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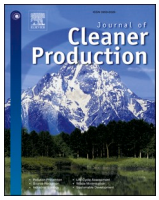

System-wide assessment of Indonesia's plastic value chain: Mapping flows and stakeholders dynamics

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A R T I C L E I N F O

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A B S T R A C T

Indonesia faces a severe plastic pollution crisis driven by extensive plastic usage and inadequate waste management. To effectively address this issue and promote sustainable circularity, it is crucial to understand the dynamics of plastic production, use, and end-of-life management, as well as the interactions among stakeholders throughout the plastics lifecycle. Without such a comprehensive understanding, mitigation efforts risk being ineffective or misdirected. Existing research tends to be fragmented, focused on specific regions or segments, and therefore fails to provide a comprehensive, system-wide analysis. This limits the development of effective and actionable interventions. To address this gap, this study employs a systems-based approach called CVORR (Complex Value Optimisation for Resource Recovery), which provides a structured framework for analysing complex resource rrecovery systems. Specifically, the study focuses on the initial pivotal steps of the CVORR approach: 1) mapping and analysing plastic mass and monetary flows, and 2) identifying key stakeholders directly involved in these movements in the Indonesian plastics value chain. This marks the first-ever systemic analysis of Indonesia's plastic value chain, offering novel insights into stakeholder power dynamics and their influence on plastic flows. The study's findings attribute Indonesia's plastic crisis to power imbalances, social norms, financial constraints, and varying value perceptions. Charting the power dynamics among formal and informal stakeholders is key to fostering synergies and collaboration across all sectors of the plastics value chain, driving transformative changes in both plastics production and waste management. Co-creating, testing, and piloting multidimensional interventions – spanning technical, infrastructural, policy, economic, and communication strategies – are essential to generate scalable solutions. Future research should focus on developing intervention strategies and further exploring stakeholder dynamics, particularly the engagement of secondary (external) stakeholders indirectly involved in plastic flows.

Nomenclature list

Abbreviation	Description
APSI	Indonesian Association of Waste Entrepreneurs
CE	Circular economy
CVORR	Complex Value Optimisation for Resource Recovery
EoL	End-of-life
EPR	Extended producer responsibility
FMCGs	Fast-moving consumer goods companies
GVC	Global value chain
INAPLAS	Indonesian Aromatic and Plastic Olefin Association
IPI	Indonesian Scavengers Association
IRS	Informal recycling sector

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Abbreviation	Description
GPAP	Global Plastic Action Partnership
GVC	Global Value Chain
KLHK	Kementerian Lingkungan Hidup Dan Kehutanan (MoEF of the Republic of Indonesia)
kt	Thousand tonnes
MCPs	Materials, components and products
MFA	Material flow analysis
MoEF	Ministry of Environment and Forestry
MRF	Material recovery facility
MSW	Municipal Solid Waste
Mt	Million metric tons
NAP	National Action Plan
NPAP	National Plastic Action Partnership
PBS	Polybutylene succinate
PE	Polyethylene
PET	Polyethylene terephthalate
PIM	Independent Indonesian Scavengers
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RT/RW	Rukun tetangga (RT) and Rukun warga (RW): Neighbourhood (RT) and community (RW) organisations/associations
TPA	Landfill (Tempat Pemrosesan Akhir, TPA)
TPS	Temporary Disposal Site
TPST	Intermediate Transfer Facilities
TPS3R	Temporary Waste Processing Site/3R Centre
SWM	Solid waste management

1. Introduction

Plastic waste mismanagement, coupled with an ever-increasing plastic waste generation rate, has raised significant concerns about pollution and environmental damage, leading to serious repercussions for the economy and society. According to the European Environment Agency, only a small portion of the approximately 390 million metric tonnes (Mt) of plastics produced globally in 2021 (Tiseo, 2022) was managed for resource recovery at the end-of-life (EoL) stage (EEA, 2023). Specifically, 9 % was recycled and 12 % was incinerated for energy recovery, while most either remained in use (stock) – typically non-packaging plastics - or were disposed of or otherwise handled through landfilling, burning, burying, littering, or unintentionally leaked into the environment (EEA, 2023). Another report stated that 9 % of plastic waste worldwide is recycled, 19 % is incinerated, and 50 % is sent to landfills, with 22 % mismanaged through disposal in dumpsites, open burning or leaking into the environment (Wilson, 2023).

Additionally, 60 % of plastics are used for short-term single-use applications, 40 % of which is plastic packaging (Wilson, 2023). Recent calls for international action, such as via the Global Plastics Treaty, highlight the importance of a systems-based approach to tackling plastic pollution by adopting improved plastic waste management practices that prevent and reduce plastic pollution (Iacovidou et al., 2020). This approach contrasts with traditional forms of reductionist thinking characterised by piecemeal and unilateral approaches that oversimplify issues, reduce complexity and often lead to stalled or unrealistic solutions, resulting in lock-ins and negative trade-offs elsewhere in the system (Iacovidou et al., 2021). A systems-based approach acknowledges the inherent interconnectedness and interdependence of system components, making it inherently holistic and multidimensional. It decodes complex dynamics by examining the measurable positive and negative impacts across environmental, economic, social and technical domains as shaped by political, organisational and institutional aspects.

Employing a systems-based approach is essential for uncovering the underlying factors that cause the pollution problem and revealing the hidden connections within the system, whilst recognising that there is not a one-size-fits-all solution to this complex challenge (Iacovidou et al., 2020, 2021; Richter et al., 2020). The latter is an important deliberation that is often undermined in political decision-making. Nevertheless, multidimensional positive and negative impacts, also known as complex value, are strongly influenced by changes in climate, geographies, cultures and political regimes (Gregson and Crewe, 2003; Iacovidou et al., 2017). For example, the lack of investment in increasing recycling plant capacity in the Global North can lead to the export of plastic waste to countries in the Global South which have fewer resources for the environmental control and management of recyclable waste materials (Wilson, 2023), whilst political regimes can influence interventions to environmental issues via policy formulation and the success of their implementation (Wilson, 2023). These indicate that a tailored, systems-based approach to tackling plastic pollution is necessary to understand the way plastic value chains are run and, in turn, help to identify the root causes of plastic pollution to highlight points of intervention (Iacovidou et al., 2020).

Central to a systems-based approach are the processes (i.e., value chain activities and performance) and structures (i.e., formal/informal arrangements that shape system organisation and decision-making) (Gerassimidou et al., 2022); these involve multiple stakeholders with diverse interests, needs, and desires to organise and prioritise values (Appadurai, 1988; Corvellec and Hultman, 2014; Iacovidou et al., 2020). The term "stakeholder" refers to any group or individual with an interest involved in the plastics value chain, and therefore, interacting with the system (Gerassimidou et al., 2022). In stakeholder theory, attributed to Freeman (2010), value is often considered in terms of money. Porter and Kramer (2018) argue that 'shared value' recognises societal needs, defining markets beyond conventional economic needs, and aligning market and non-market values (Porter and Kramer, 2018). Shared or blended value from multiple stakeholders has since formed the basis of value mapping approaches that assess value captured, lost, or distributed from multiple stakeholder perspectives and dimensions (Bocken et al., 2015; Bocken et al., 2014; Uusitalo and Antikainen, 2018). Identifying and mapping stakeholders and their complex multidimensional values requires in-depth consideration of the economic, social, cultural, political, and ecological factors of each locality, which is particularly challenging to achieve without a systems-based approach (Benington and Moore, 2010).

Identifying and mapping stakeholders and their interactions is an essential and effective instrument to enable the conceptualisation and measurement of complex value. This approach helps to visualise system relationships and uncover the complex and diverse motivations required to drive systemic change (Iacovidou et al., 2020; Ono and Tangteerasunun, 2022; Richter et al., 2020). Understanding the roles of different stakeholders across value chain processes, as well as their key drivers and activities at the regional and national level, can offer insights into the cause-and-effect relationships between them. This understanding becomes a means of managing stakeholder networks in a way that addresses (in this case) plastic pollution (Gerassimidou et al., 2022; Ono and Tangteerasunun, 2022). Effective management of stakeholder networks is achieved by comparing and contrasting their positional, epistemic, normative and coordination power, together with their varying attributes, roles, perceptions and intentions, hereafter called *power dynamics*, which influence how the system functions and evolves over time (Gerassimidou et al., 2022).

This study aims to systematically map stakeholders directly involved in the mass and monetary flows of the plastics value chain and examine their power dynamics, using Indonesia as a case study. Indonesia is currently facing a severe plastic pollution crisis and has been identified as the second largest contributor to ocean plastic pollution globally (Jambeck et al., 2015; UNEP, 2020). This crisis is driven by multiple factors, including Indonesia's position as the fourth most populated country, high volumes of plastics placed on the market (Ismawati et al., 2022; NPAP, 2020a) and widespread waste mismanagement. The resulting impacts on ecosystems, public health and socio-economic systems are unprecedented (UNEP, 2020). In our recently published work (Iacovidou et al., 2025), we explored the systemic

interdependencies within the Indonesian plastics value chain. Our findings reveal that plastic consumption is predominantly concentrated in the food and beverage packaging sector, which poses challenges due to the prevalence of multi-layered sachets. These sachets, while offering affordability and convenience, are highly problematic in terms of recyclability and contribute to waste mismanagement. The mismanagement of plastic waste in Indonesia is exacerbated by inadequate solid waste management (SWM) systems, insufficient infrastructure, weak regulatory enforcement, and limited investment in sustainable waste practices. Approximately 160 million Indonesians lack access to formal waste collection services, leading to practices such as open dumping, burning and uncontrolled littering (NPAP, 2020a; World Bank, 2021). These issues are particularly acute in rural and coastal areas, where institutional and financial constraints exacerbate ecological and social vulnerabilities to plastic pollution.

In response to this pressing crisis in Indonesia, the research-led PISCES (Plastics in Societies) project and Partnership, which involves several authors of this work, employs a structured systems analytics approach to develop an interdisciplinary understanding of the interactions underpinning plastic waste mismanagement in Indonesia, assess the costs of action and inaction, and identify targeted interventions (PISCES, 2020). It serves as an excellent example, demonstrating how locally tailored factors and variations shape the power dynamics among stakeholders within the plastics value chain. The involvement of both formal and informal sectors in recycling efforts is crucial in Indonesia; however, both face systemic barriers that hinder effective collaboration and innovation. Mapping stakeholders and their complex interactions, enables us to identify the underlying factors influencing plastic use and waste management, as well as pathways to promote sustainability and circularity in addressing plastic pollution.

While previous research has explored stakeholders' activities downstream in the plastics value chain in specific regions of Indonesia (Putri et al., 2018; Sasaki et al., 2014; Sasaki et al., 2022; Sasaki et al., 2019), comprehensive stakeholder mapping that spans the entire plastic value chain remains absent. Existing regional or sectoral studies often focus on particular stakeholders or stages, such as waste collectors, recycling facilities, or local government initiatives, but lack an overarching analysis of how all stakeholders—public and private, formal and informal—interact and influence the flow of plastics throughout the full value chain. This creates a significant gap in understanding the systemic interdependencies, power dynamics, and complex relationships among stakeholders that drive plastic production, consumption, waste management, and disposal across different regions of Indonesia. Without a holistic, system-wide stakeholder mapping, policymakers and practitioners are limited in their ability to identify critical leverage points, address systemic barriers, and develop integrated interventions that promote sustainable and circular plastic economies. Therefore, this study aims to fill this gap by employing a systems-based approach to identify and map stakeholders involved in the Indonesian plastics value chain, analysing how their dynamics influence the movement and flow of plastics throughout the system. By doing so, it illuminates the complex network of stakeholder interactions and power relationships, and contributes to the development of targeted, effective and actionable strategies for mitigating plastic pollution and promoting sustainable waste management practices across the entire system.

2. Methodology

This study employed a novel systems-based analytical approach known as Complex Value Optimisation for Resource Recovery (CVORR) to guide the analysis and enable the integration of mass, monetary and stakeholder dynamics within the plastics value chain in Indonesia (Iacovidou et al., 2020). The CVORR is designed to be an open, iterative and pluralistic step-wise systems-based approach that can support the decision-making process across multiple levels of governance. This is achieved by systematically analysing the mass and monetary flows of materials, components and products - in this case plastics - along the value chain, identifying, mapping and analysing the key stakeholders involved, and evaluating the multidimensional value, trade-offs and the complex interactions and relationships that shape the dynamics that influence system performance and outcomes (Iacovidou et al., 2017).

CVORR consists of three main parts: the *baseline analysis* (core stage), *system assessment/evaluation* (intermediary stage) and *system refinement and optimisation* (final stage) (Iacovidou et al., 2025). These parts combined enable an in-depth understanding of all processes and structures of a value chain, from production and distribution (upstream) through to consumption/use (midstream) and EoL disposal and management (downstream). Specifically, the baseline analysis helps uncover the root causes of inefficiencies or unintended consequences and support the design of interventions, of which performance is measured (system assessment) to streamline system optimisation (system refinement). More details on the CVORR approach are provided in the Supplementary Material (**Section A**). This work delineates the key foundational steps of the CVORR's baseline analytical approach, which includes mapping and analysis of system processes, mass and monetary flows, and stakeholders.

The mass flow mapping aims to define system boundaries and outline key processes directly and indirectly associated with mass flows. Material flow analysis (MFA), a widely used tool for mapping the movement of materials, components and products (MCPs) flows, highlights system inefficiencies and identifies areas where optimisation is needed. Following the MFA is the description, quantification and mapping of monetary flows. Quantifying these flows provides useful insights into the dynamic relationships among stakeholders, driven by financial exchanges, ownership, trading, infrastructure, investments, costs, and profits. This approach clarifies how data and information are exchanged, which is crucial for understanding market prices and the movement of materials, components and products. It also sheds light on how these flows are coordinated and managed, thus enhancing our understanding of the system structures, dynamics and drivers.

The integration of mass and monetary flows of MCPs improves our understanding of the contextual factors influencing stakeholders' roles, facilitating their effective mapping. Stakeholder mapping within CVORR is conducted using stakeholder theory (Freeman, 2010), which helps identify and categorise stakeholders based on their interests, priorities, and roles. These stakeholders are then represented in the Mendelow matrix (Mendelow A., 1991), with their level of power and interest in the plastics value chain. The integration of these tools into CVORR informs the governance of the value chain, highlighting how contextual factors, value-adding activities, and stakeholder dynamics influence their roles. The sections below describe the approach used to aid stakeholder identification, mapping and analysis.

2.1. Data collection

To assess the power dynamics among internal stakeholders in the Indonesian plastics value chain, a combination of primary and secondary sources was utilised, incorporating methods of data triangulation and cross-referencing. Primary data was collected from several sources, including insights from activities within other work packages of the PISCES Partnership (i.e., surveys, field data collection, and reports that provided contextual and qualitative information on stakeholder roles and interactions), personal communications with stakeholders across the value chain (i.e., informal conversations with government officials, industry representatives, recyclers, community members and actors from the informal sector, focusing on understanding stakeholder their activities, influence, and perceptions), and participatory workshops conducted as part of the PISCES project, which facilitated stakeholder engagement, enabling verification and validation of preliminary findings, while capturing perspectives on monetary flows and power relations. Collectively, these interactions aim to develop an in-depth understanding of stakeholder roles, activities, and interactions,

emphasising inclusivity and fostering an analytical framework that captures the complex, non-quantitative aspects of power within the system.

Concurrently, secondary data was gathered through a narrative review of a broad spectrum of sources, including peer-reviewed and grey literature, including government databases and relevant reports from national and international organisations. This process focused on identifying key themes, real-world trends and contextual information relevant to the Indonesian plastics value chain. Sources were systematically selected based on relevance, credibility, and recent publication dates. By cross-referencing insights from these diverse sources, we verified consistency and validity across data sources and gained a comprehensive understanding of the complex power dynamics among internal stakeholders, which informed the CVORR approach. To enhance data reliability, multiple researchers independently coded the qualitative data, followed by consensus discussions.

This comprehensive approach enabled us to build a detailed, credible understanding of internal stakeholder power dynamics, ensuring data validity, reliability, and richness.

2.2. Data analysis: mapping mass and monetary flows

Evidence from the data collection process showed that there is a lack of sufficient information to construct a fully quantitative MFA for the Indonesian plastics value chain. In such cases, constructing a qualitative MFA is an essential prerequisite, as it helps to clarify the processes involved in a value chain that dictate the MCPs' flows. Likewise, the monetary data available is fragmented, further complicating efforts to obtain insights into monetary flows and their impacts on stakeholder dynamics. Consequently, it is critical to explore alternative ways of understanding these stakeholders' dynamics (Iacovidou et al., 2020).

To address data gaps, we employed three logical assumptions as follows: 1) symmetry in the economic value of traded goods; 2) a proportional relationship in the economic value of manufactured plastic MCPs; and 3) an estimated average retail margin for fast-moving consumer goods (FMCG) companies ranging from 3 % to 10 %, for which we adopted a conservative estimate of 10 %. These assumptions were applied specifically to stages where empirical evidence was lacking and are intended to support a coherent interpretation of system-wide flows, rather than to achieve numerical accuracy.

2.3. Data analysis: stakeholder mapping using the stakeholder theory and the mendelow matrix

According to stakeholder theory (Freeman, 2010), stakeholders can be grouped into internal and external stakeholders depending on the type of their involvement in the system, whether direct or indirect, respectively (Freeman, 2010; Friedman and Miles, 2006). Within a system (i.e., value chain), internal stakeholders can be considered those who play direct roles in the physical production, consumption and waste generation and management of plastics across the value chain, while external stakeholders are those who are not directly engaged in the physical flow of plastics, but exert an indirect influence on them (Fearne et al., 2012). This distinction has been recognized as an essential dimension to broaden the boundaries of the value chain analysis (Fearne et al., 2012). An overview of the main stakeholder categories adapted within the system content, including their description, is provided in the Supplementary Material (Fig. B1).

In the Indonesian plastics value chain, the power dynamics of stakeholders are multi-variable and can be affected by several factors, such as personal values, emotions, and historical interactions. This makes it difficult to consider the interactions between all internal and external stakeholder categories concurrently. This work is the first part of our stakeholder mapping, focusing on identifying the internal stakeholders involved in the plastic waste management sector. As there are several glossary terms used to describe stakeholders in the literature, for consistency and clarity, this study uses the glossary terms (see Table C1 of Supplementary Material) defined in (Cano et al., 2022) and which are used to describe the activities of stakeholders involved in recyclable waste materials management in developing economies.

Concerning stakeholder interactions and power dynamics, the study makes use of the Mendelow matrix. The Mendelow matrix depicts four categories in a two-dimensional matrix with four quadrants using combinations of two variables, *power* and *interest* (Mendelow A., 1991), as shown in Fig. 1. Herein, *power* represents the ability of a stakeholder to influence decisions and actions, while *interest* refers to the level of concern regarding the issue of tackling plastic pollution in Indonesia. The Mendelow matrix is a useful tool to capture stakeholders' vested interest and power in the plastics system, albeit in a simplified way. Notwithstanding, it provides a good understanding of stakeholder power dynamics at a specific point in time (given that dynamics could change over time in a system) (Cuofano, 2023). Fig. 1 depicts four stakeholder categories according to their influence in making changes in the system (e.g., by an action plan): level of power in making systemic changes and level of interest in what/how these changes will be orchestrated. The four categories are explained within the context of project management, focusing on addressing plastic pollution (Cuofano, 2023; Mendelow A., 1991).

2.4. Limitations

This study acknowledges several limitations. These include constraints in data availability, reliance on secondary sources, and the use of model simplifications. To mitigate these issues, we applied a conceptual approach to map mass and monetary flows that is instrumental in integrating dynamic processes, such as information flows and decision pathways. This allows us to identify systemic leverage points within the Indonesian plastics value chain.

Rather than aiming for high accuracy and granular precision, our approach serves as a heuristic framework that evolves based on feedback and emerging patterns within the system, helping to avoid oversimplification despite data limitations. Therefore, we relied on

Fig. 1. Mendelow's matrix for stakeholder analysis. Adapted from (Cuofano, 2023). As a reference: '*power*' refers to "*the extent to which one stakeholder can arouse in other stakeholders the need to engage in activities that would not be taken otherwise* via *different forms*" (Gerassimidou et al., 2022) (p. 658), such as positional, epistemic, normative and coordination power; and '*interest*' is the likelihood/motivation of a stakeholder to use their power to ensure their underlying needs, goals, preferences and actions are addressed (Cuofano, 2023).

secondary data sources and used logical assumptions to bridge data gaps. and construct a representation of mass and monetary flows. This enables the identification of key stakeholders and an analysis of power dynamics within the system.

Another limitation is the reliance on self-reported stakeholder data, which may reflect subjective interpretations. Additionally, the selection of workshop participants may not capture the full spectrum of stakeholder perspectives. To mitigate these biases, we triangulated data from multiple sources and cross-referenced findings to enhance validity. The intentional exclusion of external stakeholders in this study reflects the complexity of the formal and informal organisation of Indonesia's plastics value chain. However, we recognise that the transition towards reduced plastic pollution and enhanced sustainability in the plastics value chain with minimum trade-offs requires a holistic understanding of synergistic cause-and-effect relationships of both internal and external stakeholders across the entire value chain (Brandon et al., 2023). A follow-up study will address the roles and degree of engagement of external stakeholders, analysed in tandem with the dynamics exerted by the internal stakeholders.

Finally, inconsistencies in available data highlight critical knowledge gaps and raise concerns about transparency and accountability in the system. These issues must be addressed to enable evidence-based and effective waste policy development in Indonesia. Despite these limitations, the study provides a valuable foundation for identifying policy leverage points and guiding future research.

3. Results

Following the CVORR baseline analysis, the mapping of the plastics mass flows was initially carried out, followed by the monetary flows and internal stakeholders mapping, as shown in Fig. 2. The flow of plastics across the Indonesian value chain provides insights into inefficiencies, impacts and intensive processes in which relevant stakeholders are involved and includes four main stages:

i. **Production**, which is the stage of production of plastic raw materials (i.e., resins), components (i.e., plastic parts of a product) and products (e.g., a container, bottle, tray, tube, etc.), referred to hereafter as MCPs, also includes imports and exports of both virgin and recycled plastic MCPs, and finished plastic (packaged and non-packaging) products.
ii. **Consumption (or use)**, including the distribution of plastic MCPs to different outlets, i.e. wholesalers and retailers such as traditional markets,[1] from where consumers/end-users can purchase them based on their needs; and the consumption/use phase in the household or on the go (i.e., outside of the household) and by the industrial, commercial and agricultural sectors.
iii. **Disposal** is the point where the plastic MCPs are no longer wanted/needed and become 'waste' and are disposed of in multiple ways, depending on local waste management practices. It is the plastic MCPs' point of exit from the use stage and entry to the (mis-)management stage.
iv. **Management**, which encompasses activities relating to the collection, sorting, and management of plastic waste, such as recycling, controlled (i.e., landfills) or uncontrolled (i.e., dumpsites) disposal, littering and open burning.

Fig. 2 presents the mass flow of plastic MCPs in thousand tonnes (kt), alongside corresponding monetary flows expressed in USD per tonne, at the national level in Indonesia. A visual legend is provided to clarify the evidence types, symbols and colour coding used. While Fig. 2 focuses on illustrating the key flows, further details on data sources, underlying assumptions, and methodological steps are included in the Supplementary Material (Section D). This separation enables the manuscript to maintain a clear and focused narrative without being burdened by extensive datasets or technical elaborations.

Fig. 2 highlights multiple entry and exit points within the plastics value chain. At the production stage, the data presented reflect domestic polymer production, plastic MCPs manufacturing and imports, including flows of virgin and recycled resins. It is important to note that data for monetary flows remain highly fragmented, necessitating the use of well-reasoned assumptions to ensure conceptual coherence.

The primary objective of this mapping exercise is not to achieve exact quantification but to enhance a systemic understanding of how mass and monetary flows move through Indonesia's plastics value chain. This broader view enables the identification of interdependencies, inefficiencies, and potential leverage points for sustainability improvements. Furthermore, by concentrating on trends and relationships rather than accurate data, the analysis facilitates deeper insights into the stakeholders' interactions that shape their behaviours and decision-making power. Although the map presents national-level data, we acknowledge that regional variations exist. As such, this representation serves as a strategic tool for revealing system-wide patterns, rather than a definitive account of local conditions. Prioritising insight over numerical accuracy enables the development of a flexible analytical framework that can accommodate the complexity and dynamics of Indonesia's plastic value chain.

It is important to note that the evidence used for constructing mass and monetary flows is highly fragmented. Consequently, the analysis relies on reasoned assumptions to enhance conceptual clarity. The aim is not to achieve precise figures, but to provide a systems-level understanding of how mass and monetary flows enable the interactions among stakeholders within Indonesia's plastic value chain. This broader perspective helps identify key patterns, inefficiencies, and opportunities for improved stakeholder collaboration. While the current mapping reflects national-level data, regional variability is acknowledged. By prioritising interpretive insights over numerical precision, the analysis enables a more flexible and context-sensitive framework for understanding stakeholder dynamics and informing future interventions.

3.1. Stakeholder identification and mapping at the national level

According to the stakeholders theory those who administer the flows of plastic MCPs and whose interest(s) emerge via their direct involvement in the mass flow processes are referred to as internal stakeholders (Fearne et al., 2012). Fig. 3 maps the main internal stakeholders involved in the plastics value chain in Indonesia following matching the colour coding system used to depict the mass flows for clarity (see Fig. 2). Specifically, the pink colour indicates stakeholders operating in the upstream and midstream part of the value chain (i.e., production, incl. imports/exports, manufacturing, distribution, and consumption/use) and the blue colour indicates stakeholders operating in the downstream part of the value chain (i.e., disposal and management).

Fig. 3 is colour-matched with the description of stakeholders' role in the plastics value chain in Table 1. The description of certain stakeholders allowed for additional internal stakeholders to be identified; also outlined and described in Table 1. Table 1 sheds light on the differences between the local variations and the broader international discourse surrounding waste management terminology contributing to a more comprehensive global understanding of the Indonesian context.

3.1.1. Exploring stakeholders operating upstream of the plastics value chain

The upstream and midstream part of the plastic MCPs value chain consists mainly of traders (i.e., importers and exporters), the plastics industry - that includes the polymer and plastic manufacturers at the production stage - as well as distributors, wholesalers/retailers at the interface between production-distribution, and consumers/end-users at

[1] Traditional market is defined as the place where purchase of goods and transaction between sellers and buyers occurs including stores, marketplaces, and businesses in the hospitality sector.

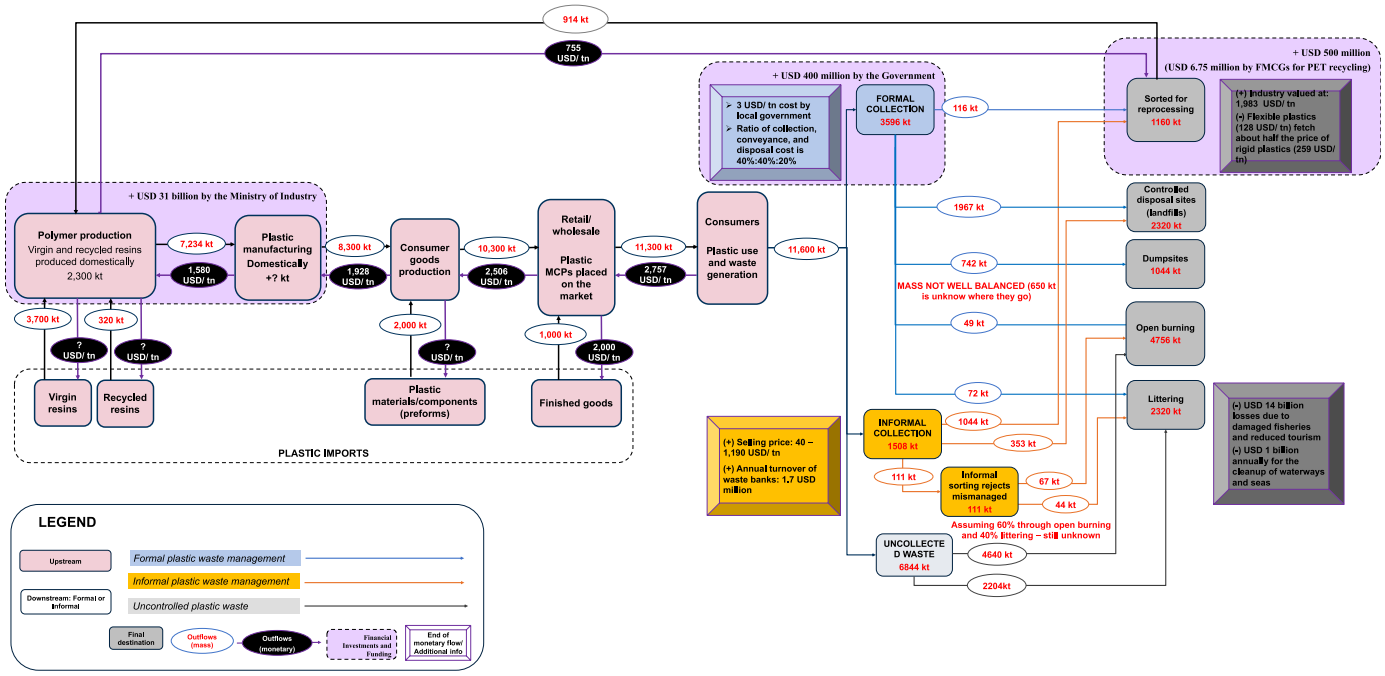

Fig. 2. Mapping of mass and monetary flows of plastic material, components and products (MCPs) across all stages of the value chain in Indonesia.

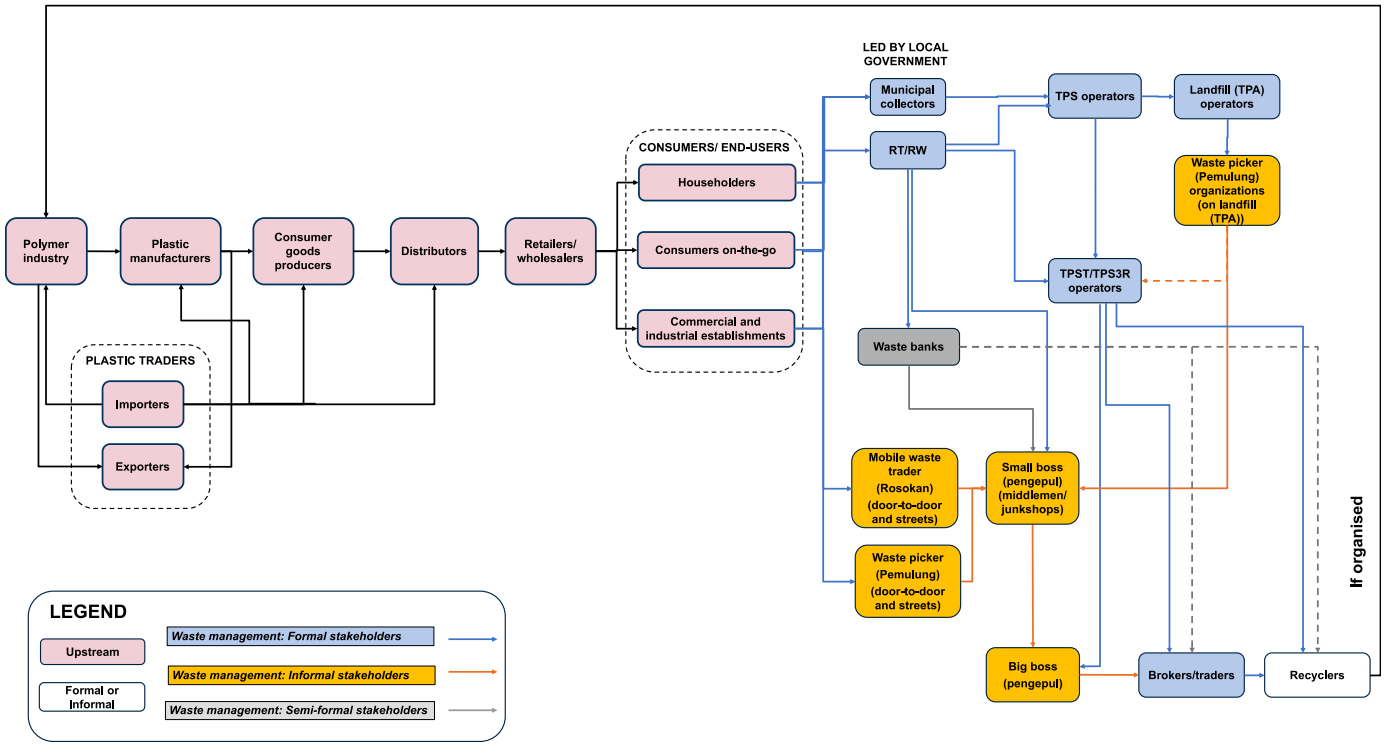

Fig. 3. Simplified map of the internal stakeholders involved across the plastic MCPs value chain in Indonesia. The pink colour indicates stakeholders operating in the upstream and midstream part of the value chain; stakeholders involved in the downstream part of the value chain are indicated with blue colour for formal stakeholders, orange for informal stakeholders and grey for semi-formal stakeholders. A brief explanation of local acronyms: RT/RW refers to the neighbourhood (RT) and community (RW) organisations/associations; TPS refers to the temporal disposal site; TPST/TPS3R resembling material recovery facilities (MRF); TPA refers to controlled disposal site similar to landfills; pemulung refers to waste pickers; rosokan refers to mobile waste traders; pengepul refers to waste collectors and buyers. Dotted lines indicate the specific route is less common. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
The main types of internal stakeholders operating upstream (pink rows) and downstream (blue rows) of the plastics value chain in Indonesia are categorised based on stakeholder theory (into Shareholders, Employees, Consumers, Suppliers, and Investors)*, stage of operation in the value chain, formality and their description.

Stakeholder type	*Stakeholder name*	*Stage in the value chain*	*Formal/ Informal*	*Description*
Supplier	**Polymer industry**	Production	Formal	Processes petrochemicals into polymer resins.
Shareholder (Investor downstream)	**Plastic manufacturers**	Production	Formal	Companies engaging in plastic MCPs manufacturing.
Supplier OR Shareholder	**Plastic traders**	Production	Formal	Companies that import or export plastic MCPs.
Shareholder (Investor downstream)	**Consumer goods producers**	Production	Formal	Businesses that produce and sell consumer packaged goods from plastics.
Employee	**Distributors**	Distribution	Formal	Intermediary companies that distribute plastic MCPs in the market.
Investor	**Retailers/ Wholesalers**	Storage/ Consumption	Formal	Buyers and sellers of plastic MCPs directly to consumers/end-users/end-users (e.g., household or consumer on-the-go) namely ***retailers*** or to other businesses in bulk (e.g., retail stores) namely ***wholesalers.***
Consumer	**Consumers/ End-users**	Consumption/ Waste generation	Formal	Householders, consumers on-the-go, commercial and industrial establishments.
Supplier	**Waste Collectors**	Waste collection	Formal	**Rukun tetangga (RT) and Rukun warga (RW):** Neighborhood (RT) and community (RW) organizations/associations for waste collection. **Municipal collectors:** Employees assigned by the local government for waste collection. **Private businesses:** EcoBali, etc.
		Waste collection	Semi-formal	**Semi-formal collectors:** Companies of waste disposal in illegal dumpsites.
		Waste collection	Informal	**Pemulung (Waste pickers):** Waste pickers contributing to the informal waste collection.
		Waste collection (waste buyer)	Informal	**Rosokan (Mobile waste traders):** Waste traders moving from place to place, often using motorcycles, to purchase waste from households and public spaces such as markets, sidewalks, and streets, and then sell to small these materials to pengepul.
Supplier	**Small scrap dealers**	Waste sorting	Formal	**Temporary Disposal Site (TPS) operators:** Initial sorting of waste takes place.
		Waste sorting	Formal	**Temporary Waste Processing Site / 3R Centre (TPS3R) operators:** Sorting of waste driven by 3R (reduce, reuse, recycle).
		Waste collection and sorting (waste buyer)	Semi-formal	**Waste bank (Bank Sampah):** Community-based organisation who buy recyclable waste materials, and plastic waste specifically of certain economic value.
		Waste sorting at landfill	Semi-formal	**Pemulung organizations:** Selling scrap collected from landfills either to reprocessors or to pengepul.
		Waste sorting (waste buyer)	Informal	**Small pengepul (middlemen/junkshops):** Intermediate stakeholders that buy recyclables from pemulung, rokosan or RT/RW and sell them to big pengepul.
Supplier	**Large scrap dealers/ Semi-reprocessors/ Aggregators**	Waste sorting (waste buyer)	Informal	Intermediates that buy recyclables plastic waste from small pengepul or big waste banks (Bank Sampah Induk) and typically store and pre-process plastic waste, also known in Indonesia as **big pengepul.**
Supplier	**Brokers/traders**	Waste trading	Semi-formal/ formal	Typically work for one or more recycler and buy the plastic waste from TPS3R/TPST, big pengepul and sell to recyclers.
Shareholders (supplier upstream)	**Plastic waste reprocessors**	Plastic waste sorting/reprocessing	Formal	**Intermediate Transfer Facilities (TPST) operators:** Government-run waste processing centers – its system is more complex than TPS3R.
		Plastic waste recycling	Formal & Informal	**Recyclers (pelaku daur ulang):** Private sector-led recycling plants and small-scale mechanical recycling plants.
Supplier	**Landfill (Tempat Pemrosesan Akhir, TPA) operators**	Plastic waste disposal	Formal	Operators in formal waste disposal sites

* **Shareholders (or owners)**: own a company or part of it through shares of stock, and have a financial stake in the business and expect some form of financial return from them; **Suppliers**: provide services or produce raw materials and in return receive part of financial return from products and services; **Customers/Consumers**: purchase the product of the company for personal use and receive the benefit from products and services; **Employees**: are hired by the company to conduct a specific task under terms of employment and put their livelihoods at stake; **Investors**: are those who buy stocks from traded companies as part of their portfolio and sell to consumers (retailers) or other companies (wholesalers); and those who invest the money of their clients to buy securities or assets primarily interested in the financial risk-return aspects of an entity's securities and their portfolio-fit, such as banks, savings and loan associations and insurance companies.

the consumption stage. The roles and dynamics of the most influential stakeholders upstream in the value chain are provided below:

- **Polymer industry:** is a sector that produces feedstock materials for plastic manufacturers. Indonesia has only one petrochemical company[2] (i.e., PT PERTAMINA) that produces naphtha-based raw materials for its subsidiary, PT Polytama Propindo. Other polymer manufacturers source their naphtha-based raw materials from Thailand, China and the Middle East. The government has focused on developing the capital-, technology-, and energy-intensive petrochemical/polymer industry, which supplies raw materials for almost all sectors such as plastic, textile, pharmaceutical, agriculture, etc. (IPEN, 2022). The production capacity of this industry may significantly impact the imports of raw plastic materials (i.e., resins), as Indonesia has the potential to be one of the largest polymer producers in Asia. In 2019,[3] Indonesia ranked 8th out of 13 countries in polymer production (Kameke, 2022). Currently, the domestic demand for plastic raw materials is not matched by the national industrial supply of polymer resins (IPEN, 2022). According to INAPLAS data, only 30 % of plastic demand in Indonesia is fulfilled by the local plastic industry with the rest being fulfilled by imported virgin plastic (INAPLAS, personal communication, 2023).
- **Plastic manufacturers:** use the plastic pellets produced by the polymer industry and are classified based on the types of plastics they produce namely rigid, flexible, and woven. There are nearly 1600 plastic manufacturing companies in Indonesia, the majority of which are located in Java and Sumatra (IPEN, 2022). The development of the plastics manufacturing industry has received special attention from the national government due to its important role in the economic activity of the country (IPEN, 2022). The most prevalent plastic manufacturer is the packaging industry covering from 36 % (Ratnawati et al., 2020) to 56 % of total plastic manufacturing (IPEN, 2022).
- **Consumer goods producers:** include businesses that use plastics in their finished products, especially packaging, such as fast-moving consumer goods companies (FCMGs) and brand owners. While some consumer goods producers may engage in overlapping activities with plastic manufacturers — such as producing plastics for their services (e.g., electronics) — the majority of them preliminary source plastic components from plastic manufacturers, with their core business centred on finished products. The food and beverage manufacturing sector is the major plastic producer and user in Indonesia, utilizing nearly 60 % of domestically produced and imported plastics (Ratnawati et al., 2020), and contributing about 5 % to the GDP in 2022 (Nurhayati-Wolff, 2023). This industry, especially FMCG companies, contributes considerably to plastic pollution, indicating the need for consumer goods producers to accelerate and expand their actions on mitigating plastic pollution issues (Tearfund, 2020). The lack of waste collection and recycling infrastructure in Indonesia exacerbates mismanagement (open burning and littering) of considerable amounts of plastic waste generated from FMCG (Tearfund, 2020). According to MoEF's Ministerial Regulation 75/2019, plastic producers — including plastic manufacturers, consumer goods producers and retailers — are required to submit waste management plans and report progress annually, forming the basis for an extended producer responsibility (EPR) framework (SYSTEMIQ, 2021b). However, this regulation lacks specific funding levels and compliance penalties, leading to a somewhat 'voluntary' implementation of EPR (SYSTEMIQ, 2021b). The widespread production of low-value, non-recyclable plastic materials in the food packaging sector, such as sachets and pouches,[4] further complicates the situation (IPEN, 2022), since consumers' demand for these products is driven by perceived value tied to daily income realities. Disruptions in this supply chain could risk livelihoods and lead to social unrest. Concurrently, funding from consumer goods producers for waste management remains low, primarily limited to voluntary CSR (corporate social responsibility) initiatives. Implementing a mandatory EPR system might pose challenges for the plastics industry, requiring effective financing mechanisms and technical guidelines (SYSTEMIQ, 2021b).
- **Traders:** are exporters and importers of both raw materials for plastic manufacturing and MCPs placed in the market to meet the national total plastic demand (Ratnawati et al., 2020). In 2020, the Minister of Industrial Affairs issued a Government-Borne Import Duty (BMDTP) facility regulation No. 134/PMK.010/2020 related to the imports of raw materials to increase productivity in certain industries (Bea Masuk Ditanggung Pemerintah, known as BMDTP policy) provided by the Ministry of Finance (NLP, 2020). Plastic industries are eligible to obtain a BMDPT Facility, i.e., to reduce the cost of plastic raw materials (e.g., naphtha and condensates) import and promote plastic MCPs production domestically. This, on the one hand, can help the country to meet plastics MCPs demand at lower production costs, and on the other hand it can boost competitiveness, employment, and the country's economy (Ratnawati et al., 2020). There is little known about how they operate.
- **Distributors and Retailers/Wholesalers:** these are intermediates of plastic MCPs between production and consumption. Distributors transfer and distribute consumer goods from plastic manufacturers, consumer goods producers and importers to the point of sale (i.e., retailers/wholesalers). It should be noted that the MCPs distribution can also be conducted by employees of plastic manufacturers and consumer goods producers. Retailers/wholesalers are responsible for displaying and often promoting the consumer goods. A multitude of consumer goods placed on the market comes in plastic sachets or pouches, as a response to the product affordability by the Indonesian consumers. These stakeholders have an important role to play at the regional level (micro-scale spatial level). For example, in remote areas where there is a lack of competition, retailers hold strong power over their relations between producers-distributors and consumers/end-users. They can influence the extent to which consumers/end-users engage with different plastic MCPs and determine the types and degree of plastic MCPs penetration in the local market.
- **Consumers/end-users:** are the major users of plastics, primarily of those produced by the plastic packaging industry, e.g. food and beverage and personal care products, and of other plastic goods

[2] A petrochemical company processes oil and gas-derived raw materials into naphtha and petroleum condensates to produce olefins, aromatics and paraffin. These are used as inputs to monomer production that are later processed into polymer resins.

[3] In the Asia-Pacific region, China, was the largest polymer producer.

[4] Sachets and pouches are typically multi-layered products – commonly made of plastic-plastic and plastic-aluminium - that cannot be easily recycled, and yet they are widely used at national level (IPEN, 2022).

placed on the market (either as a component or a finished product), such as those used in the household (storage containers, furniture, etc), in agriculture, electrical and electronic equipment manufacturing, construction and automotive sectors (Ratnawati et al., 2020). Currently, there is a strong preference for small proportions of goods contained in sachets, amongst consumers/end-users; a habit that is now strongly embedded into social norms. Over 160 million Indonesians have no access to waste collection leading to self-mismanagement, such as open burning, littering into water bodies and on land or burying (NPAP, 2020b).

3.1.2. Exploring stakeholders operating downstream of the plastics value chain

In Indonesia, the disposal and management of plastics involve the consumers/end-users and is also comprised of waste collectors (formal and informal), sorting centres, small and big scrap dealers (pengepul), brokers and reprocessors (Table 1). The roles and activities of stakeholders involved downstream of the plastics value chain are provided below.

- **Waste Collectors (formal):** are responsible for the collection and transportation of MSW to landfills (Tempat Pemrosesan Akhir, TPA) and Temporary Disposal Sites (TPS) (NPAP, 2020b). These include neighbourhood and community (RT/RW) organisations (Table 1) that are responsible for the collection and disposal of household waste into TPS/TPST (Intermediate Transfer Facilities) (Ratnawati et al., 2020) and the municipal collectors employed by the local government for the collection and disposal of MSW from TPS/TPST to TPA (Ratnawati et al., 2020). These waste management efforts are typically led by the local communities (RT/RW), local government, and/or private sector entities in collaboration with the local authorities; however, it is not common for local authorities to outsource waste management to private parties (SYSTEMIQ, 2021b). Recyclable waste materials, such as plastics, may be separately collected and transferred to sorting centres, e.g., TPST/TPS3R (Temporary Waste Processing Site/3R Centre) (Table 1).
- **Waste collectors (informal):** includes both pemulung and rosokan, who have different social statuses. ***Pemulung***, commonly referred to as waste pickers, are marginalized individuals of lower socioeconomic status, who collect –not purchase– recyclable plastic waste from door-to-door, streets (incl. traditional markets), and waste disposal/dumping sites (e.g., TPA) (Chaerul et al., 2014). Their activities are often viewed as unsafe and illegal. In some areas, pemulung receive support from local government or private entities (e.g. SYSTEMIQ-the system change company (SYSTEMIQ, n.d.)), which may provide shelters, or designated waste picking zones in landfills (World Bank, 2021). In certain instances, pemulung conduct initial sorting of waste collected from landfills and act as hybrid stakeholders, combining waste collection with small scrap dealing. The sorted waste is then supplied to big pengepul (i.e., large scrap dealers/semi-reprocessors/aggregators). If a private sector entity manages the landfill, they may purchase plastics collected by pemulung, providing them with a stable income (IPI, personal communication, 2022). A large proportion of pemulung are affiliated with the Indonesian Scavengers Association (IPI)/Independent Indonesian Scavengers (PIM) (IPI/PIM, n.d.), with reportedly over two million members, including 25,000 in Jakarta (World Bank, 2021). While the associations can be considered as external stakeholders in the system, it is important to note that many individuals involved in these organisations are usually pengepul. Rosokan are self-employed waste collectors who purchase recyclables from households and public spaces, making them preferable to waste generators compared to pemulung. Waste generators usually regard giving waste to pemulung as a form of charity, while transactions with rosokan are typically seen as more straightforward. It should be noted that the term ‘waste pickers’ is broad and can encompass various roles, with terminology differing in the literature, such as ‘waste collectors’ or ’scavengers’ (Asim et al., 2012; Sasaki et al., 2019; Sembiring and Nitivattananon, 2010); some of these terms are detailed in Table 2.
- **Small scrap dealers (formal):** are TPS (landfill) operators who work for the local government and are involved in waste sorting before transferring it to TPST/TPS3R facilities. They include both public and private sorting facilities using 3R-driven methods, particularly manual sorting lines (GIG, 2020). The primary goal of TPS3R operators is to separate recyclable materials from residual waste before further processing, similar to the operation of material recovery facilities (MRF). When TPS3R operators engage directly with industries that require agreements about quality and quantity, they act as large scrap dealers due to the additional pre-processing of plastic waste. These sorting centres sort, bale and sell plastic waste for recycling to domestic recyclers or exporters. However, the formal waste sector often struggles to establish agreements with the recycling industry, resulting in recyclables being diverted to big pengepul (personal communication). This highlights the challenges faced by the sector in effectively contributing to recycling efforts (SYSTEMIQ,

Table 2
Main categories of pemulung (waste pickers) and pengepul (waste buyers) involved in the IRS in Indonesia, including a description of their task.

Categories of IRS stakeholders*	Criterion for categorization	Definition/Task
Pemulung on streets	Location of activity	Collect, sort and bale recyclables from streets and bins [a,b]
Pemulung on TPS	Location of activity	Collect waste from temporary storage sites (TPS) [b]
Pemulung on TPA	Location of activity	Collect recyclable waste from final disposal sites (TPA) [b]
Pemulung door-to-door	Location of activity	Collect recyclables from households [b]
Domestic pemulung	Occupation type	Sort out recyclable waste at their home – usually women [a]
Live-in pemulung (anak buah rumah)**	Occupation type	Live in residence provided by big pengepul and are continuously employed – they pick, sort and process waste[a,c]
Live-out pemulung (anak buah lapangan)**	Occupation type	Do not live in residence provided by the big pengepul, but are continuously employed – they pick, sort and process waste [a,c]
Independent pemulung (sendiri) **	Occupation type	Temporary employer – employee relationships[c]
Part-time pemulung (buruh) **	Occupation type	Part-time waste pickers with other jobs – temporary employer-employee relationships [c]
Small boss (bos kecil) **	Occupation type	Lower level bosses to big bosses [c]
Big boss (bos pemulung) **	Occupation type	The boss of pemulung [c]
Small pengepul (itinerant waste buyers)	Retail type	Buy recyclables from door to door in households [b]
Small pengepul - middleman	Retail type	Buy recyclable materials from pemulung or itinerant buyers[b]
Small pengepul - junkshop	Retail type	Owner of a junkshop, self-employed itinerant buyer middleman who do not have direct connection to recycle factories and usually has around ten followers [a]
Wage laborers for big pengepul	Workers	They engage in sorting, packaging, buying, measurement, washing, cutting, drying and transport [a]

* *According to* Table 1.
** (Sasaki et al., 2014).
[a] (Sasaki et al., 2019).
[b] (Sembiring and Nitivattananon, 2010).
[c] (Sasaki et al., 2014).

2021b), as shown in Fig. 2. The priority for the formal waste management sector is to expand waste collection (SYSTEMIQ, 2021b). Currently, the main funding source for formal waste collection and management comes from the retribution fees, while EPR could serve as a complementary funding source, particularly in promoting circularity (SYSTEMIQ, 2021b). Still, there are concerns about whether EPR funding might disincentivize local government (SYSTEMIQ, 2021b).

- **Small scrap dealers (semi-formal):** consist of waste bank (bank sampah) operators who often sell their recyclables to brokers (Ratnawati et al., 2020). Waste banks, supported by the local government, NGOs, or private sectors, use economic incentives to encourage community involvement in recyclable waste management, especially in lower-middle-class communities (Ratnawati et al., 2020). Typically owned by women who view waste as a valuable economic commodity, these semi-formal entities operate with local government support. At waste banks, people create accounts and are credited with the monetary value of their recyclable waste materials (usually non-organic) based on monthly updates from the secondary plastic waste market. In Indonesia, over 11,500 waste banks operated with an estimated annual turnover of ca. USD 1.7 million in 2020 (IPEN, 2022). However, waste banks face logistical challenges, as their longevity depends on the supply of recyclable waste from individuals and the demand from off-takers networks, creating financial dependencies (Ratnawati et al., 2020). For example, (Putri et al., 2018) found that only 4 % of waste banks in Jakarta collaborated with recyclers, while 96 % relied on brokers/traders and small pengepul, who are often unreliable off-takers (Putri et al., 2018). In rural and semi-urban areas, small pengepul typically serve as the primary off takers (personal communication). This leads to lower selling prices and the accumulation of recyclable waste, which presents space challenges; anecdotal evidence suggests that this issue is mitigated by disposing of excess recyclable waste in landfills/dumpsites (Ratnawati et al., 2020).
- **Small and large scrap dealers/aggregators (informal)**: these are small and big ***pengepul***, also known as "bosses", who sort plastic waste to increase its market value before selling it to generate income (see Table 2). They can store substantial volumes of recyclables and potentially achieve a higher level of segregation and processing than private sorting facilities in the formal sector. Informal sorting stakeholders act as a link between informal and semi-formal collection stakeholders (i.e., pemulung and waste banks) and brokers/traders or formal recyclers, facilitating the buying and selling of recyclables between these groups. The bosses oversee various activities, including collection, sorting, packaging, buying, washing, cutting, drying, transporting, and transactions with brokers/traders and pickers (Sasaki et al., 2019). Some small and big pengepul may employ pemulung to maximise recyclable waste yield by loaning them money or providing shelter (API, personal communication, 2022) (Table 2). This practice raises concerns regarding modern slavery,[5] as the financial vulnerability of pemulung may trap them in circles of forced labour within waste management networks; however, there is currently insufficient evidence to substantiate this claim, and the present study has not yet explored this aspect. The significant contribution of bosses to plastic recycling rates is recognized by stakeholders in the plastics value chain, who perceive that implementation of EPR is more feasible within the informal plastic waste stream than in the formal one (SYSTEMIQ, 2021b).
- **Informal recycling sector**: the informal recycling sector (IRS) encompasses semi-formal and informal waste collectors, scrap dealers, and small and big aggregators (*pengepul*). IRS involves labour-intensive recycling activities that typically operate in low-income environments with limited technological capacity (Wilson et al., 2017). While waste banks may diminish the activities of both small and large pengepul, they face significant challenges in this competition. First, waste banks require substantial administrative efforts and human resources, which can hinder their operational efficiency. Second, rosokan often provide more competitive prices for collected materials (personal communication). Furthermore, small and large pengepul are generally more attuned to the monetary flows and fluctuations in plastic prices, while waste banks frequently lack this critical market awareness. Table 2 presents the primary stakeholders involved in the IRS, including both pemulung and pengepul. It should be noted that stakeholder mapping and system analysis related to pemulung depends on their activity location. However, limited evidence hampers effective categorization of pemulung based on occupation type.

- **Brokers/traders**: these are the intermediates that connect small scrap dealers and pig pengepul with the recyclers, yet their operations and activities remain underexplored.
- **Plastic waste reprocessors (formal and informal)**: include the formal TPST operators, also known as transfer facility operators, in which various waste management activities such as collection, sorting, reuse, recycling, processing, and final processing of waste take place; and recyclers, which may fall into either formal or informal category based on their reliance on IRS for feedstock acquisition. The most prevalent plastic polymer that is accepted by recyclers is PET followed by polyethylene (GIG, 2020).
- **TPA operators (formal)**: governed by local government, are responsible for the management and operation of controlled waste disposal sites. However, there is a lack of official statistics regarding operational models for service delivery in the formal sector, such as whether operators are public employees or contractors in public-private partnerships. This absence of data hinders efforts to identify barriers and drivers for expanding waste collection coverage and to determine models suited to national and local capacities (Wilson et al., 2017). Despite their pivotal role, TPA operators encounter several challenges, including poor adherence to sanitary practices (World Bank, 2021) and insufficient technical capacity for SWM (SYSTEMIQ, 2021a). This is due to inadequate funding and regulatory enforcement, resulting in over 50 % of TPAs reverting to open dumpsites since 2018 (SYSTEMIQ, 2021a). Additionally, limited land availability for new TPAs combined with existing sites operating beyond their designed capacities (World Bank, 2021), reflects systemic weaknesses in TPA operations that hinder compliance with established standards.

Many downstream stakeholders in the value chain may play dual roles, e.g., a formal collector may also act as a pemulung, an aggregator can act as a broker/trader directly engaging with recyclers, and small scrap dealers such as waste banks can also sell directly to recyclers. There are complex stakeholder networks across Indonesia, that may vary by region. The formal stakeholders in the downstream value chain are mainly led by the local government. The role of local government is to implement policies for household waste collection, including plastic waste, and provide services for plastic pollution prevention. To enhance the plastic waste management system, local government must consider local needs and often establish partnerships with RT/RW organisations/associations (see Table 1) (Maryanti, 2017). However, local governments face financial constraints, as the majority of their budgets are allocated to healthcare, education, irrigation infrastructure and road construction, leaving insufficient resources for SWM (NPAP, 2020b).

[5] Modern slavery according to the UN is *"an umbrella term covering practices such as forced labour, debt bondage, forced marriage, and human trafficking … Essentially, it refers to situations of exploitation that a person cannot refuse or leave because of threats, violence, coercion, deception, and/or abuse of power"*.

3.2. Stakeholder dynamics using the mendelow matrix

In Indonesia, all internal stakeholders have a high interest in changes to the plastics value chain due to their direct involvement in the flow of plastic MCPs, which drives their efforts to address plastic pollution. However, the level of power among internal stakeholders varies, depending on their attributes, roles, and activities within the system. As illustrated in Fig. 4, internal stakeholders can only be grouped into *key players* and *keep informed* stakeholders.

Key players in the Indonesian plastics system include upstream stakeholders, such as the plastics industry (i.e., polymer industry and plastic manufacturers) and consumer goods producers, both of whom wield significant influence in orchestrating changes within the system. Polymer resin and plastic manufacturers have a high influence over the types and volumes of plastic produced, with their interest in addressing plastic pollution closely tied to concerns about business reputation, regulatory compliance and sustainability. Consumer goods producers determine the types of plastic materials and components used in their final products, thereby significantly influencing demand for plastics and shaping market dynamics. Additionally, the plastic industry possesses substantial lobbying power, impacting government policies and decision-making processes (Gerassimidou et al., 2022). Their vested interest is further linked to financial objectives, regulatory compliance and the direct effects of consumer preferences and environmental concerns on their operations.

Downstream in the value chain, the main key player is the plastic recycling industry, which includes large scrap dealers/semi-reprocessors/aggregators (big pengepul) and plastic waste reprocessors. This industry is inherently connected to the availability and quality of recycled plastic materials (secondary plastic material), playing a pivotal role in addressing plastic pollution. Their power is stronger within the downstream part of the system; large scrap dealers possess power, exerting control over the acquisition of recyclable plastic waste from waste collectors and managing transactions with small scrap dealers. Reprocessors influence large scrap dealers/semi-reprocessors/aggregators and feedstock demands for recycling. The plastic recycling industry may have lesser power than the plastics industry upstream, but effective implementation of EPR could enhance their influence in the market of recyclable materials. Nonetheless, the decision-making of the plastics industry upstream (e.g., to promote a reduction and replacement of plastics in the system), can severely impact the recycling industry's business and limit its decision-making power.

In the Indonesian context, this situation may differ due to uncertainties surrounding the structure and role of the IRS. Given the emphasis on recycling within Regulation 72/2019, producers are looking into the formal or informal recycling systems to fulfil their recycling and take-back responsibilities; with the IRS gaining preference (SYSTEMIQ, 2021b). In this context, the IRS has the potential to thrive, influencing the dynamics of the plastics value chain (NPAP, 2020a). This situation presents opportunities to leverage stakeholder interest and increase their power, ultimately fostering a win-win solution for all parties involved.

Keep informed are all remaining internal stakeholders operating upstream, midstream and downstream of the plastics value chain. Below there is a brief explanation of each stakeholder's interest and degree of power:

- Plastic traders have limited influence over the type and amount of plastics they trade, as this is dictated by the needs and demands of the plastics industry and consumer goods producers and the decisions of regulatory bodies, but their interest is high as potential disruption in the system will limit their activities and profit, as this directly associated with the availability and trading of plastic raw MCPs. However, they possess a hidden power in influencing the plastics supply and demand via their strategic interactions and relationships in the market, and adaptability to changing market dynamics.
- Distributors rely on decisions made by both consumer goods producers and retailers; the former due to changes in products that may require different transfer and/or selling routes, and the latter due to retail product inventory management based on clientele's preferences and demands. Therefore, they have a high interest in potential changes as this would require them to alter their product offerings, market demand and relationships with suppliers.
- Retailers and wholesalers rely on decisions made by consumer goods producers, and in the Indonesian rural context also by the distributors. Their power is potentially higher due to retail product inventory that will dictate which products they purchase and in which quantities. Being the final point of the supply chain, their activities are linked to plastic pollution and therefore, any changes require them to adopt different marketing strategies to retain competition (retain their clientele and keep them happy) and reputation.
- Consumers/end-users possess high power with their preferences, but this power is suppressed by marketing forces and remains in a lethargic state. Collective actions that help to boost consumers' interest in changes in the plastics value chain, could shift the power dynamics. However, there is an important point to make; consumers with pro-environmental behaviour are likely to have a different stance and interest in changes in the system (e.g. replacement of sachets with containers, preference to bio-based alternatives) compared with consumers that are driven by socio-economic conditions (e.g., perceived and actual affordability, convenience, accessibility). These attributes are shaped by social norms and personal circumstances that are difficult to change.
- Waste collectors, specifically pemulungs and rokosan hold a central role in Indonesia's waste management sector and exert a direct impact on recycling rates. Nonetheless, their power is restricted by their operations within informal and often unregulated settings. Their interest in tackling plastic pollution is highly driven by the implication changes in the plastics value chain will have on their security and ability to generate an income, as plastic waste constitutes the major bloodline of their operations.

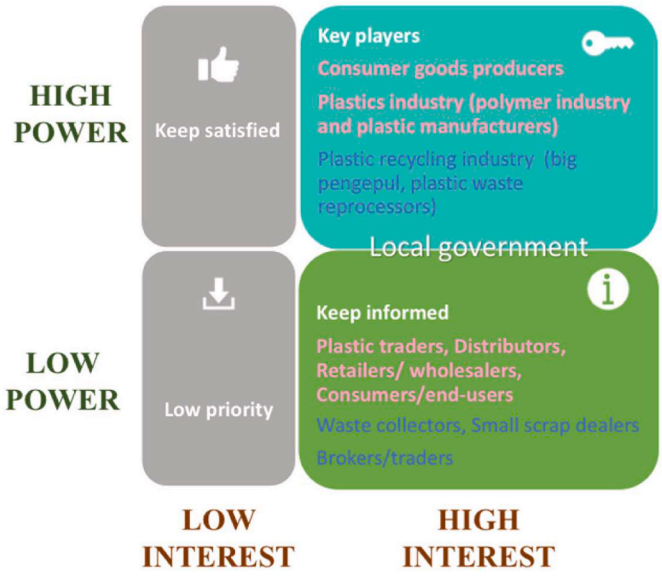

Fig. 4. Grouping of internal stakeholders involved in the plastics MCPs value chain in Indonesia according to the Mendelow matrix (stakeholders in pink and blue coloured text refer to upstream and downstream, respectively, following Table 1). Local government transcends between the two categories depending on the context. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

- Small scrap dealers have a high interest in changes in the plastics value chain as it will affect the supply and demand of recyclable materials and, hence, their profitability. Specifically, waste banks play a significant role in local waste management systems and community engagement; however, their power is constrained by the presence of informal and less structured settings. Specifically, waste banks rarely sell recyclables directly to the recycling industry; this lack of partnerships with recycling industry off-takers creates instability in their business (Ratnawati et al., 2020). Despite this, waste banks exhibit a high level of interest due to their direct involvement in waste collection and community engagement. Likewise, pengepuls (small bosses) rely on large scrap dealers/semi-reprocessors/aggregators for their operations and therefore, have limited influence over changes in the system. Their strong interest in addressing plastic pollution is linked to the quantity, quality and demand of the materials they acquire.
- Brokers/traders have limited power to directly influence recycling practices and regulations since they rely on decisions made by manufacturers upstream and the recycling industry downstream. However, their influence on the trading of recyclable materials, as they connect suppliers and buyers in the market, indicates their suppressed power.

Somewhere between the *key players* and the *keep informed* stakeholders lies the local government, which is responsible for waste collection and management. Local government is expected to have a high power over changes in the system due to its regulatory ability, including the enforcement of taxes on products (e.g. the plastic bag ban), recycling programs (see ADIPURA),[6] and other waste management regulations. While the Provincial Governor oversees SWM when multiple regencies and cities are involved, most settlements or communities depend on the local government for waste management, which is funded mainly by its budget and governed by local policies. However, the local government's power in Indonesia is highly influenced by the central government and the prevailing political landscape, often limiting financial autonomy to deliver community improvements. While government-led initiatives convey a sense of authority, in practice, they frequently reflect the input and participation of local communities in waste management efforts. Still, local governments maintain a strong interest in plastic pollution due to its direct impact on their communities, including environmental degradation, public health concerns and waste management costs under their jurisdiction.

It is important to recognise that waste collection and disposal capacities differ markedly across local governments in Indonesia. This study focuses on the national level, but urban areas on major islands typically have more advanced waste management infrastructure and resources, than peri-urban, rural and remote areas, especially on smaller islands. These areas often face significant challenges, including limited resources and infrastructure. Given these regional disparities, tailored assessment is necessary to evaluate the specific waste management needs of each region, ensuring that strategies are both effective and contextually appropriate.

[6] The MoEF has implemented the national scale Clean City Program (Adipura) as an incentive for municipalities to strive towards sustainable development, grouped into four categories: metropolitan, big, medium and small city (Ratnawati et al., 2020). The Adipura program monitors and assesses the performance of local governments according to the waste management system (i.e., waste collection coverage and operation of the final disposal site) they have established and operate and city cleanliness and then ranks and classifies them into 5 classification from the best to the worse: Class 1, Cass 2, Class 3, Class 4, and Class 5 (i.e., Adipura award). In the context of Adipura program, data provided by municipalities as self-reports and published by the national solid waste information includes: solid waste collection rate, at-source solid waste treatment rate, TPS3R treatment rate, and collection rates by waste banks and informal collectors (Ratnawati et al., 2020).

4. Discussion

As Manning et al. (2023) purport, "*codesign and collaborative engagement with stakeholders are important features of systemic intervention, and therefore, tools such as visual mapping which facilitate understanding of the system are important contributions to the multimethodological approach*" (Manning et al., 2023). Through the identification, mapping, and analysis of internal stakeholders in Indonesia, it is evident that there is a significant lack of integration between the activities of formal and informal stakeholders (Sembiring and Nitivattananon, 2010). Additionally, the absence of partnerships among key stakeholders within the plastics value chain contributes to the failure of the system to address plastic pollution (UN-ESCAP, 2021). The collaboration of all internal stakeholders, including the plastics industry, service providers (formal and informal SWM services), consumers/end-users, and government (both national and local) is essential for the planning, implementation, and monitoring of the production-consumption/use-management of plastics. Such collaboration is a fundamental prerequisite for making transformative changes to tackle the problem effectively. In Indonesia, where there is high variability in institutional governance, funding, and regulation needs across regions (SYSTEMIQ, 2021a), locally tailored interventions are needed. These can be technical interventions primarily directed to the plastics industry upstream (e.g., designing recyclable single-layer plastics instead of multilayer sachets) and the plastics recycling industry downstream (e.g., increasing waste collection rates and sorting efficiency). Additionally, infrastructural (e.g., constructing more SWM facilities to handle local waste streams), communication (e.g., campaigns of awareness), economic and policy interventions at the level of local government (e.g., restriction of single-use plastics through bans and taxes, or incentivization though refilling stations and provision of traditional baskets instead of plastic bags). Furthermore, at the level of consumer/end-users and collectors, integrating the IRS into formal structures can enhance waste management efficiency and stakeholder collaboration. One may suggest that the best-suited type of intervention is a combination of the above; further elaboration on this is beyond the scope of the present study.

Concerning governance, decision-makers face a dilemma when considering the integration of IRS into formal structures, due to the operational challenges and additional costs this will introduce (Sembiring and Nitivattananon, 2010). Literature reports the waste picker phenomenon as a policy problem, with policy distinctions arising from varying interpretations (Porras Bulla, Rendon, and Espluga Trenc, 2021; Zisopoulos et al., 2023). While concerns are raised regarding the IRS operations, including issues related to occupational and public well-being and safety, child labour, uncontrolled pollution, untaxed activities, crime and political corruption, it is important not to overlook its significant, rapid and cost-effective contribution to the solid waste and resource management system (Velis et al., 2022; Velis et al., 2012). The IRS plays a crucial role in providing livelihoods in low- and middle-income developing countries, and thus it cannot be neglected (Velis et al., 2022). Ignorance of the key role of stakeholders involved in IRS reflects a bias in business studies towards the Global North, whilst the exclusion of pengepuls as standard business stakeholders underscores the challenge in mainstreaming the circularity in the plastics value chain. To promote the circular economy in the Global South, particularly in Indonesia, it is crucial to redefine the system boundary to encompass stakeholders engaged in IRS, including waste pickers, scrap dealers, and aggregators (Wilson, 2023). The inclusion of the IRS alongside the formal waste management sector could improve their livelihoods and working conditions, increase recycling rates and reduce waste management costs for local government (UN-ESCAP, 2021; Wilson, 2023).

The geographical, cultural and political peculiarities of Indonesia, create the space for technical, infrastructural, policy, economic, and communication interventions with the plastics industry and IRS integration, creating decentralised infrastructures, called Living Labs, to aid

the co-design, testing and piloting of reuse and refillable alternatives, and of plastic waste collection techniques for management, yielding scalable solutions. These Living Labs could serve as platforms to empower consumers and local service providers, including businesses and government bodies, to collaboratively devise locally tailored strategies for maximising the effectiveness and efficiency of all types of interventions in reducing plastic consumption, improving its use, and management. This would maximise the recovery of value embedded in plastics by preventing their leakage in the form of litter or gaseous pollutants (via open burning). Concerning IRS, pemulung and rokosan have the potential to significantly contribute to the national plastic waste recycling rate. However, their actual impact is often constrained by challenges such as inadequate infrastructure, a lack of formal recognition, and insufficient support (NPAP, 2020b). They are reported to provide higher plastic waste recovery (accounting for 67 % (World Bank, 2021)) than waste banks (Putri et al., 2018). These interventions would, in turn, enhance collection rates, reduce plastic pollution, and alleviate poverty, serving as a scalable global solution for areas with insufficient SWM services in low- and middle-income countries (Velis et al., 2022). Further exploration of the potential of interventions to reduce plastic pollution and promote sustainability in the system, and challenges/barriers regarding their implementation, is needed.

The complexity of the Indonesian SWM system, coupled with limited publicly available data on stakeholders' roles and interactions, presents significant challenges in analysing stakeholders' dynamics. Global value chain (GVC) analysis offers valuable frameworks for understanding these dynamics (Dallas et al., 2019; Gereffi et al., 2005). For example (Gereffi et al., 2005), proposed a GVC framework to investigate governance patterns through stakeholders' transactions, elucidating power relationships (Gereffi et al., 2005). Alternatively (Dallas et al., 2019), introduced a GVC framework categorising power into four types – bargaining, demonstrative, institutional, and constitutive – based on intentional/non-intentional exertion of power and dyadic/collective actor configuration (Dallas et al., 2019). While both GVC frameworks apply to Indonesian stakeholders, their application was hindered by a lack of monetary data that would shed light on the transactional flows.

Furthermore, power in this system is not static; stakeholders may demonstrate different types of power at different stages of the value chain, as acknowledged by Dallas et al. (2019). As such, fixed classification of stakeholders in certain power types is not recommended. Nonetheless, conducting a comprehensive stakeholder analysis, beyond the scope of this mapping exercise, would be necessary to delineate the intricacies of power dynamics among stakeholders. Notably, the influence exerted by the plastics industry through covert collaborations and affiliations with organisations and regulatory agencies underscores its potential for concealed power dynamics beneath formal interactions. Given these challenges, the Mendelow matrix is a practical tool for delineating stakeholder power and distinguishing their interest across the system (Fig. 4).

While previous studies have examined stakeholder dynamics at specific points along the plastics value chain or within local contexts, there remains a lack of integrated, system-wide analyses that capture the full range of stakeholder roles, governance, and waste management across Indonesia and in similar contexts. This study addresses this critical gap by systematically synthesising these diverse elements to uncover how stakeholder interactions shape plastic flows and outcomes. Instead of relying solely on a single framework or narrowly focused research, we collated evidence from multiple sources to compile a holistic assessment of stakeholder dynamics, integration, and intervention opportunities. This integrative approach allows us to identify systemic gaps and leverage points more effectively. While prior literature often depicts a fragmented stakeholder landscape hindering systemic change, our research demonstrates that targeted stakeholder analysis tools can effectively identify leverage points, a practical contribution that bridges the gap between theory and implementation. This critical comparison emphasises that addressing plastic pollution requires a nuanced understanding of internal stakeholder relationships and contextual governance challenges, an area less explored in existing frameworks.

The study provides a reproducible approach to streamlining the analysis of stakeholders' influence on the plastics value chain in any regional context. Our findings have several relevant implications for future policy and research. The study highlights the non-uniformity of stakeholder influence and the risks of oversimplification when assessing governance in complex systems. By revealing the multifaceted and shifting nature of power within Indonesia's plastics value chain, we argue for more tailored, systemic interventions that recognise informal dynamics and the role of less-visible actors. The research also reinforces the value of systems thinking and mixed-method approaches in contexts where data limitations are significant.

5. Conclusions

In a developing nation like Indonesia, plastic pollution is a highly complex issue, which persists due to power imbalance, social norms, financial constraints and perceptions of value that cannot be addressed through a 'silver bullet' or a 'one-size-fits-all' solution. Using a systems-based analysis, the study showed that the flow of plastics in the Indonesian value chain is administered and controlled by a complex web of formal and informal internal stakeholders that are directly involved in the system. The study also sowed that while all internal stakeholders have a high interest in changes introduced in the plastics value chain, their power varies significantly.

The upstream plastics industry holds a dominant position in financial assets within the plastic value chain, indicating substantial lobbying power in negotiations with the government. Specifically, the combined economic activities of traders and the substantial lobbying power of the plastics industry and consumer goods producers create critical dynamics upstream of the plastics value chain, restricting the ability of the plastics recycling industry to effect change. Although large scrap dealers/semi-reprocessors/aggregators and reprocessors may appear to have limited influence in decision-making processes, forthcoming Extended Producer Responsibility (EPR) policies are likely to enhance their role in the system. Understanding the power dynamics of consumer/end-users and local government is essential to empowering innovation and action at the regional level. Currently, local governments face infrastructural, regulatory and technological limitations that hinder effective collection and management services. These findings are further supported by existing policy lock-ins, financial investments, industry leadership and public engagement in Indonesia.

Stakeholders with the greatest influence over potential changes in the Indonesian plastics value chain are those who currently hold or are in the process of acquiring (due to forthcoming policies and political regime changes) control over plastic flows. Interestingly, the network of stakeholders operating in the downstream part of the plastics value chain has received comparatively less attention in power-related analyses, despite offering significant potential for rebalancing power dynamics and driving systemic change. Fostering collaboration between key stakeholders upstream and downstream of the plastics value chain is essential to creating the conditions for transformative change towards improving plastic waste management and hence, reducing plastic pollution. A tailored, multi-scale-based approach, linking top-down understanding at the national level with bottom-up insights from the regency/municipality level, can help identify locally suited interventions across the plastics industry, informal recycling sector and beyond. To this end, building robust and inclusive stakeholder networks is critical. Facilitating such strategic networks will act as a catalyst for orchestrating coordinated transitions across the plastics system, ultimately contributing to a sustainable and circular plastics economy.

To build on this research, future research efforts should prioritise developing specific intervention strategies for Indonesia's plastic pollution crisis and delve deeper into the roles and interactions of both internal and external stakeholders. It's crucial to account for regional

differences in resource and waste management capabilities and tailor solutions accordingly. Further investigation is also needed to uncover hidden power dynamics within the plastics industry and to better understand and support the informal waste sector and the often-overlooked brokers and traders that connect them to the formal recycling system. This comprehensive approach will enable the development of effective and sustainable waste management solutions.

CRediT authorship contribution statement

Eleni Iacovidou: Supervision, Conceptualization, Writing – review & editing, Methodology, Formal analysis, Visualization, Funding acquisition, Writing – original draft, Project administration, Investigation, Data curation. **Spyridoula Gerassimidou:** Writing – original draft, Methodology, Data curation, Visualization, Formal analysis, Investigation, Conceptualization. **David C. Wilson:** Writing – review & editing. **Jessika Richter:** Writing – review & editing. **Susan Jobling:** Funding acquisition, Writing – review & editing. **Eddy Soedjono:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2025.146082.

Data availability

Data will be made available on request.

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