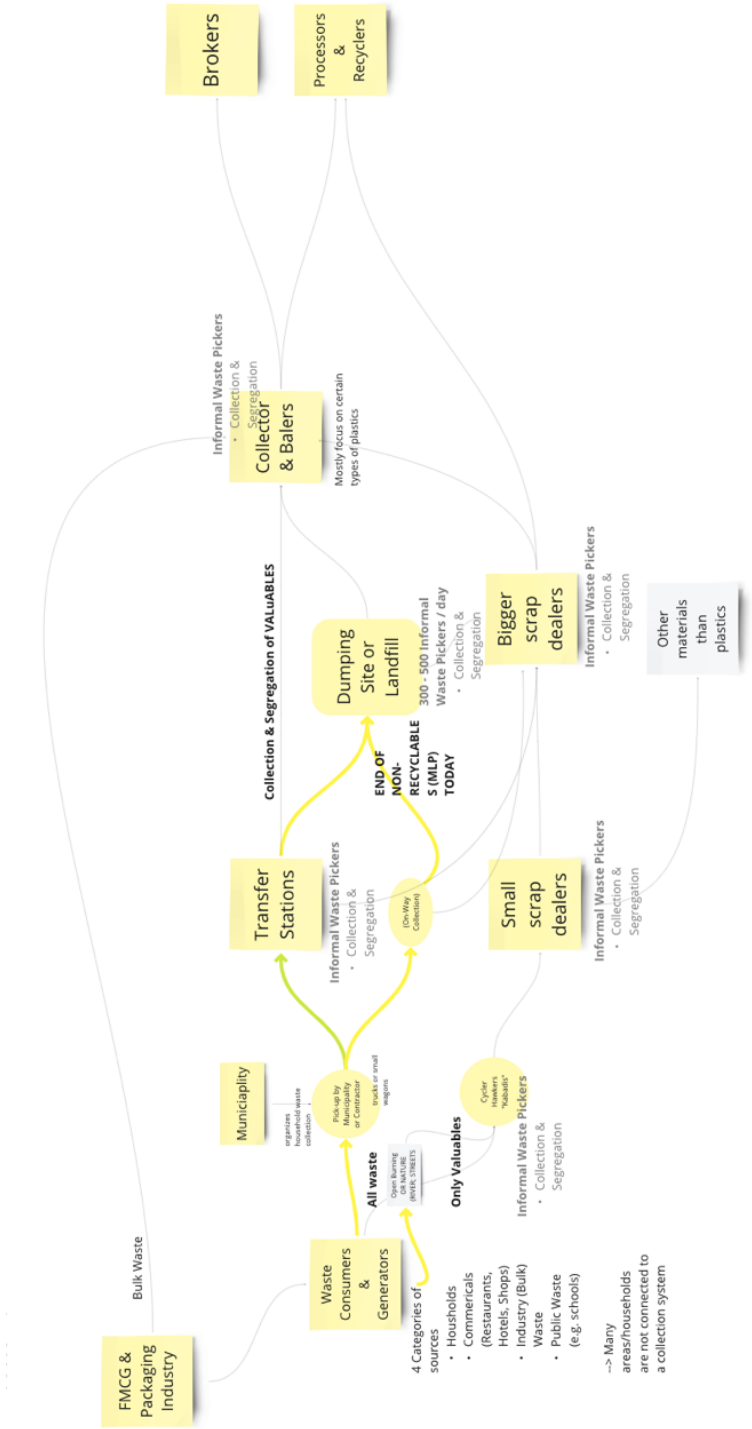

Figure 8: Kathmandu Plastic Waste Management System - based on field visits and interviews with market actors and experts

Kathmandu, the capital of Nepal, is home to over a million residents and serves as the nation's primary economic and socio-economic nexus. As the heart of trade and commerce, it plays a pivotal role in Nepal's GDP, with tourism and handicrafts leading the sectors. The city's rapid growth, coupled with its sizable population, has accentuated disparities in resource access and opportunities.

However, this growth has also brought forth challenges in waste management. The escalation in waste generation and inadequate disposal infrastructure have heightened environmental and health concerns. While measures are being taken to address these challenges, Kathmandu's journey reflects the broader difficulty of balancing development with sustainability in expanding urban areas. Figure 8 illustrates the current status of Kathmandu's plastic waste management system, shedding light plastic waste pathways.

The flow of materials, indicated by arrows, moves from left to right. Beginning with the generation of plastic waste from various sources, the flow includes several levels of segregation, influenced by the actors symbolized by the boxes in the flow diagrams above.

Starting from the top left, plastic-producing industries create products from plastic materials. Fast-moving consumer good brands (FMCG) and the packaging industry in Nepal predominantly represent these industries. During production, certain production wastes, which are typically of high purity, are generated and sold directly to larger collectors as bulk waste. Products containing plastic are then released into circulation by these industries before they reach their end of life and are disposed of.

Major contributors to plastic waste in Kathmandu include industrial waste, households, commercial entities such as restaurants, the hotel industry, and public institutions. In most cases, household waste remains unsegregated and contains various waste materials. Only a few of the 32 wards in Kathmandu have introduced household segregation into wet and dry waste categories. This municipal solid waste (MSW) undergoes several handling methods afterward.

For certain areas in Kathmandu, waste management companies contracted by the municipality collect waste from households and businesses. This waste is transported either to larger transfer stations or directly to the Banchare Danda landfill, approximately a 45-minute drive from Kathmandu City. However, it was observed that not all households are connected to this collection infrastructure, forcing them to rely on other informal or illegal disposal methods.

Transfer stations, managed by distinct entities, have agreements with the waste management companies. Many of these stations are situated in the city center to transfer waste from smaller collection vehicles to larger trucks. Trucks and wagons of contractors deliver the collected MSW to offload it.

Figure 9: Transfer Station near Teku, Kathmandu

Figure 10: Kathmandu Banchare Danda landfill site

Informal waste workers typically have around 30 minutes to manually segregate valuable materials, including high-value plastics. The leftovers are loaded into larger trucks for transport to Banchare Danda landfill site, while the segregated plastics are sold to large scrap dealers.

At the Banchare Danda Landfill Site, 300-500 informal waste workers sort waste daily, segregating directly from the landfill. The collected materials are then sold to plastic collectors and also large scrap dealers.

Smaller and larger scrap dealers, known as 'Kabaddi wallas', purchase waste from informal waste workers, collection crews, and transfer station operators. The more substantial dealers specialize in materials like plastics, separating mixed plastics into types such as HDPE and PET. These larger dealers purchase from smaller dealers and sell to either (a) bigger collectors or balers, (b) other national brokers, or (c) recyclers directly. Smaller dealers operate more locally and may deal with other materials besides plastics, like wood and metal.

Figure 11: Cycle Hawker in Pokhara, Nepal

Cycle Hawkers, another category of informal waste workers, procure valuable materials such as plastics, metals, and cartons directly from households using bicycles. They typically sell these materials to smaller scrap dealers. Collectors and balers usually focus on specific plastic types, buying in large quantities from scrap dealers or transfer stations. They often possess baling machines to compress plastics for extended transportation. These collectors may further sort plastics based on specific polymer types and quality criteria. They are generally located outside the city center for better transport access. The segregated and baled plastics are sold to recyclers in Kathmandu or national and international brokers near the Indian border in the Terai region. These brokers trade plastics nationwide and export them to India.

In conclusion, Kathmandu's collection processes reveal a multifaceted landscape of waste management. The lack of overarching coordination by the Kathmandu Metropolitan Municipality is evident. This results in a multitude of actors participating in the collection processes, spanning various levels and geographical locations within the city. Such a myriad of stakeholders gives rise to an extremely fragmented and complex system. Notably, local

power structures and mafia-like hierarchies have been observed to influence the processes, as was gathered from various interviews conducted in the field. This intricate system inherently leads to inefficiencies, driving up the collection and segregation costs per unit. Consequently, there's a noticeable decrease in segregation and circularity. Given the deep-rooted political dynamics at play, transforming these processes may pose significant challenges in the foreseeable future.

Collection and Segregation in Tansen Municipality

Tansen is a municipality situated 175km from Kathmandu and finds its place between Butwal and Pokhara. Located in the hilly region of Nepal, Tansen stands at an elevation of 1,350 m. While it's strategically connected by a major roadway that links Butwal and Pokhara, the actual accessibility is somewhat reduced due to the challenging road conditions and the region's hilly nature. To illustrate, the most direct road route to Kathmandu spans 321km and requires approximately 10 hours of travel by car. With a population of 31,095, Tansen's population is approximately 1% of that in the Kathmandu Valley. The municipality represents the characteristics of a typical medium-sized town in the hilly regions of Nepal.

Figure 12: Picture of Tansen

During a field visit conducted on the 22nd and 23rd of April 2022, it was observed that there isn't a prevalent practice of segregating waste at the household level in Tansen. The responsibility of waste collection is undertaken by municipal staff, who transport the collected waste to a designated site located a 10-minute drive from the town's central area. The municipality utilizes two vehicles dedicated to this purpose. It's noteworthy that no other waste collection companies were observed operating at the generators level during this visit. At the aforementioned dumpsite, a certain level of segregation was noticed, particularly concerning PET and HDPE plastics. Although less than 40% of these plastics were being collected, while the rest remained on the dumpsite. Seven individuals were identified as being engaged in the segregation process at this site. Notably, other

polymers such as LDPE, PP, and MLP were left unsegregated. The sorted plastics are stored temporarily before being acquired by one of the four identified small-scale collectors within Tansen. Discussions with a collector revealed that these plastics are eventually transported to Butwal for further management.

In summary, a significant portion of plastics in Tansen are disposed of in open areas. While PET and HDPE undergo basic segregation, other polymer types remain uncollected, missing out on recycling or appropriate disposal opportunities.

Drawing a parallel with Kathmandu, it's evident that Tansen's challenges are magnified due to its limited plastic waste volumes and its hard-to-reach location. The logistical and geographical constraints inflate the costs of segregation, thus hindering efficient plastic waste collection. Observations from Tansen, when combined with data from Kawasoti and Rathanagar, suggest that rural areas might need more robust mechanisms for effective plastic collection and segregation.

Recycling Pathways

Having outlined the collection and segregation processes in Nepal, attention will now turn to how plastic waste is processed according to different polymer types. As demonstrated in the Macroeconomic Chapter, PET, HDPE, LDPE, and smaller proportions of PP are collected and segregated for recycling.

These materials, in addition to being processed in some industries within Kathmandu and Pokhara, are predominantly transported to the Terai region for further processing. The analysis indicates that the main facilities for processing are located in Bharatpur, Hetauda, Butwal, Bhairahawa, Parasi, Birgunj, and Biratnagar. However, a significant amount of plastics, according to conducted surveys, is not recycled in these locations. Instead, it is transported via border towns and highways across the border for recycling in India.

Subsequently, the following material flows for different types of plastics have been identified:

Material Type	Streams and Market Developments
PET	PET is primarily transported legally to India. The major export company Ganesha Overseas in Parasi facilitates the legal export of PET fibers to India. This is possible by processing PET into fibers, since unprocessed plastic waste cannot be legally exported. Within Nepal, the most notable facility is a closed-loop recycling plant operated by Himalayan Life Plastic in Pokhara. Additionally, there are two or more smaller PET to fiber recycling plants catering to the national market.
HDPE	Most HDPE finds its way to India through informal channels. Within Nepal, there is a production of pipes and buckets utilizing a mixture of collected HDPE and LDPE, with over 15 companies identified in the Kathmandu area alone.
LDPE	Similar to HDPE, LDPE is also primarily sent to India through unofficial means. In Nepal, the material is used in the production of pipes and buckets, combining collected HDPE and LDPE, with the same 15+ companies in Kathmandu participating in this market.
PP	The majority of PP is transported to India informally. In Nepal, PP is used in the production of various types of strings.
MLP	Multi-layer plastic has yet to be collected in a systematic manner. Nonetheless, different markets and applications are expected to emerge. Small-scale uses for energy recovery through incineration as refuse-derived fuel in cement factories have been noted, despite the current ambiguity of their legal status in Nepal due to the lack of clear guidelines and regulations. One of NIDISI's local partners has gathered letters of intent, indicating significant demand within the cement production industry. Additionally, pioneering small-scale applications in road construction and building materials (such as bricks, boards, and insulation) have been observed.

In the course of interviews conducted with the recycling industry in Nepal, it has been determined that the quality of the material is one of the main challenges in recycling plastic waste technically and economically. This refers to both the cleanliness of the material and the purity of the types. This situation is especially caused by the often absent waste segregation at the household level and the resulting mixture of wet and dry waste. Consequently, plastic waste is heavily contaminated with other organic and inorganic components. Additionally, manual segregation complicates the matter, as plastic polymer types cannot always be clearly and correctly identified.

Moreover, there is simply a lack of recycling infrastructure in Nepal, leading to the export of most plastic waste. Due to the highly fragmented, incomplete, and inconsistent regulation and implementation of waste management, as well as the absence of political and economic incentives to build infrastructure in the country, there is only a very limited private sector interest in investing in the sector. This deters particularly medium to large companies from establishing relevant recycling infrastructure, contributing to the further fragmentation of the market with many small companies and stakeholders. As a result, the sector is severely underfunded and limited to less capital-intensive areas, which also explains the low use of machinery and the high reliance on manual labor.

Finally, the transportation of plastic waste represents a significant problem in Nepal's waste management. Since currently a large part of the plastic waste in the Terai region is processed for export to India, it is not economically viable to transport plastic waste, particularly from more remote areas in the Hilly and Mountain regions, to the Terai and then to India. This is due to a lack of measures to increase the efficiency of collection and processing for transport, as well as a lack of local recycling solutions that would make a long transportation route with many intermediaries unnecessary.

Disposal Mechanisms

Based on the analysis of literature as well as observations in the field, the following end-of-life destinations for plastic waste, that is not segregated for recycling, could be identified in Nepal (ADB, 2013):

- Dumpsite
- Landfill
- Open dumping
- Open burning (without energy recovery)
- Riverside and river dumping

Of all these disposal methods, only landfilling can be considered environmentally sound. The other methods have significant negative and long-lasting environmental impacts. Other methods, minimizing ecological impacts and emissions, such as controlled incineration with or without energy recovery, are not yet implemented in Nepal at scale and are at best, experimental.

As noted in the section on collection and segregation, with a collection efficiency of only 62% (CBS, 2020), a definite 38% of Nepal's waste is being disposed of through the aforementioned methods. In addition to this 38%, there is an undefined proportion of collected waste that cannot be routed towards recycling. The exact percentage of plastic within the total waste in Nepal cannot be determined from the current data.

Regarding the aforementioned end-of-life destinations, it is assumed that only a fraction reaches sanitary landfills. This is partly because only six municipalities in Nepal have constructed landfills according to a sanitary landfill concept. These municipalities include Kathmandu Metropolitan City (KMC), Lalitpur, Pokhara, Ghorahi, Dhankuta, and Tansen, where they are implemented to offer a more controlled and environmentally friendly waste disposal method.

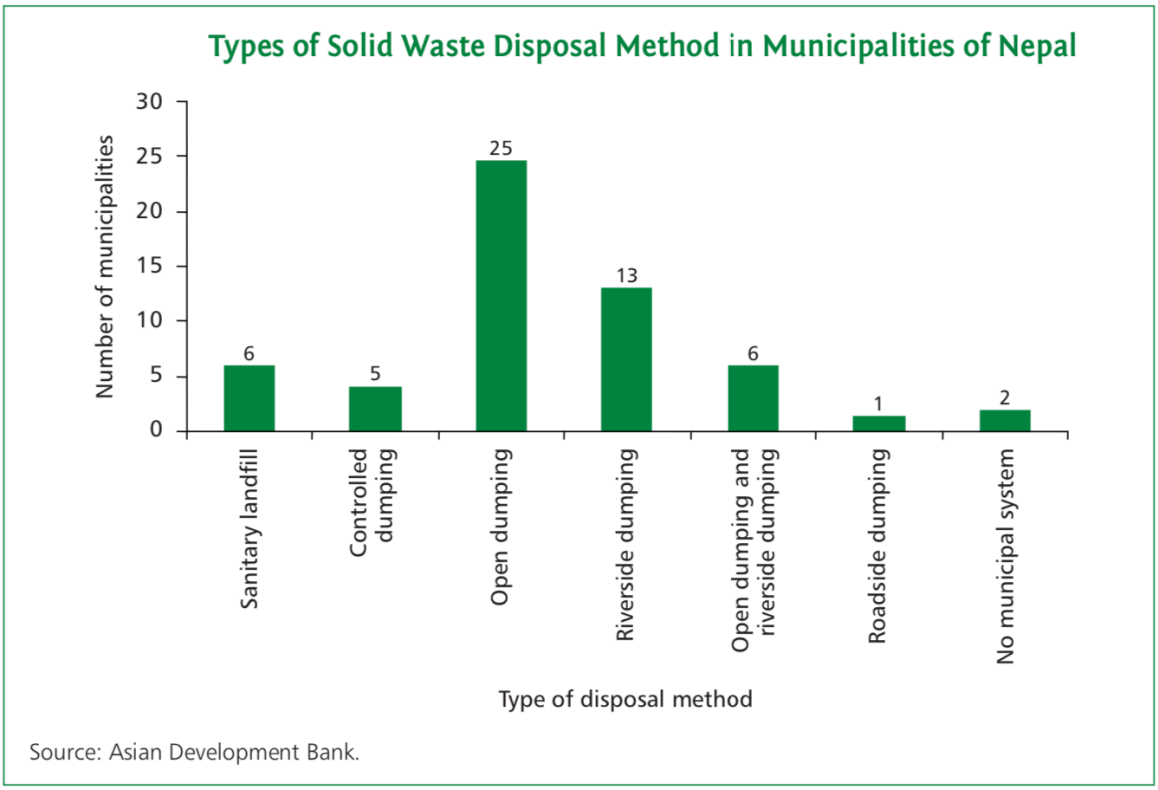

Figure 13: Types of Solid Waste Disposal Methods in Municipalities of Nepal (ADB, 2013)

Unfortunately, open dumping is still a prevalent practice in many municipalities in Nepal. According to the ADB (2013) report, out of 58 municipalities assessed, as many as 45 engage in open dumping, including riverside and roadside dumping, which pose significant environmental and health risks.

It should be noted that while 37% of municipal solid waste (MSW) in Nepal is disposed of in sanitary landfills, the sanitary conditions of these landfills are often not met. The following section investigates the sanitary landfills in Pokhara and Kathmandu against the Verra PWRS criteria. As will be shown, neither landfill meets the criteria for a sanitary landfill and differ only marginally from open dumping.

In rural areas, flammable waste such as paper and plastics is openly burned either within household premises or on the streets. This uncontrolled burning of waste in open areas poses a significant risk as it releases carcinogens like dioxins, furans, and black carbon, which are harmful to human health and contribute to climate change as a short-lived climate pollutant (CCAC, 2023). Burning waste is often intentionally done to recover recyclable materials or may occur spontaneously due to the combustible nature of the materials. This practice leads to air pollution and worsens respiratory diseases among the local population.

Exkurs: An in-depth evaluation of "sanitary" landfills of Pokhara & Kathmandu

According to the ADB (2013), six municipalities have implemented sanitary landfill sites. During the study the status of the landfills in Kathmandu Metropolitan City and Pokhara have been evaluated based on criteria to comply for the definition of a sanitary landfill provided by Verra Plastic Collection Methodology. The filed visits were conducted on 15th of October 2022 in Kathmandu on the newly opened Banchare Danda landfill and on 16th of October 2022 in Pokhara.

The findings indicate that none of the designated landfills fully comply with the criteria, and therefore, they cannot be classified as sanitary landfills.

Figure 14: Overflowing leachate drainage system at Banchare Danda landfill

For instance, Kathmandu's Banchare Danda landfill complies with 2 out of 10 criteria, does not comply with 5, and partially complies with 3 criteria. Issues such as uncontrolled access, waste scavenging, and an overflowing leachate drainage system that flows directly into the river were observed. Despite being operational for several months, the pump system to recirculate leachate upon reaching maximum capacity has not been completed. Compacting and cover-up practices are insufficient and irregular, as is the delivery of soil. Due to a lack of bulldozers, waste is inadequately distributed and often dumped beyond the sanitary lining boundaries. There are no measures or protocols for fire prevention and firefighting; in case of a fire, firefighting efforts are approximately two hours away.

In Pokhara, the site designated for end-of-life disposal of municipal waste complies with 2 criteria, partially complies with 2 criteria, and doesn't comply with 6 criteria. There is a lack of access control as well as a clear demarcation of the waste disposal area. Waste is dumped haphazardly across the area and is insufficiently and irregularly covered and compacted with soil or similar materials. There are no measures in place to prevent fires, and the workers present are not informed of any safety protocols. The leachate drainage and treatment system has long been completely dysfunctional and overgrown. Highly contaminated water is uncontrollably leaking from the landfill and can be found on the surface around the site.

To summarize, it has been observed that in Kathmandu and Pokhara, unsegregated plastics are frequently discarded at unsuitable end-of-life destinations. Consequently, a significant volume of plastic waste enters natural environments, including rivers and groundwater systems, thereby inflicting considerable ecological harm. It is reasonable to infer that the predicament extends beyond these cities to the majority of municipalities throughout the country, particularly given that Kathmandu and Pokhara are considered to meet sanitary landfill standards. Notably, the Kathmandu Banchare Danda landfill is among the newest and most advanced landfills in Nepal.

Figure 15: Overview of Pokhara landfill site

Figure 16: Leachate nearby Pokhara landfill which is excessing the landfill uncontrolled

Political Framework Analysis

After an extensive discussion on the types of plastic waste generated in Nepal and the processes of their collection and further processing, the focus now shifts to a detailed examination of the political regulations governing waste management in Nepal. The central question is: What legal and regulatory mechanisms govern plastic waste management in Nepal? The subsequent discussion will explore potential changes to be expected in political regulations and the implications these may have on the NIDISI ReValue initiative.

For the research investigation, three key aspects have been analyzed: (1) the institutional setup and capacity, (2) the laws and regulations, as well as (3) the financial mechanisms.

The methodology included an analysis of the political regulations themselves, as well as a review of various journal articles and reports. In-depth desk research was conducted in April 2022, which was then revised in August 2023 to ensure current relevance. Regulatory and legal frameworks on solid waste were obtained from the Nepal Law Commission website.

Institutional setup and capacity

Under the new constitution, Nepal has introduced a three-tiered government - federal, provincial, and local government. The country is decentralized into the federal government with 7 provinces, 77 districts, 6 metropolitans' cities, 11 sub-metropolitans' cities, 276 municipalities, and 460 rural municipalities. The Constitution of Nepal (2015) and the Local Government Operation Act 2017 has given local government authority to manage solid waste. However, the institutional capacity of the local level governments for waste management appeared to be weak. The world bank document has identified following issues in the institutional setup and capacity:

- **Lack of technical support unit at federal level for providing technical and policy support to the local level governments:** This unit will help local governments to improve the waste management service delivery in the long term by providing necessary technical and policy support.
- **Poor project development and execution** due to inadequate infrastructural resources and technical capacities at local level.
- **Inadequate involvement of provincial government in solid waste management activities within the province:** Involving provincial governments can help in bringing neighboring local level government (municipalities) together and formulate a common waste management facility.
- **Inadequate staff in the solid waste management division at local level:** The division is understaffed, and the existing staff have limited technical capability which has created gaps in the roles and responsibilities to manage waste effectively.

Laws and regulations

The major laws and regulations focusing on solid waste management in Nepal are the Solid Waste Management Act (2011) and Solid Waste Management Rules (2013). The government of Nepal enacted these laws and rules to maintain a clean and healthy environment by reducing the adverse effects of solid waste.

The SWM Act of 2011 is structured into ten chapters, each addressing different facets of solid waste management. Chapters 2 through 8 are particularly pertinent to this research endeavor. Chapters 2 and 3 outline the provisions pertaining to the generation, collection, and disposal of solid waste, as well as the establishment of transfer centers and landfill sites. These chapters delegate the responsibility of managing solid waste to local authorities, charging them with the implementation and operation of the necessary infrastructure. Typically, this responsibility falls to the Municipalities, encompassing the collection infrastructure with Collection Centers, transport, segregation, transfer centers, and landfill sites. Both waste generators and local authorities are

generally encouraged to adhere to the principles of Reduce, Reuse, and Recycle, albeit on a voluntary basis. Furthermore, local authorities are urged to plan for the development of sanitary landfills to minimize environmental harm. However, the Municipalities' responsibilities exclude hazardous waste, medical waste, chemical waste, and industrial waste, which are to be disposed of properly by the generating entities themselves.

Chapter 4 governs the extent to which local authorities may engage the private or community sectors in fulfilling their solid waste management responsibilities. It is mandated that no entity shall operate in solid waste management without a license from the local authorities. While companies may proactively apply for a license, local authorities are also permitted to outsource their responsibilities to the private sector. This is often achieved through a tender process designed to stimulate high levels of competition and may include Public-Private Partnerships.

Chapter 5 details the service charges that local authorities may levy on waste-generating entities. Chapter 6 encourages minimization of the environmental impact in solid waste management, particularly regarding landfills and end-of-life destinations. It states, "The Local Body shall prepare a master plan for the financial, economic, social, physical development, and environmental conservation for the landfill site affected area and implement the plan by preparing various programs" (p.16, Solid Waste Management Act, 2011).

Chapter 7 anticipates the creation of a Council for solid waste management, which will work at the national level to further develop and implement national policies. To technically support the local bodies, as indicated in Chapter 8, a Technical Cooperation Center is proposed to be established in the Kathmandu Valley.

The SWM Rules of 2013 are primarily an extension of the SWM Act of 2011, elaborating on certain aspects such as the handling of medical and chemical waste and the operation and closure of sanitary landfills. However, both guidelines lack detailed content or guidelines on how to technically execute solid waste management to fulfill these responsibilities. For instance, they only prescribe segregation at the source into organic and inorganic waste. A commonly noted criticism is the absence of any obligation or incentive for further segregation and recovery of valuable materials for recycling (NHSRP, 2023).

In addition to the above-mentioned regulations, the government of Nepal has also introduced a plastic bag regulation and directive, 2011, which prohibits the production of plastic bags below 20 microns. The federal government has also issued a new Solid Waste Management Policy in 2022. This policy has focused on the mobilization of waste as a resource by utilizing innovative technologies. Additionally, this policy includes strategies for developing legal basis for waste management through classification according to their nature, preparing and implementing separate standards based on classification of waste. Furthermore, the policy has emphasized collaboration with private sectors, national and international NGOs, mobilization of foreign aid in waste management, and ban on waste disposal in public places (Himalayan News Service, 2022).

However, with the prevailing laws and regulations, the problem of solid waste management is still on the surface. A World Bank report on assessment of SWM services and systems in Nepal (2020b) has identified following gaps in the laws and regulations causing inefficient management of waste:

- **Lack of separate rules and regulations for different types of waste:** The Solid Waste Management (SWM) Act covers all types of waste. However, there is a necessity to develop distinct regulations for different waste categories including plastic waste. A UNDP study in 2020 found that 76% of municipalities in Nepal have no policies/programs for managing plastic waste.
- **Poor enforcement and implementation of rules and regulations:** Enforcement and implementation of the existing rules are weak, leading to issues in waste management. For example, three out of four Municipalities do not segregate plastic waste from solid waste before disposal. Moreover, 38% of

Municipalities report not having a suitable disposal site nearby. Particularly in rural municipalities, it was discovered that 50% of them still use open dumping as their primary method of disposal (UNDP, 2020).

- **Lack of special policies related to solid waste management at local levels after the restructuring of federal government:** Local government does not have any special policies or plan for waste management. It is essential for improving waste management service delivery performance in the long term.
- **Lack of provisions mandating processing of waste and disposal of inert materials only:** municipalities only contract for collection and disposal. Engaging entities for processing could increase recovery rates. Only 4% of Municipalities reported collaborating with companies for Plastic Waste Management (UNDP, 2020).

Based on the gaps mentioned above, some adjustment is required in the SWM rules and regulations. Currently the SWM regulations are more focused on the collection and landfilling of waste, however, the regulations could also integrate 3R principles to address the waste management problem. Additionally, the regulations can also incorporate initiatives for resource recovery such as producing RDF from plastic waste (ADB, 2012).

Financial mechanism

The local governments are responsible for waste management. Most of the revenue of local level governments comes from federal government transfers (95%). With the total revenue collected by the local governments, they should finance infrastructure and resources for solid waste management activities. However, the ADB (2013) report on SWM indicates that only 9.22% of the total municipal budget is allocated for SWM. Also, 60-70% of the SWM budget is allocated for collection and street sweeping and 20-30% of the SWM budget is allocated for transportation (ADB, 2012). This shows that more focus is towards collection and transportation of waste compared to processing and recycling. Additionally, the UNDP found out, that "out of 285 municipalities, only 12 (4%) of them have allocated budget" (p.2, UNDP, 2020) for plastic waste management. The world bank document has identified following issues in the financial mechanism:

- Lack of sufficient funds to finance infrastructure and resources for solid waste management.
- Local level government lacks guidelines for setting and revising solid waste management fees to waste generators.
- Lack of EPR to finance waste recovery of low value plastics: EPR aims to ensure that companies take responsibility for end-of-life costs related to the packaging (and other products) they put on the market. EPR systems play a significant role in minimizing plastic waste in the environment and allow setting up and financing reliable and systematic waste management structures to ensure that waste is collected, sorted and treated.

A study by Bharadwaj et al., 2020 indicates that plastic waste recovery could help generate revenue. The study reveals that the anticipated revenue from recovered plastic waste could surpass the cost of managing plastic waste by a factor of 1.38, while also preventing an annual inflow of 4,220 tons of plastic waste into the environment. Moreover, the study indicates that increased collection efficiency of waste material and material recovery rate would reduce the financial burden on municipal authorities (Bharadwaj, Rai & Nepal, 2020). To increase collection efficiency and recovery rate, collaboration with private actors will be essential. However, existing regulations pose significant barriers to private actors with capital entering this sector. For example, the contract period for private actors in waste management in Pokhara is on average 2-3 years. This time frame is not adequate to recover the investment made by the private actors. Additionally, there is no process for contract renewal and if the contract is renewed the timeframe is not specified, which makes private actors uncertain whether to invest further (Goyal et al., 2020). Also, the high cost for bidding tenders for waste management services creates a barrier for private actors to enter the market.

Stakeholder Analysis

In this chapter, the aim is to adopt a stakeholder perspective of the plastic recycling market in Nepal. The following research questions will be addressed:

1. Who are the primary stakeholders in Nepal's plastic waste management sector, and what are their respective interests?
2. Who could be potential partners in establishing a supply chain for the *ReValue Method*?

In the first part of this chapter, stakeholders are identified based on the Supply Chain Analysis and categorized into stakeholder groups. These stakeholder groups are explained by discussing their activities, motives, resources, influence on the plastic market, and other attributes.

In the second part of the chapter, implications for the project are analyzed and discussed. This includes prioritizing stakeholder groups in terms of cooperation opportunities for the NIDISI ReValue project.

Stakeholder Identification & Analysis

Based on the Supply Chain Analysis and experiences from NIDISI ReValue in Nepal's plastic waste management sector, the following stakeholder groups have been identified and categorized as follows:

- Plastic Collectors & Aggregators
- Informal Waste Workers
- Plastic Recycling Industries
- Plastic Manufacturers
- Government & Regulatory Bodies
- Impact Organizations

The subsequent sections will further analyze these stakeholder groups.

Plastic Collectors & Aggregators

Their primary activity entails the collection of plastic waste from various sources, including households, businesses, and institutions. They often engage in purchasing plastics from Informal Waste Workers, serving as an intermediary step in the waste management hierarchy. These stakeholders are responsible for aggregating the waste from smaller collectors and segregating it by material type and grade. The size of these aggregators can vary significantly, with smaller local entities handling a variety of materials and operating with limited space and machinery. In contrast, larger aggregators typically have more space, are situated further from city centers, and may specialize in specific types of plastic, utilizing machinery to process greater volumes into distinct material types and grades.

Their business models are built upon access to large sources of plastic waste, the ability to buy low and sell high, and establishing reliable partnerships. In their pursuit of profit, some may prioritize short-term gains over sustainable practices, often at the expense of labor conditions, which are characterized by cheap labor and indifference towards working conditions.

Resource-wise, these Collectors and Aggregators maintain relationships and connections with both the sources of waste and other entities within the plastic collection network, such as waste pickers, brokers, and fellow collectors. They possess or have access to land for storing plastics, and some may have invested in machinery and vehicles, which necessitates significant capital for land, machinery, labor, and other operational costs.

A noteworthy attribute of this group is the prevalence of Indian nationals, who are actively engaged in trading with India, including the sale of plastic waste, which, despite being illegal in many cases, is a common practice due to lax law enforcement. Mafia-like structures are reported within this sector, with some companies compelling households to subscribe to their services. This coercion is symptomatic of a broader disregard for legal compliance, in favor of maximizing profits, as evidenced by the illicit export of plastic waste to India.

In terms of influence and power, while individual collectors may not wield significant clout, especially in metropolitan areas like Kathmandu, their influence can be contingent on their size and the total number of collectors in a given area. Collectively, however, their access to waste sources grants them a considerable degree of leverage within the waste management value chain.

Informal Waste Workers

The Informal Waste Workers in Nepal represent a critical yet under-recognized segment in the plastic waste management sector. These individuals, often working independently and not formally recognized by any organization, are integral to the industry as they collect, sort, and sell recyclable materials. This group includes cycle hawkers, street and landfill collectors, and sometimes those working within transfer stations. Their daily labor involves manually collecting and segregating plastic waste, which is then sold to Collectors and Aggregators. Unfortunately, these Informal Waste Workers face challenges in obtaining regular and fair compensation for their labor-intensive efforts.

The absence of formal registration for their employment leaves Informal Waste Workers without social security benefits, leading to increased vulnerability and societal stigma. Basic rights are often denied, and they are subject to marginalization, with many coming from low socio-economic backgrounds and facing discrimination due to caste or ethnic affiliations.

The primary motivation driving these workers is the necessity to generate income for survival and to improve their living conditions. With the goal of meeting daily needs and supporting their families, they strive to collect as much clean plastic as possible within short time frames to sell at the highest possible prices.

Despite their limited resources, which typically include their physical labor and relationships with fellow workers, these individuals often demonstrate an entrepreneurial spirit. However, their impact on the plastic waste market in Nepal is significant, as they provide essential services in the absence of mechanized segregation systems. Yet, their influence is constrained by their low bargaining power, low social standing, and low investment abilities.

Plastic Recycling Industries

Plastic Recycling Industries engage in the acquisition of segregated plastic waste or pre-processed plastics, which they transform into granulates, pellets, or flakes. These materials then serve as the raw materials for the creation of new plastic products. The recycling industries typically purchase plastic waste in bulk from collectors, establishing a critical end-point in the plastic waste value chain.

Plastic Recycling Industries from both Nepal and India, playing distinct roles in the Nepalese market. Indian companies tend to purchase substantial volumes of plastic waste from Nepal, reflecting their larger scale and broader market reach. In Nepal, the industry is comparably smaller, focusing on specific types of thermosetting plastics while often exclude lower-value plastics from their operations. Notable within the Nepalese context is Ganesha Overseas, an Indian entity with a significant presence in Nepal, specializing in the trading and processing of PET waste, which is then exported and utilized to manufacture fiber in India.

The primary aim of these industries is to procure large quantities of high-quality, clean plastic waste at minimal cost, while simultaneously maintaining efficient processing practices through modern machinery and technology. Despite a keen interest in innovation, Nepalese companies frequently lack the necessary capital to expand on a

large scale. This limitation affects their ability to make plastic waste collection more feasible and economically viable.

Challenges for the Nepalese Plastic Recycling Industries include inadequate capital for innovation and scaling, issues with the quality and cleanliness of collected plastics, and difficulties in securing consistent supplies. The use of technology in these processes is also limited within Nepal.

An example of a Nepalese company in this sector is Black Asian Pipe Udyog, based in Kathmandu. This company procures plastics such as LDPE and HDPE from local collectors and produces polythene pipes and sheets predominantly used for construction and insulation. With a monthly output of 20 tons, they stand as one of the prominent polythene pipe recyclers in the country.

The influence and power within the recycling sector vary greatly depending on the company's size and the types of plastics they specialize in. Nepalese companies contribute to a segment of plastic being recycled, albeit smaller when compared to their Indian counterparts, which have greater access to capital and technology. However, the potential for recycling in Nepal remains significant. Advancements in technology that enable more efficient processing could also allow for a broader range of plastic types to be recycled, thereby enhancing the industry's capacity to create new markets and exert a more substantial influence on plastic waste management in Nepal.

Plastic Manufacturers

Plastic Manufacturers are engaged in the production of virgin plastics and various forms of plastic packaging, thereby introducing a substantial amount of plastic products into the market that eventually become waste. Additionally, their manufacturing processes generate considerable factory or bulk waste, which is a byproduct of production activities.

A prominent example within this sector is the Chaudhary Group, an Indian-owned conglomerate operating in Nepal. This group is known for producing widely consumed instant noodles packaged in MLP bags. One of their factory managers reported that they produce approximately 50 tons of MLP waste monthly, which represents a considerable disposal cost.

The primary motive of Plastic Manufacturers is to meet customer demand by delivering safe and visually appealing packaged products while striving to minimize production costs. The disposal of bulk waste constitutes a significant portion of these costs, which they aim to reduce or eliminate.

Resources-wise, the fast-moving consumer goods industry, which Plastic Manufacturers are a part of, is capital-rich and often includes foreign companies. They leverage advanced technology and possess operational and logistics expertise, enabling them to optimize production processes and manage complex distribution networks. In terms of influence and power, Plastic Manufacturers wield considerable impact on the plastic waste crisis. They are at the forefront of producing the plastics that eventually contribute to environmental waste, and the cost of managing this waste is often externalized to society and the environment. However, with their substantial capital investment capabilities, political connections, and bargaining power, they also have the potential to drive change. By developing better solutions for managing bulk waste, such as collaborating with recycling companies, and redesigning products to minimize the plastic footprint and facilitate recycling, plastic manufacturers could significantly alter the landscape of plastic waste management in Nepal.

Government & Regulatory Bodies

Governmental and Regulatory Bodies linked to waste management include the Ministry of Environment, Science, and Technology; local municipalities; waste management departments; and regulatory agencies responsible for overseeing environmental and recycling policies. A detailed examination of their roles is available in the section dedicated to political framework analysis within the research report.

The primary activities of these bodies encompass the formulation of laws and regulations, enforcement, and monitoring of waste management practices. Additionally, they are responsible for providing essential infrastructure such as landfills and collection systems, which are fundamental components of waste management.

The overarching motive of these government entities is to deliver social services to the public. However, challenges such as corruption and missing technical waste management expertise, especially at the municipal level, complicate their objectives. There is often ambiguity regarding their intentions and the resultant impact on the plastic waste management market.

Resources at the disposal of these Government and Regulatory Bodies include the mandate to organize and manage waste, along with the necessary funding to facilitate such services. Despite these resources, there is frequently a deficiency of expertise in designing and implementing effective waste management systems.

In terms of influence and power, these bodies theoretically possess the authority to enforce substantial changes. Nonetheless, with a few exceptions, where effective waste management systems have been established, this power remains largely underutilized. The gaps in knowledge and a lack of genuine interest, compounded by individual benefits often overshadow the needs for sustainable plastic waste management are persistent issues. This situation highlights the need for a more knowledgeable, interested, and ethically driven approach to capitalize on the potential power these bodies hold to improve Nepal's plastic waste management.

Impact Organizations

In Nepal's plastic waste management sector, Impact Organizations play a pivotal role, driven by a mission to improve environmental and social conditions. These organizations fall into two primary categories:

Firstly, there are **international development organizations** like the UNDP, World Bank, and Asian Development Bank. Their activities mainly involve the allocation of foreign investments to both public and private sectors, along with providing consultancy services. Their efforts are geared towards supporting the development of waste infrastructure at various administrative and operational levels.

Secondly, there are **national Impact Organizations** such as Doko Recyclers, Blue-waste-to-value, Green Road Waste Management, AVNI Ventures, and Creasion. These entities are actively engaged in promoting, establishing and managing sustainable and responsible waste management infrastructure on the ground, often combining their environmental initiatives with commercial activities and research efforts. They may engage in selling recycled plastics or offering related services in Nepal, funded by grants, sponsorships, or CSR contributions, frequently sourced from international donors.

The motivation for these organizations is twofold: to generate a positive societal impact while meeting the obligations to their funders and donors. This can encompass ecological and/or social benefits, depending on the organization's specific objectives. Some national Impact Organizations lean more towards business and economic goals, whereas others prioritize their environmental or social mission.

Resource-wise, both types of organizations benefit from international funding, with grants and donations coming from other international organizations and countries. For the international entities (Type 1), their global recognition and authenticity are essential in securing these funds. They employ skilled and experienced personnel, including international and locally trained experts, who bring valuable knowledge and best practices from around the world.

On the other hand, the national Impact Organizations (Type 2) exhibit a hands-on approach, with a workforce that may be less formally skilled but is deeply connected and respected within local communities. They also often possess practical assets such as machinery, land, and expertise in new recycling technologies.

In terms of influence and power, international development organizations (Type 1) have significant potential impact, but their effectiveness is contingent upon their ability to work through governmental institutions and local partners. When communication and monitoring falter, as has occurred in some projects, their influence is undermined. Conversely, national organizations (Type 2) typically wield more localized influence. Yet, if they manage to ensure long-term profitably, they can become transformational leaders, setting precedents for more commercial actors to follow and establishing new markets in the sector.

Implications on NIDISI ReValue Partnerships

The NIDISI ReValue project in Nepal, with its aim to incorporate low-value plastic waste into road construction financed by Plastic Credits, necessitates strategic partnerships with various stakeholders. A matrix has been constructed to analyze these stakeholders based on two dimensions: power and interest in the project. Here, we will discuss the implications of this analysis for potential partnerships.

Plastic Collectors & Aggregators are crucial stakeholders for the ReValue project, particularly the larger organizations which exhibit both high interest and power. Their role is essential as they currently control main parts of the access to low-value plastic waste. They have the infrastructure, the networks, and the know-how to collect and process plastic waste, making them invaluable for the operational success of the project.

Their high interest is fueled by the potential to tap into new markets and to benefit from the financial incentives offered by the Plastic Credits system. By partnering with the project, these aggregators can enhance their revenue streams and operational efficiency, especially if they can scale up their machinery and processing capabilities. This presents an opportunity for the ReValue project to incentivize the adoption of sustainable practices among Plastic Collectors and Aggregators.

However, their existing operations may not align with the rigorous standards required for Plastic Credits certification. ReValue must therefore work closely with Plastic Collectors and Aggregators to professionalize their processes, integrating social and environmental safeguards as well as stakeholder engagement. This endeavor could involve extensive training, capacity building, and possibly a cultural shift within the organizations, which could be a significant undertaking but is vital for long-term success.

Informal Waste Workers stand out for their high interest in the ReValue project due to the potential improvement in working conditions and additional income prospects through the Plastic Credits system. However, their individual and collective low power poses a challenge for direct collaboration. They are numerous and dispersed, working without the formalization and structure that the project requires.

The ReValue project needs to address the formalization of Informal Waste Workers role, ensuring they benefit economically and that their work conditions meet safety standards. This could mean establishing cooperatives or partnerships to provide a more structured and supportive environment for Informal Waste Workers.

Their integration into the project is essential from a social sustainability perspective, but this should be approached with caution in the initial scaling phase. The project must balance the need to build a robust operational model while also creating an inclusive system that can later expand to empower these workers more directly.

The **Nepalese Plastic Recycling Industry**, despite having high interest, faces challenges with low power due to their limited investment capabilities. The ReValue project presents an opportunity for them to access new

technology and capital, making the collection and recycling of low-value plastics more viable. This could significantly enhance their processing capacities and allow them to tap into markets previously out of reach. For the ReValue project, this means actively engaging with this stakeholder group to understand their limitations and to collaboratively seek solutions that can boost their role in the recycling value chain.

In contrast, the **India-related Plastic Recycling Industry** wields both high interest and power, positioning them as potentially strong and influential partners for the ReValue project. Their existing infrastructure, technological capabilities, and capital make them adept at processing larger volumes of waste, including low-value plastics. The project can benefit from their scalability and efficiency, which could provide a steady supply of processed materials for road construction. This partnership could also pave the way for knowledge transfer and cross-border collaboration that benefits the entire regional recycling ecosystem.

Plastic Manufacturers have significant power due to their production scale and the resulting bulk waste, which includes low-value plastics that are pertinent to the ReValue project. Despite this, their interest in the project might be low, as it falls outside their primary business activities. However, as the sustainability agenda gains momentum globally and in Nepal, the potential for these manufacturers to engage with the ReValue project could increase.

The project could leverage Plastic Manufacturers power by positioning the use of industrial plastic waste in road construction as a sustainability milestone. This not only aligns with global environmental goals but could also serve as a brand enhancer for Plastic Manufacturer. The ReValue project could offer them an opportunity to showcase their commitment to sustainability and reduce disposal costs, creating a win-win scenario. Engagement strategies might include emphasizing the cost-saving benefits of waste management, the potential for positive brand association, and the alignment with global sustainability trends.

Government & Regulatory Bodies are pivotal as policy setters, possessing the ultimate authority to shape and direct the market dynamics for plastic waste management. Their engagement and endorsement are essential for the NIDISI ReValue project, as they can facilitate or impede access to waste sources and are instrumental in integrating innovative projects like this into the national waste management framework.

Despite their critical role as enablers of long-term project success, their actual interest in the project may be variable and potentially limited. This can be attributed to a range of factors, including the prioritization of resources, political will, and the influence of corruption. The variability in their commitment to social wellbeing, which is integral to the ReValue project's objectives, presents a complex challenge.

Nonetheless, their capacity to overrule market mechanisms and set the stage for transformative change underscores the importance of aligning the project’s goals with Government and Regulatory Bodies priorities. By doing so, the project can tap into the authority and influence of them to ensure its successful implementation and to foster a more sustainable and responsible plastic waste management ecosystem.

It is therefore imperative to engage actively with Government and Regulatory Bodies, not only to secure their buy-in but also to leverage their policy-setting capacity to establish a conducive environment for the project. Collaborating closely with local politicians and stakeholders to advocate for the project can also place necessary pressure on decision-makers, turning Government and Regulatory Bodies from a potential risk factor into a cornerstone of the project's strategy.

Impact Organizations exhibit both high power and interest, making them some of the most valuable potential partners for the ReValue project. Their alignment with the project's environmental and social goals, coupled with their resources and expertise, positions them as ideal collaborators. International development organizations

(Type 1) can provide consultancy, funding access, and leverage for engaging with governments, while national impact organizations (Type 2) can offer on-the-ground implementation support.

The ReValue project can benefit immensely from the expertise and networks of Impact Organizations, particularly in navigating the complexities of implementing a project that intersects with both commercial and social objectives. These organizations can assist in establishing credible and effective waste management systems that are environmentally sound and socially responsible. Furthermore, they can help to communicate the project's impact, which is crucial for securing ongoing support and funding.

For Type 1 Impact Organizations, the ReValue project should tap into their vast experience in large-scale project management and their ability to facilitate partnerships across different stakeholders, including government entities. Their global perspective and understanding of best practices can be invaluable in designing the project's framework and ensuring its alignment with international standards.

Type 2 Impact Organizations offer the ReValue project grassroots insights and the agility to adapt to local conditions. Their hands-on experience with community engagement and their entrepreneurial approach to waste management can drive the project's acceptance and success on the ground. However, the project must work closely with these organizations to ensure that their involvement does not compromise the professional and operational standards required for the project's long-term viability.

In conclusion, for the ReValue project to harness the full potential of its stakeholder network, it must craft a multi-faceted partnership strategy. This strategy should recognize and utilize the unique strengths of each stakeholder group, address their concerns, and align their interests with the project's objectives. By doing so, the project can create a robust and resilient ecosystem capable of transforming Nepal's approach to managing low-value plastic waste.

Technological Analysis

Plastic waste requires different processing depending on the material, to enable proper recycling or disposal. Additionally, it is processed using varying technology levels in different geographical contexts. To effectively initiate the NIDISI ReValue Project and contribute to meaningful improvements in local plastic waste management structures, the existing technology used in Nepal will first be investigated. Subsequently, the discussion will address which technologies are sensible for use, especially with regard to LVP. For this purpose, the following two research questions are posed:

1. What technologies or machinery are in current use for plastic waste management in Nepal?
2. What potential enhancements can be made to machinery for general plastic waste management, and specifically for the treatment of low-value plastic waste?

Methodologically, a literature review of different journal articles and reports from development organizations was conducted. In addition, stakeholders were interviewed as part of the Supply Chain Analysis, and systematic observations were recorded to make more precise statements about the technological status of plastic waste management in Nepal.

Status of Technology Use in Nepal

Collection and transportation

Rickshaws and carts are commonly used for primary collection from households and smaller institutions. Tractors are commonly used for secondary collection or transport between different collection, aggregation and transfer points. Dump trucks are usually used for transportation to the disposal sites or also for larger and long-distance deliveries to the recycling industry (Labra et al., 2023). However, it's worth noting that not all municipalities have access to or commonly use all three types of vehicles for waste management purposes (ADB, 2013). In general, it can be observed that the use of technology, especially in more remote and smaller municipalities, significantly decreases.

The Waste Management Baseline Survey 2020 reveals that 70.7% of the municipalities have tractor/power tiller, 61.6% have tippers/trucks and 23.7% have dozer. On average, most of the municipalities have more than one tractor/power tiller and one tripper/truck. (CBS, 2020)

In Pokhara metropolitan city, closed tipper vehicles, with an average capacity of 2 tons are commonly used for waste collection and transportation. A common model used by these providers is TATA 407. Apart from this, one service provider uses a compactor tipper (Goyal et al., 2020).

Figure 17: TATA 407 closed tipper

Figure 18: Compactor tipper

In Kathmandu metropolitan city, rickshaws, carts and trailer tractors are still widely used for collection and transportation of waste (Shrestha, 2018). Data from the metropolitan city shows that it used to operated 7 trucks, 1 power trailer and 130 manual carts for collecting waste (Urban Development Ministry, 2015). Similarly, report from Nepwaste project has also listed different types of vehicles used for collection and transportation of waste as shown in Figure 20 (Shrestha, 2018).

Figure 19: Backhoe loader transferring waste to container truck in Kathmandu

	Vehicle Types	Total	No. of functional vehicles in use	No. of non-functional vehicles
1	Container Truck	17	16	1
2	Tipper	23	20	3
3	Compactor	12	5	7
4	Dumper Placer	12	3	9
5	Hermetic Self-Discharging Garbage Truck	50	33	17
6	Road sweeper	5	1	4
7	Self-discharging & Loading Garbage Truck	30	3	27
8	Backhoe loader	3	1	2

Figure 20: List of vehicles used for collection and transportation in Kathmandu (Shrestha, 2018)

Although there appear to be sufficient vehicles in Kathmandu for collection and transportation, more than half of the vehicles are not functional as they were acquired in the late '80s and '90s (Shrestha, 2018).

Itahari sub-metropolitan city uses tractors attached with box trailers to collect and transport waste. These tractors have a capacity of 3 tons. The city also uses cycle trolleys which have a capacity of 400-500kg for collection and transportation of waste. (World Bank, 2020b)

Figure 21: Tractor trailer in Itahari

Figure 22: Open tipper in Waling

Similarly, Waling municipality uses tipper vehicles for collection and transportation of waste. However, these vehicles are not closed, unlike those in Pokhara. (NEFEJ, 2020)

Looking to Nepal's neighboring country, India, similar vehicles are used for waste collection. They use handcarts or tricycle with containers or bins, tricycle with hydraulic tipping containers, light commercial vehicles (mini truck) with hydraulic tipping containers, and four-wheeled mini trucks with international standard garbage collection bins for primary collection. To save travel time, urban municipalities in India have installed Global Positioning System (GPS), Geographic Information System (GIS) and Global System for Mobile Communication (GSM) in their trucks. (Singh, 2019).

Transfer Stations

The Waste Management Baseline Survey 2020 reveals that 15 municipalities use transfer stations for processing solid waste. Transfer stations typically serve to shift waste from smaller urban transport vehicles to larger vehicles for transport to landfills. Additionally, in some transfer stations, recyclable materials not yet sorted out are further segregated. Among them, 5 municipalities have compaction facilities, 4 have segregation facilities, 3 have sorting facilities, and 2 have other facilities to reduce the volume of wastes. The study also reveals that only 2 municipalities are equipped with front-end loaders, another 2 have conveyors, 3 have walking floors, and 3 have compactors as part of their waste management infrastructure. (CBS, 2020)

Generally, it can be noted that the use of technology in transfer stations is usually minimal. Observations made during the Supply Chain Analysis indicated that waste is often directly dumped from smaller transport vehicles into larger ones via ramps. In some cases, waste is dumped on open ground for a segregation process and manually searched by several waste workers for recyclable materials. The loading of larger transport vehicles is also typically done with a great deal of manual labor. Front-end loaders were only observed at larger transfer stations and were the exception rather than the rule.

Segregation and Processing for Recycling

The segregation stage, which precedes recycling, is predominantly conducted manually in Nepal. Once the incoming waste at segregation locations or transfer stations is unloaded, waste workers segregate the waste into different waste categories, which can very significantly. In case of plastics, segregation is commonly done by polymer types such as HDPE, LDPE, PP, PET, etc. Segregation based on quality grades of plastic waste was rarely observed in Nepal. Several sources and reports affirm the practice of manual sorting. For instance, a report from the Nepal Forum of Environmental Journalists (2020), focusing on waste management across three municipalities, highlights the significant role of human labor in the sorting process. Likewise, another report also indicates that waste is segregated by scavengers in Kathmandu (Rana, 2013). Internationally typically used systems such as magnetic separators, waste screening systems or sensor-based technology was not observed. Even basic equipment such as conveyer belts for manual hand sorting are still extremely rare.

Figure 23: Manual sorting of waste

Recycling plastics in Nepal is mostly an informal activity with many small-scale plastics recyclers buying direct from waste collectors. Limited activities have been done on plastic waste recycling. Among different types of plastics, PET plastics are recycled within Nepal and other types of plastics are sent to India for recycling. (Labra et al., 2023)

Figure 24: Baling of PET bottles

The waste plastics are mostly recycled into pellets and granules. Based on our visit and report we found the use of shredding, bailing machines and plastic extruders among private ventures for plastic recycling in Nepal. Of the three machine types mentioned, balers are the most used, followed by plastic extruders. The use of shredders is still very limited in Nepal. For example, Recycler Saathi, an initiative by CREASION, collects PET bottles from various sources, which are then baled before being sent to their recycling partner (Recycler Saathi, 2023). Avni ventures run their own PET baling center, where PET plastics are compressed and sold to recycling companies (Avni, 2023). Three Star Pipe Udyog from Pokhara uses plastic extruder for melting and extruding waste plastic to make electrical insulating wiring pipes (Goyal et al., 2020). Green Road Waste Management from Pokhara uses shredder and baler machines for plastic recycling.

Figure 25: Baled PET bottles

A few municipal bodies also utilize machines for plastic recycling. The NEJEF report highlights the use of plastic shredding machines by Waling Municipality as part of their plastic waste management efforts. (NEFEJ, 2020)

Compared to Nepal, India employs a mix of mechanical separation technologies such as trommel screens, air density separators, and manual separation (PwC, 2017). Overall, a higher level of technology use can be observed both in collection and segregation. The waste management appears more organized and centralized.

Figure 26: Trommel screen used for waste segregation in India

India also has diversified options for plastic recycling. Particularly LVP waste is often used for construction purposes. For example, the practice of incorporating plastics into road construction gained substantial traction in 2015 when the Indian government endorsed the use of plastic materials in road construction, particularly in urban areas. (Datta et al., 2017). As a result, India has developed over one hundred thousand kilometers of roads in at least 11 states. Additionally, LVP waste is repurposed as an alternative fuel source (RDF), wherein waste plastics are directed to cement kilns. The Indian government has also specified specification for RDF used in cement plants (Saha et al., 2017). Another prominent avenue is the recycling of PET bottles, with data indicating the presence of 1,777 known plastic recycling units in India (Singh, 2014).

Final disposal

The terminal phase of waste management culminates usually at the landfill site, where all unsorted waste is deposited. Informal Waste Workers routinely engage in the retrieval of recyclable materials from this mixed waste stream, a process conducted manually. These workers sort the recyclables into burlap sacks for accumulation. Upon filling these sacks, they are then sold to scrap dealers, typically on a weekly cycle.

The incoming waste and separated materials are generally transported via larger trucks. In major landfill sites, for example, the Kathmandu Banchare Danda landfill, bulldozers are employed to distribute, compress, and cover the waste with earth. However, this procedure is not prevalent on smaller landfill sites, and even at larger sites, there is often a shortage of bulldozers to carry out these operations to meet the criteria of a sanitary landfill, according to local employees and engineers involved in the landfill planning and operations.

Figure 27: Waste disposed at landfill site

Figure 28: Informal Waste Worker collecting recyclables

Figure 29: Waste collected in gunny bag

Figure 30: Loading recyclable waste to send it to scrap dealer

Implications for Technical Development

To effectively manage the growing volumes of waste in Nepal, it's crucial to implement a variety of machines and technologies. Only through this can the increasing amounts of waste be processed efficiently, and a maximum proportion be directed towards recycling opportunities. However, for the investment in technology to be worthwhile, centralization, standardization, and legalization of many processes in Nepalese waste management are essential. This is the only way to justify the technological effort and lead to meaningful optimizations in waste management.

As NIDISI ReValue focuses particularly on the processing of LVP, it is important to consider which technology should be introduced in Nepal specifically for the segregation and further processing of LVP for road construction under the *ReValue Method*, to ensure efficient and economic provision of LVPs.

Starting with segregation, the use of automatic sorting systems and conveyor belts for material transport within a facility can lead to significant efficiency gains. However, it should be ensured that the technology employed is easy to maintain and that there is a good availability of spare parts in Nepal. Ideally, therefore, machines from India should be utilized, as this makes importation the easiest and the necessary technology is already available there. Since manual segregation can still be sensible in many areas, it should be further optimized with a flat conveyor belt moving the waste at approximately 0.1m per second for inspection.

For further processing after segregation, the use of shredders becomes necessary. They are essential for the preparation of LVP for use in road construction, for which the material must be shredded to a size smaller than 10mm. So far, such shredders are scarcely available in Nepal, as they are only truly necessary for recycling, a sector that is still small in Nepal with a large portion being directly exported to India. The additional use of balers can help to compact both shredded and unshredded plastic waste, making transport more efficient. Particularly, shredded plastic waste has a large volume with a weight of under 100kg per cubic meter. While balers are somewhat available, they are not sufficiently widespread and are comparatively inexpensive and easy to maintain.

Thus, the initial hypothesis of ReValue is confirmed: the use of shredders and balers will become necessary to establish the supply chain of LVP for road construction in Nepal. Furthermore, both types of machinery can contribute to further reducing transport costs for other types of plastics and to improving their recyclability. However, if other segregated plastic types are to be shredded, particular attention must be paid to the purity and cleanliness of the material before shredding. Many recyclers have reported issues with the quality of material delivered after manual segregation in Nepal and are therefore skeptical about already shredded material, as it is more difficult to control for purity and may need to be re-segregated.

Conclusion

Macro-Economic Analysis

Nepal faces a significant challenge with plastic waste management, as evidenced by the projection of generating approximately 988.7 tons of plastic waste daily by 2023. This equates to a staggering annual accumulation of 360,875 tons. Looking ahead, the anticipated growth in plastic waste generation by 8.34% by 2030 signals an urgent need for proactive measures.

A detailed analysis of waste composition reveals that households are the primary contributors to MSW, with plastics making up 12%. Institutional and commercial wastes have a higher plastic content, increasing it to a total of 16% plastics within the overall waste matrix. The presence of significant organic waste complicates segregation efforts, particularly in areas without established protocols.

Urban centers, particularly in central Nepal and the eastern Terai region, exhibit higher volumes of plastic waste, which is exacerbated by factors such as increased economic activities, better road accessibility, higher income levels and tourism activities. The predominance of HDPE in the polymer composition of Nepal's plastic waste further distinguishes it from global trends, pointing to unique local consumption patterns and waste management challenges.

However, it is important to acknowledge the limitations of the current data, which predominantly represent urban areas and may not fully encapsulate the country's rural waste generation profile. There is an evident necessity for more current, inclusive, and geographically expansive research to form a holistic view of Nepal's waste management needs.

Supply Chain Analysis

Regarding collection and segregation, it is generally the regulatory responsibility of municipalities to manage these processes in Nepal. However, they often find themselves overwhelmed by this task, resulting in regulations that are inadequately introduced and enforced. As a result, this leads to highly fragmented and inefficient systems that are heavily reliant on private and informal sectors, as well as economic interests. With no economically viable disposal or recycling options for many types of plastics and a high degree of market fragmentation, the overall collection rates are low, leaving significant amounts of plastic waste uncollected and outside the scope of potential recycling processes.

Regarding the trajectories of plastic waste, the study has identified various material flows with different disposal methods, ranging from linear practices such as open dumping and burning, to more sustainable approaches including circular practices like the mechanical recycling of PET into bottles or HDPE and LDPE into black polyethylene pipes. These practices vary depending on factors such as the type of material, location, concentration of plastic waste, proximity to recycling facilities, as well as the development and coordination of waste management infrastructure.

Through the analysis, it has been determined that a substantial portion of plastic waste across all polymer types is not collected or segregated for recycling due to the lack of cost-effectiveness in collection, segregation, and recycling processes, as well as the absence of incentives. Given the widespread lack of landfills meeting internationally recognized standards, it is evident that a significant proportion of this unmanaged plastic waste eventually enters natural environments, including rivers, and ultimately the ocean.

Conversely, a noteworthy amount of plastic waste is directed towards recycling processes by exporting it to India. There are various pathways, both open and closed-loop, in place. Despite this, the recycling industry in Nepal is limited in size, and according to conducted surveys, most plastics are transported to India for recycling.

The practice of plastic segregation is more consistently observed in larger cities and their central areas compared to rural regions. In urban centers such as Kathmandu, Pokhara, and Bharatpur, materials like HDPE, LDPE, and PET are segregated for recycling. In contrast, the findings indicate that segregation in rural areas tends to be more cursory, with only HDPE and PET generating higher value. Multi-layered plastics (MLP) are not segregated but are disposed of in various ways throughout the country.

Political Framework Analysis

The introduction of a three-tier government system under the new Constitution and the Local Government Operation Act 2017 has decentralized solid waste management responsibilities, primarily to local governments. However, significant challenges in institutional setup and capacity have been identified, such as inadequate technical support, poor project execution, limited provincial involvement, and understaffing in local waste management divisions.

The Solid Waste Management Act of 2011 and its corresponding Rules of 2013 lay a foundational legal structure that mandates local authorities to implement and oversee waste management activities. However, the lack of detailed guidelines and incentives for segregation and recycling in these regulations suggests a need for more robust policy development. The introduction of the plastic bag regulation and the 2022 SWM policy underscores the government's commitment to addressing the plastic waste issue but also points to the necessity for ongoing policy evolution and enforcement to accommodate technological advancements and systemic needs.

While the establishment of a Council for SWM and a Technical Cooperation Center represents a step forward in addressing technical and policy support challenges, the findings highlight the critical need for capacity building at the local level, enhanced provincial involvement, and the creation of technical support units.

Stakeholder Analysis

In the chapter on stakeholder analysis, several key groups involved in Nepal's plastic recycling market are meticulously examined for their roles, interests, and potential partnership opportunities. Identified stakeholders include plastic collectors and aggregators, informal waste workers, recycling industries, manufacturers, government and regulatory bodies, and impact organizations, each playing a distinct yet interconnected role in the waste management ecosystem.

Plastic collectors and aggregators emerge as pivotal actors, bridging the gap between waste generation and recycling, with their business models critically hinging on the economics of buying low and selling high. Their influence varies by size and location, and they face challenges such as legal compliance and operational sustainability.

Informal waste workers are the backbone of the collection process, albeit under-recognized and under-compensated. They represent a substantial portion of the workforce, collecting and sorting recyclables, and their entrepreneurial drive is often overshadowed by their vulnerability and lack of bargaining power.

Recycling industries are the endpoint in the plastic waste value chain, with a critical role in transforming waste into reusable materials. While Nepalese industries focus on certain types of plastics and usually encompass lower quantities due to technological and capital constraints, Indian-related companies have a broader scope, significantly influencing the flow and processing of Nepal’s plastic waste.

Plastic manufacturers, contribute significantly to the market’s plastic content and face the dual challenge of meeting consumer demand while managing production waste responsibly.

Government and regulatory bodies possess the theoretical authority to enforce substantial changes in waste management practices. However, their effectiveness is often undermined by inefficiencies and lack of transparency, leading to mismanagement and gaps in the implementation of environmental policies. This challenge is compounded by a deficit in technical expertise, particularly at the municipal level, and occasionally, the prevalence of self-interest, which can overshadow the prioritization of sustainable plastic waste management systems.

Lastly, impact organizations, including both international entities like the UNDP and national groups, are instrumental in driving sustainable practices and innovations in waste management. Their efforts are fueled by a blend of environmental and social motivations, and they leverage international funding and community connections to influence the sector.

Overall, the findings underscore the potential for cooperation among these stakeholders, particularly in the context of establishing a supply chain for the NIDISI ReValue project. It emphasizes the importance of prioritizing stakeholder groups to facilitate partnerships that can advance the effectiveness and sustainability of plastic waste management in Nepal.

Technological Analysis

The landscape of waste management is characterized by a low adoption of technology and a high reliance on manual labor. The use of vehicles for waste collection is limited, with traditional means such as rickshaws and carts still prevalent, even in metropolitan cities such as Kathmandu and Pokhara. Only for longer transport distances and aggregated waste amounts trucks and tractors are used. Dump trucks are sometimes observed in more urban areas but are often antiquated and non-functional.

Only a minority of municipalities in Nepal have access to appropriate vehicles for waste transport and management, and their numbers are few. Advanced and adequate waste management technologies are scarce. Transfer stations, serving as intermediate waste sorting locations, are in use by just 15 municipalities, with a minimal presence of technology to aid in the process. The stations that do exist largely depend on manual methods for the transfer and segregation of waste.

The segregation of recyclables from waste continues to be a manually intensive task, with workers sorting waste into categories by hand. Plastic recycling is conducted by small-scale informal recyclers and a handful of private ventures, but again, the technology in use is limited, with balers and extruders being the most common technology implemented.

Overall, the key findings point to an urgent need for technological enhancement in Nepal's waste management sector. The current system's heavy reliance on manual labor and the minimal use of machinery not only hinder efficiency but also reflect a broader issue of technological lag in this critical area of public health and environmental management.

Implications

Macro-Economic Analysis

There is a significant amount of MLP and PP film plastics available in Nepal that are currently not collected for recycling but could be utilized for *Plastic Roads* under the *ReValue Method*. The analysis indicates that certain high-value plastics like HDPE, PET, LDPE, and rigid PP are collected to a significant extent and sold for recycling activities in urban areas, as confirmed by plastic aggregation hotspots in Pokhara and Kathmandu. However, MLP and PP film plastics are generally not collected at these spots. Consequently, based on the findings, MLP and PP film plastics offer an available and consistent source of materials for road construction and other activities from a macro-economic perspective.

There is a great potential for plastic recovery due to the high amount of plastic waste currently available, and growth is expected in the future. From a macro-economic perspective, the analysis suggests a favorable environment for plastic waste collection and recycling activities. Considering projected population growth and urbanization, a continuous supply of plastics, both now and in the future can be anticipated.

There is high potential in central and south-eastern Nepal to achieve higher volumes of plastic collection. To maximize plastic recovery, focusing on bigger cities and industrial sources would be advantageous if MLP and PP film are targeted for sourcing. Geographical location plays a significant role in the volumes and consistency of plastic supply. Central and south-eastern areas of Nepal are identified as hotspots for plastic generation and have reliable access to road network infrastructure, making them promising for setting up plastic collection and processing units for recycling, including *Plastic Road* construction. For MLP and PP film, it is recommended to concentrate on bigger cities, as their share of the overall waste may be relatively lower than other plastic types, although further confirmation is needed. Considering this condition, selecting a location near one of the biggest cities is advisable as a first step.

Supply Chain Analysis

The recycling pathways for HDPE, LDPE, and PET are functional in urban areas as well as in the Terai region, leading to a good recycling rate due to given profitability. Consequently, the ReValue project should not focus on these types of plastics in geographic urban clusters or the Terai, as additional incentivization through Plastic Credits would primarily result in a competitive advantage but not necessarily higher recycling rates.

Conversely, more remote regions in the Hilly and Mountain regions face challenges due to their difficult accessibility and the lack of scale effects from their lower waste volumes, which hardly allow for the economical collection, processing, or recycling of plastic waste. It is precisely here that there is potential to enable the collection and processing of various polymer types through Plastic Credits. Additionally, the use of balers could significantly reduce transportation costs with minimal financial expenditure.

Overall, there is great potential to establish more recycling infrastructure in Nepal and to completely recycle the plastic waste that is currently exported to India after mainly manual processing. This could drastically shorten transport routes, leading to cost reductions in recycling and consequently to larger volumes of plastic waste that can be recycled profitably. However, what is currently lacking are investments in machinery for the industrial processing of plastic waste into recyclate, as well as the linkage with the manufacturing industry.

The situation is different for low-value plastics such as MLP, for which there are only experimental uses beyond disposal. It has been demonstrated that in Nepal, sanitary landfills are currently the only environmentally sound disposal option available, but in realty these often resemble dumpsites, creating the most urgent need for action. Here, the ReValue project concept offers a long-term solution in the combination of material use in road

construction, as well as financing through Plastic Credits, if implemented correctly in collaboration with political institutions.

As has been shown, the disposal and recycling chains for plastic waste in Nepal represent an extremely fragmented market with overwhelmed political institutions and opaque power structures. Accordingly, the barriers, complexity, and uncertainties in scaling waste management initiatives are high. Therefore, solutions should only be developed in collaboration with legally responsible institutions, especially with the Municipalities, to reduce fragmentation in the long term and to increase the efficiency and attractiveness of the market through better predictability for further investments. Equally important is the collaboration to ensure the complete capture of various waste streams, some of which also have a negative value that must be regulated to prevent improper disposal.

Political Framework Analysis

The absence of laws and regulations specifically addressing plastic waste poses significant challenges on its management. Without clear guidelines, there is a lack of direction on how to handle and dispose of or recycle plastic waste properly. This, in turn, leads to institutional uncertainty and instability, as there is a lack of well-defined structures and roles for different stakeholders involved in waste management, hindering effective coordination.

As a result, it becomes difficult to implement innovative solutions, such as *Plastic Roads* and Plastic Credits, to effectively tackle the plastic waste problem. Without a well-defined legal framework, innovative solutions may only remain in the pilot stage, limiting their full-scale implementation and impact.

Though, when considering low-value plastic waste in particular, the implementation of Plastic Credits and the use of these plastics in road construction could play a vital role in addressing the current regulatory gaps. This approach has the potential to resolve the improper disposal of LVP and simultaneously provide better funding for plastic waste management, until comprehensive regulatory frameworks have been designed and implemented.

Stakeholder Analysis

The NIDISI ReValue project requires strategic alliances with key stakeholders for its execution. Therefore, large Plastic Collectors and Aggregators are critical for their access to low-value plastics and established infrastructure, and they offer significant potential for mutually beneficial collaboration through the Plastic Credits system. However, aligning their practices with the project's sustainability standards is essential.

Informal Waste Workers, while highly interested in the project for potential economic and safety benefits, have low power due to their informal status. Structured support systems like cooperatives could enhance their role in the projects future but render them unsuitable partners for the initial stages.

The Nepalese Plastic Recycling Industry presents an opportunity for the project to aid in technological and capital enhancements, allowing them to process a broader range of plastics. The India-related Plastic Recycling Industry, with its advanced capabilities, emerges as an even stronger potential partner for efficient waste processing at scale and cross-border knowledge exchange.

Plastic Manufacturers hold significant power and could be incentivized to participate by highlighting the project's sustainability and cost-reduction benefits. Government & Regulatory Bodies are critical for policy support and project integration, necessitating active engagement to align the project with national waste management strategies and ensure long-term access to waste sources.

Impact Organizations, both international and national, are key potential partners for their environmental and social expertise and can provide vital support in project consultancy and on-the-ground implementation.

In essence, a multi-faceted partnership strategy that leverages the strengths of each stakeholder group and aligns their interests with the project's objectives is crucial for the ReValue project to effectively transform Nepal's plastic waste management landscape.

Technological Analysis

The findings emphasize the importance for Nepal to adopt various machines and technologies to efficiently manage the increasing volumes of waste and enhance recycling. Centralization, standardization, and legalization are identified as necessary steps to make technological investments worthwhile and optimize waste management.

For segregation, automatic sorting systems and conveyor belts are recommended for efficiency, but with consideration for easy maintenance and local availability of spare parts. Machines from India are preferred due to the ease of importation and existing availability. Manual segregation is still considered valuable, optimized by a flat conveyor belt moving at a speed that allows for effective segregation.

The processing phase requires shredders to prepare LVP for road construction by reducing it to smaller than 10mm. However, shredders are not widely available in Nepal, with most plastics being exported to India for recycling. Balers, which compact plastic waste for more efficient transport, are somewhat available and considered inexpensive and easy to maintain.

The hypothesis of ReValue, that shredders and balers are essential for establishing an LVP supply chain for road construction in Nepal, is confirmed. They could also reduce transport costs and enhance the recyclability of other plastics. Nevertheless, caution is urged regarding the purity and cleanliness of segregated plastics before shredding, as contaminated materials could complicate recycling processes and require re-segregation.

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