Waste Management in Nepal: Characterization and Challenges to Promote a Circular Economy

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Waste Management in Nepal: Characterization and Challenges to Promote a Circular Economy

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Abstract
In Nepal, the informal sector is responsible for treating 15% of household waste. It is the only alternative to landfilling and open disposal; however, the current waste management system does not acknowledge informal recyclers aggravating various challenges and vulnerabilities that the sector already faces. This study identifies and validates for the first time the challenges of the informal waste sector while providing a granular understanding of the actors that shape waste management in the region. The study uses primary data collected over a period of 6 months in Kathmandu and Lalitpur, the first and third most populated areas in Nepal. The methods considered were semi-structured interviews, questionnaires, and a co-creation workshop with formal and informal actors. A novel characterization of waste management actors was conducted to identify two profiles namely cyclists and scavengers and question the formality of the collection centres. Findings suggest that the price volatility of recycled materials and the lack of treatment and absence of regulatory capacity are among the main challenges in promoting a circular economy from the informal sector. The recommendations to overcome these challenges are a series of policy reforms, such as an extended responsibility producer scheme and the review of the tax on recycled material transport. The main policy implication from the finding reveals that circular economy is already being promoted by the informal sector — a responsibility that should fall under the remit of the regional and national governments. The study concludes that integration is not only necessary to improve the conditions of informal workers but essential to developing a circular economy in Nepal.

Keywords Formal and informal waste management sector · Waste pickers · Waste management policies · Scavengers · Sustainability · Circular economy

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Introduction

Circular economy can be interpreted as an economic system in which the end-of-life of products and materials is reduced through circular strategies such as reusing and recycling [1]. This principle is being transversally adopted by most sectors and countries to transform waste management and create close loops of materials and energy [2, 3]. Despite its merits, the implementation of a circular economy is subject to the multiple physical, environmental, and social interactions within the production and waste management systems [4]. In developing countries, this dependency is exacerbated by poor infrastructure coupled with a lack of training and effective regulations on environmental matters. These conditions are pushing the informal actors to thrive [3, 5–7].

The informal waste sector (IWS) or informal recyclers are individuals that collect, sort, and sell waste as a way to generate income and whose activities are not supported by formal authorities [8]. Informal recyclers are the base of the workforce pyramid and perform the most labour-intensive and least compensated parts of recyclables extraction from mixed wastes and open landfills [7]. The nature of their work, their scarce negotiation power and the price volatility of collected materials place informal recyclers as one of the most vulnerable groups not just in the waste management chain but also in the social hierarchy [9].

Despite the lack of recognition, the IWS plays a very vital role in promoting the circular economy [10–13]. Muswema et al. (2018) reported that informal recyclers in South Africa are responsible for up to 90% of recycling streams of materials with high commercial value. In China, 60% of the electric and electronic waste (e-waste) is processed by the IWS, which led to a burgeoning second-hand market all over the country [15]. In Brazil, more than 600,000 informal recyclers are working in cooperatives that collect 2/3 of all recyclable dry waste sent for recycling in the Southeast region of the country [16]. Informal recyclers use technologies with low environmental impact to prevent materials from ending up in landfills [5]. This service leads to economic savings for public sectors, who are usually in charge of financing waste management systems [17, 18].

Recognizing and including in formal waste management is not only fostered in their management capacities but is also promoted from an environmental justice perspective. Achieving a just transition for a circular economy means combining circular economy policies with social protection measures to avoid negatively impacting working conditions, health, livelihoods, and job opportunities of the poor sectors of society, such as informal waste workers [19].

The integration of the IWS is plagued with several challenges. Firstly, 'informality' captures a wide variety of worker profiles. Policies aimed at integrating IWS must recognize and consider this heterogeneity to reach the effective inclusion of the IWS [20]. Secondly, it is essential to include the voice of informal workers when designing and reforming waste management systems [21–23]. If not, integration efforts run the risk of being inefficient and further affecting an already vulnerable sector. Thirdly, the IWS is driven by demand and supply [24]. Operators in this sector typically recover high-value waste and ignore other types such as organics and plastic bags [25]. These market dynamics limit the potential of the IWS to further increase the recycling rates in the Global South [26]. Fourth, regulations discourage the participation of the IWS in waste management services in favour of the formal sector [16, 27]. The relationship between the formal and informal sectors is characterized by an imbalance of power and lack of transparency. Informal recyclers are usually exploited and do not receive fair wages for the work they perform [23]. In practice, the collection and treatment of materials clashes between both sectors, resulting in efficiency

losses [28]. Furthermore, the IWS is more vulnerable to health and safety issues [13, 29] such as criminal activities [30], child labour [31], and high occupational health risks [32]. Although these challenges are transversal to all countries in which informal recyclers are part of waste management, the specific characteristics differ from case to case.

The average household waste generation in Nepal is 0.223 kg/person/day, from which more than 60% corresponds to organic waste followed by plastics and paper products [33, 34]. The current waste management in Nepal is linear, as more than 90% is disposed of in landfills and open dumps, including riverside dumps and open burns [33–35]. The pollution of water resources and the public health hazards in the localities surrounding waste treatment areas have been identified as critical issues in Nepal [33, 36, 37]. In this context, the need of promoting a circular economy approach to restructure waste management is imperative.

Household solid waste management in Nepal is riddled with several environmental problems on top of a complex network of formal and informal actors [36]. Waste management falls under the remit of the municipalities, who operate based on the guidelines in the Solid Waste Management Act [38]. Saliently, these guidelines do not mention or recognize informal recyclers as valid actors within the waste management system [38]. In the Wider Kathmandu Valley, informal recyclers process up to 15% of waste and, in many cases, represent the only alternative to landfilling and open disposal [32].

A systematic understanding of how the IWS can contribute to promoting circular economy in Nepal is still lacking. This gap presents an opportunity for this study to identify current challenges of the IWS and the interactions between the formal and informal actors that make up the waste management systems in Nepal. To further strengthen the systematic understanding, this research addresses the case of Kathmandu and Lalitpur, two main cities in Nepal. The focus is limited to these geographies because of the larger presence of informality within the waste management sector, fairly representing the IWS's characteristics at a national scale.

Consequently, this study aims to (i) identify and validate the challenges of the IWS in Nepal; (ii) provide a granular understanding of the actors, conditions, interactions, and hierarchical forces that shape waste management in the region; and (iii) contribute with a set of recommendations to promote the participation of IWS into the circular economy in Nepal.

Literature Review

A systematic review of scientific and grey literature is developed to create a general understanding of the sociocultural, economic, and environmental conditions around waste management in Nepal. The systematic review of scientific literature was developed using Google Scholar engine. As illustrated in Table 1, for each search, a set of mixed words were inputted. The first 50 results were screened by order of relevance to Nepal and the year of publication (2011 and onwards). Only publications in English and international scientific journals were considered. The same keywords were used to review grey literature and policy reports on Google search engine. The keywords used for each search along with the 11 sources identified are shown in Table 1.

The analysis of the 15 sources obtained from the literature review aids in describing the IWS in Nepal in three distinctive ways. Firstly, the IWS is numerous and represents the most expanded alternative to landfills and open dumps, mostly in urban and semi-urban

Table 1 Summary of the systematic literature review

Keywords		Selected articles
Nepal +	Health; informal waste workers; waste management; risk	[32, 39, 40]
	E-waste; informal waste workers; urban;	[41]
	Informal waste workers; health; urban;	[29]
	SWM; urban; social life cycle assessments;	[42]
	Waste management; urban; foreign aid;	[43]
	Ethnography; waste management; urban;	[44]
	Informal economy; urban; gender;	[45]
	Solid waste management; municipal solid waste; plastic waste recovery; financing solid waste management;	[46]
	Solid waste management; waste composition;	[33, 36]
	Waste collection frequency; waste collection time; composting; degradable waste; non-degradable waste;	[47]
	Resource recovery; municipal solid waste; scrap shop recycling; source segregation;	[35]
	Municipalities; waste generation; waste management	[34]

settlements [35, 36, 41, 42, 44]. Secondly, the IWS in Nepal suffers from discrimination and their vulnerability is strongly related to the inherent health risks of waste collection and sorting [32, 39, 40, 42]. Thirdly, the implementation of a circular economy in Nepal requires the formal sector, including the local and national authorities, to validate the IWS and recognize its capacity [35, 38, 42, 43, 46, 47]. A thorough characterization of waste management in Nepal that includes the voice and perspective of the formal and informal actors is still missing.

Methodology

A broad research question, such as the one being explored in this study, necessitates a qualitative approach to address it [48]. The interactions between the waste management actors noted in this paper are first-hand experiences of those actors themselves. Data collection methods employed in this study are semi-structured interviews, questionnaires, and a co-creation workshop with the waste management actors of Kathmandu and Lalitpur. Primary data collection is conducted in two phases. The first is semi-structured interviews and questionnaires which are aimed to identify the challenges in promoting a circular economy in Nepal, characterize the actors that compose the waste management systems, including those absent in the literature, and establish their position along the waste management chain. The second phase is the co-creation workshop which intends to validate the outcomes of the interviews and incorporate new findings from the discussion between different actors. Data collection was carried out over a period of 6 months. A description of each method is presented in the sections below.

Semi-structured Interviews and Questionnaires

A total of 58 stakeholders participated in primary data collection. Twenty-eight semi-structured interviews were conducted with three groups of stakeholders: representatives of the formal sector, clients of both the formal and informal sectors, and informal waste workers. The interviews enabled to get deeper insights into the waste management challenges and helped triangulate how these actors understand their own and others' roles. Interviews were in English and Nepali and were recorded, transcribed, and translated for further analysis.

A purposive sampling method was adopted to identify representatives of the formal sector. A total of 8 representatives were interviewed: private waste service providers (2), non-governmental organizations (4), young and innovative entrepreneurs (1), and representatives from the local government (1).

The clients of the formal waste sector encompass individual households as well as companies, while the clients of the IWS are predominantly individual households. Snowball sampling was used to identify clients from both groups. Face-to-face interviews were conducted with six stakeholders, while 30 stakeholders opted to complete an online questionnaire. All interviews and questionnaires were conducted in Nepali. The interview and the questionnaire guides are presented in the supplementary information.

The informal waste workers were shortlisted from waste collection and management centres to ensure a representative sample that includes the entire hierarchy of the waste ecosystem. A total of 20 informal waste workers were interviewed in Nepali.

Co-creation Workshop

Co-creation workshops provided an opportunity for stakeholders to voice their opinion. For this study, a co-creation workshop with ten different stakeholders from the formal and informal waste management sectors was held in Kathmandu. The workshop was divided into two parts. In the first part, participants were presented with the actors' characterization obtained from the interviews and questionnaires and then allowed to validate and provide feedback on this characterization. In the second part, participants were invited to collectively reflect on the challenges of the IWS and propose solutions to promote a circular economy in Kathmandu and Lalitpur. Participants were provided with the preliminary challenges identified during the interviews and questionnaires. The workshop was captured via both audio and video for analysis. The agenda of the workshop is presented in the supplementary information.

Data Analysis

The data analysis was carried out in two phases. The first phase entailed a thematic categorisation of the transcription and summary of the interview and questionnaire responses. The themes are (i) the role of the formal and informal actors; (ii) the challenges to promote a circular economy in Nepal; and (iii) the solutions to address these challenges. The researchers discussed the preliminary results to obtain a characterization of waste actors and a set of key challenges and their respective strategies to promote a circular economy in Nepal. These initial results provided input for the co-creation

workshop. The second phase included an assessment of workshop discussions from the video recording and the notes taken during the workshops. The outcomes were reviewed and used to fortify the pre-defined categories in the first phase.

Results

Nepal is divided into 77 districts (Fig. 1) which together generated an estimated 3023 t/day of municipal solid waste (MSW), equal to a national average of 0.223 kg/capita/day in 2017 [33]. Of this amount, 65% corresponds to organic with the potential to be composted and 25% are easy-to-recycle materials such as plastics, metals, and papers (Ibid.). Households in the Terai or plain regions (southern Nepal) generate 80% more waste in comparison to the Mountain region (northern Nepal). Among the 293 local administration bodies or municipalities in Nepal, Kathmandu, and Lalitpur are the first and third most populated areas with an estimated population of 1,277,000 and 288,584, respectively in 2017 [36, 49].

Only 14% of municipalities in Nepal send a fraction of the waste collected for recycling [50]. However, there is no official data on the recycling rates in the country. In Kathmandu, the most robust estimations indicate a recovery potential of 44% for materials such as textiles, plastics, and leathers [35]. From this potential, the current estimated recycling rate is only 8%, undertaken by both the formal and informal sectors [33, 35].

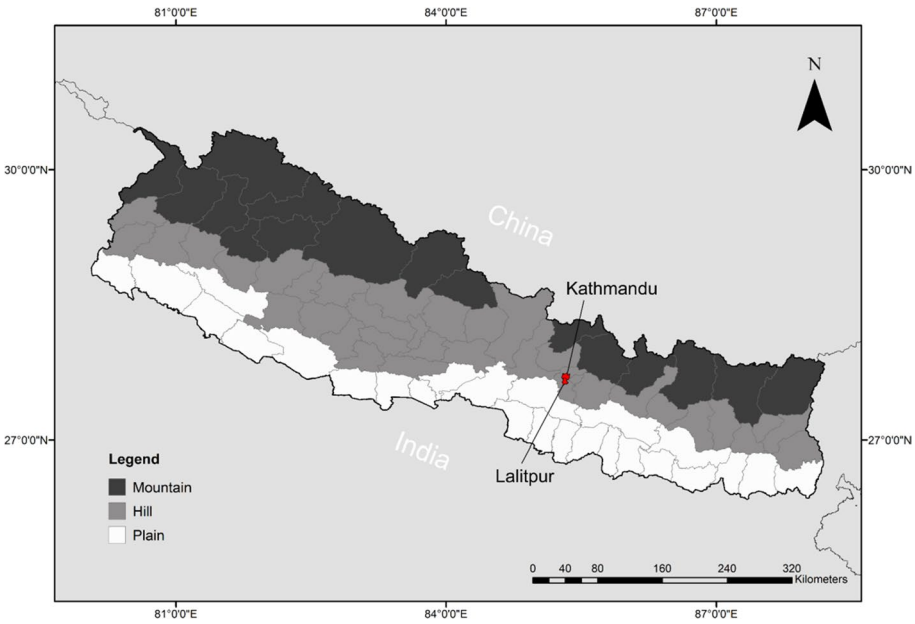

Fig. 1 Location of Kathmandu and Lalitpur in Nepal

Interaction Between Waste Management Actors

Interactions between waste actors largely occur during waste generation and treatment (Fig. 2). The waste that is generated by households, institutions, and commercial sectors has two possible routes. The first route goes through the waste management system that is set up by the municipality. The waste that is collected through this route is mixed, comprising organic, inorganic, recyclable, non-recyclable, and sometimes hazardous waste. At this point in the waste management chain, often it is either private service providers or the municipality itself that are the first port of call. In rare circumstances, certain organic waste treatment companies are involved at this stage. In those instances, waste producers separate organic material to be taken away by these organic waste treatment companies. Afterwards, the waste is transported to either a transfer station (if collected by the municipality or the private sector) or recovery centres. The municipality or private sector unofficially contract out the waste recovery to the IWS. However, sometimes this part of the process is skipped, and waste is transported directly to the landfills by the municipality and the private sector. The mixed waste is segregated at the landfills by scavengers who then sell it to nearby waste collection centres.

In the second route, waste generators separate the more "valuable" items such as metal, glass, and paper. Then this segregated waste is picked up by cycle hawkers, which go door-to-door to collect these specific waste items. The cycle hawkers take or (rarely) buy waste from the waste producers, and then bring it to waste collection centres to sell. The cycle hawkers have no say in the pricing of the types of waste that the waste collection centres buy. In some cases, waste collection centres are registered with the government and pay taxes, and in other cases, work unregistered and are not subjected to any tax; thus, they are both formal and informal. The collection centres process some of the waste, such as sorting and extracting copper from wires, and then specific aggregators buy certain waste types from the centres. Aggregators are typically registered with the government. Some waste processing happens at the aggregator's site such as sorting, compressing, and shredding.

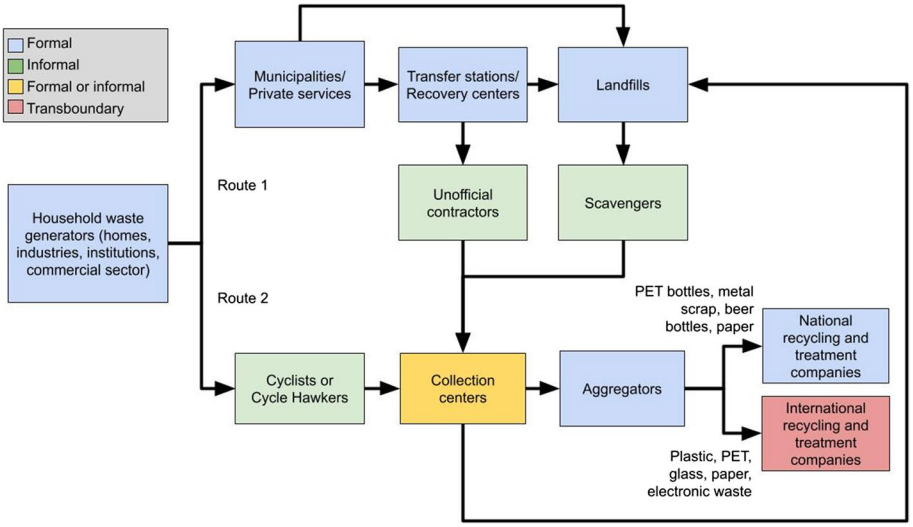

Fig. 2 Interaction of the waste management actors. The solid lines indicate waste streams

These aggregators then take the waste to specific recycling industries inside or outside of Nepal. Waste such as paper, PET plastics, and metal scraps are recycled within Nepal, but e-waste, glass, and other types of plastic are sent illegally to India to be recycled.

It is evident that the informal sector intrinsically completes Nepal's waste management system (see Fig. 2). Collection centres play a unique role enabling all actors to converge — a defining point where informality transforms into formality. These results are consistent with findings from similar studies conducted in other developing countries and demonstrate that the informal sector in Nepal has critical relevance for circular economy markets [14, 51].

Profiles for the Waste Management Actors in Nepal

Waste management in Nepal is regulated by the Solid Waste Management Act [38]. This act establishes a comprehensive list of requirements to obtain a formal license to work as a private agent in the waste management sector. In practice, most of the stakeholders recognize that the payment of taxes is the key distinction that separates formality from informality. Based on this distinction, a profile description for each actor identified in Fig. 2 is presented below.

Formal Waste Management Actors

Door-to-door collection and roadside pickup from open piles or containers are the most usual types of collection methods in Nepal. Commonly, rickshaws and carts are used for primary collection, tractors for secondary collection (between transfer stations), and dump trucks for the final transportation to landfill or disposal sites. Vehicles, equipment, and operations practices are the main influence on the efficiency of waste transfer from the primary collection point to the final disposal sites. The main formal waste management actors are described in the sections below.

Household Waste Generator Household waste generators are actors that dispose waste in a house, institutional, or commercial collection. As waste generators use taxes to fund the municipal operation, they are considered formal actors. An 80% of the house generators claim that they segregate waste into organic and inorganic, from which most state that they compost the organic waste in their yards. This contrasts with what is stated in literature, which suggests that only 30% of households practice segregation and traditional methods for composting, mostly in rural areas [36].

Unlike municipal waste collection users, households that employ the services of the private waste sector tend to be more aware of the collection costs. These users declare a service payment of US$1.3–2.6 per month depending on the company. Interviewees also mentioned that private waste companies provide higher collection frequencies compared to the municipal counterparts. On rare occasions, households sell materials such as empty shampoo bottles, newspapers, damaged electronic items, scrap metals, cans, and glass bottles to informal waste workers, receiving up to US$0.12 per kg. However, waste generators from commercial shops have a more established relationship with the informal waste workers and usually sell materials to the same waste picker.

Most household generators see the IWS as necessary as they contribute to cleanliness and are seen as an important part of the recycling process. They also view cycle hawkers as

a helpful group to get rid of voluminous waste. Some household generators perceive IWS as a source of potential health hazards as they can be exposed to transmissible diseases and respiratory infections (including COVID) when going door to door for collection without safety protocols. Household generators who do not interact with IWS typically seek services from the private sector.

Municipalities In Nepal, municipalities are the local government bodies that oversee waste collection services. In general, municipal administrators perceive IWS as unreliable, so they prefer working with the formal sector. In less busy and inaccessible areas, local governments normally have verbal agreements with formal companies to collect waste. However, local government representatives recognize that informal waste workers are influential in increasing awareness around the value of waste.

The waste collection efficiency of the municipalities is estimated to be in between the range of 70% and 90% in major towns and is below 50% in several small towns, resulting in a national average of 62% [36]. In Kathmandu and Lalitpur, the collection efficiency is 86% and 62%, respectively [36]. In terms of costs, municipalities tend to spend around 10% of the total budget on solid waste management, of which about 60–70% is spent on street sweeping and collection. About US$30 per tonne of waste was spent from the process of collection to disposal in the fiscal year 2012. The monthly tariff is in the range of US$0.10 to US$2.08 for households [36].

Certain municipalities apply a tax (known as "scrap tax") to the transfer of recyclable waste within their territories, mainly when using highways for transportation. Similarly, a valued added tax of 13% is imposed on bulk transportation of waste scraps around the country. The scrap tax discourages the participation of formal and informal recycling actors since it reduces the net income of collecting and selling material.

Private Services Private services represent two types of companies. The first type corresponds to companies in charge of collecting waste to landfills. They do a similar job as municipalities, but the collection is more frequent. In some areas, these companies also use municipal transfer stations and recovery centres to store waste, which is transported to landfills by municipal trucks. The second type corresponds to waste treatment companies that collect and treat recoverable materials. Organic waste treatment companies specialize in materials such as vegetable leftovers and garden trimmings, which make up more than 60% of waste in Kathmandu and Lalitpur [36].

Collection Centres Collection and recovery centres are installations managed by one or more people (usually a family business) where informal cycle hawkers sell the collected material. Most of the collection centres are officially registered and pay taxes, but some of them are set up as informal centres and forgo registration and taxes. Despite these varied structures, the working conditions do not differ in formal and informal collection centres.

Collection centres are in direct competition with each other. The average daily transactions of a collection centre are between US$41.2 and US$82.4, with an average profit per day of US$4.1. The collection centres have access to technology such as compressors or balers and have the capacity to store the material until the price is convenient enough to be sold.

Aggregators Aggregators are formal companies that process large amounts of materials to sell them in local and international markets. The main international market is

India, which presents a critical issue because exporting certain types of waste such as plastic is illegal. However, India is the only option as there is no recycling capacity for materials like glass or plastics other than polyethylene terephthalate (PET) in Nepal.

Each aggregator is usually focused on one kind of material (e.g., plastic, metal, or cardboard), which is obtained from the collection centres. These aggregators offer between US$0.16–0.18 per kg of metal and US$0.11–0.12 per kg of plastic and have a profit of US$411.8–494.1 per month coming solely from cardboard recycling. The aggregators working near city centres have better access to collection centres and lower costs compared to those working far from urban agglomerations. For cardboard and metal, aggregators might skip the collection centres and work directly with cyclists.

Aggregators are associated in the "*Nepal Kawadi sangh*" umbrella group. This organisation has a record of aggregators and collection centres on a national scale and represents the sector's concern about waste management policies and other relevant topics. Compared to the rest of the actors, those who work in the aggregators' business are normally well-educated and trained.

Recycling and Treatment Companies (National and International) Recycling and treatment companies are formal organizations that transform certain types of waste into new materials. The domestic capacity of Nepal allows the treatment of PET bottles, metal scrap, beer bottles, and paper. Other materials are sent to international markets such as India [36].

Landfill In Kathmandu and Lalitpur, the waste is disposed of in the Sisdol Landfill. Originally, this landfill was expected to reach its capacity and end in 2008. However, since there is no alternative, the Sisdol landfill is still in operation [32, 43].

Informal Waste Management Actors

The IWS in Nepal consists of all the workers that are not formally recognized by the local government as a part of the waste management mechanism. The IWS contributes almost 15% of total waste management and US$2.4 million per year to the national economy [43]. As informal workers are not licenced by the local government to collect and manage waste, contrary to requirements in the Solid Waste Management Act, 2011, of Nepal, their legality is often questioned [38]. Wages earned through informal work are not affected by income tax and other regulatory mechanisms as they are not legally registered businesses. Hypothetically, these taxes would be imposed on the income earned during the transportation and transfer of recycled goods to large recycling industries. Nevertheless, unlicensed activities are normally not sanctioned.

The materials treated by the IWS result in savings in collection, transportation, and disposal costs for municipalities, and a lower level of littering and pollution in public spaces. This is only possible due to the low operational costs and margins of the IWS. Therefore, the unrecognised costs of informal labour such as lack of social security and safety equipment are cross-subsidising the recycling markets in Nepal.

Informal waste workers who belong to the lowest rung of the waste management hierarchy are commonly known as *kabadiwalas.* These workers are engaged mostly in the

collection of reusable and recyclables like papers, plastics, metal, and glass and selling them to local scrap shops. Kabadiwalas and scrap shops are present in significant numbers in Nepal, particularly in urban areas like Kathmandu, where reusable and recyclable materials are abundantly available. It is estimated that between 10,000 and 15,000 informal waste workers operate in Kathmandu Valley [41, 52]. Informal waste workers are mainly responsible for collecting reusable and recyclable materials from households, institutions, and commercial establishments [35]. The characteristic differences in the type of work kabadiwalas carry out can be further categorized into cyclists and scavengers.

The threats and vulnerabilities that kabadiwalas face are multidimensional; however, social and health issues are the most challenging [32]. Occupational health risks, including physical injuries and cuts, are common. Other health conditions, like respiratory diseases, are also reported in literature [29]. The main informal waste management actors are described in the sections below.

Cyclists Cyclists or cycle hawkers are informal waste workers who go door-to-door to collect waste from the house or commercial collection points. Cyclists typically use bicycles with saddles mounted for hanging sacks for the collection and transport of waste. They usually cover between 10 and 12 km per day and do not have a fixed territory they work in. Cyclists are typically aged between 25 and 40 years old, work individually and do not associate with other waste collectors. A cyclist can earn between US$66–82 per month and US$1.65–4.12 per day.

Unlike other informal actors, the nature of the cyclists' operations allows them to interact directly with waste generators. This interaction enables local communities to recognise cyclists as key stakeholders in the waste management chain. Additionally, the exchange between waste generators and cyclists establishes an unconventional network within the waste collection services. Waste generators know when and how to separate the material for the cyclists, in turn, cyclists are familiar with neighbourhoods with the highest quality materials. This socio-logistic capital is a key advantage that IWS has which is lacking in formal collection services.

Scavengers Scavengers or waste pickers are individuals who roam around the city, dumpsites, and landfills collecting valuable waste material. Once collected, they sell the material directly to intermediates known as collection centres. On average, scavengers' income is less than cyclists. Workers in this group are the most illiterate and vulnerable in the whole waste collection and treatment chain.

The main difference between scavengers and cyclists is the ownership of a mode of transportation for collection. As scavengers move mainly on foot or are concentrated around landfills, their interaction with waste generators is scarce or none. This absence of this type of interaction translates into a lack of recognition, which along with the risk of working around landfills, increases their vulnerability.

Unofficial Contractors Unofficial contractors were identified by the municipal administration as informal actors who segregate and collect the materials from the transfer stations to the collection centres. Some of these actors belong to collection centres themselves and establish sporadic agreements with kabadiwalas to use their workforce when needed. Unofficial contractors use trucks and other motorized means of collection and have

verbal arrangements with municipalities. Although informal, unofficial contractors are listed above cyclists and scavengers in the waste management hierarchy due to their bargaining power with collection centres and municipalities, hence why they are not categorized as kabadiwalas.

Challenges of the Informal Waste Management Sector in Nepal

Current literature uses a fairly generic approach to identify the cross-cutting challenges faced by the IWS to promote circular economy [21, 51, 53, 54]. This study categorises these challenges as multidimensional and acknowledges that there is a lack of power to address them. These are key features to consider when promoting integration initiatives for the informal sector. For Kathmandu and Lalitpur, the main challenges of IWS along with solution approaches proposed and validated by waste management stakeholders are summarized in Table 2.

The challenges indicated in Table 2 are consistent with the multidimensionality (social, technical, economic, and regulatory) described in the literature [20, 21, 51, 53, 54]. Among the solution approaches, only the volatility of prices (challenge 1) and the unsustainable consumer behaviour (challenge 3) offer space to be addressed by the IWS solely. In Nepal, the solutions are largely regulatory, highlighting the fundamental role of centralized governments to address the challenges and enforce the regulations.

Table 2 Challenges of the informal waste management sector in Nepal to promote a circular economy

Challenge	Proposed solutions
Ch 1. The volatility of the sale prices of the collected material affects the profitability of the informal waste sector	- Creation of cooperatives and small/medium businesses led by informal recyclers to form their own collection centres and increase collection volumes. With higher volumes, higher bargaining power and prices - Application of a subsidy scheme to establish a minimum sale price for collected material
Ch 2. The lack of domestic capacity to treat and recover material forces local actors to export material, even when banned	- Decrease the requirement to lease the land for the development of recovery infrastructure - Reform the regulation that bans the export of certain materials to India and other markets
Ch 3. Consumer behaviour and negative attitude towards informal recyclers affect the dignity and profitability of recycling markets	- Education campaigns on sustainable waste management and circular economy
Ch 4. There is excessive use of discardable and short-lifespan products whose recycling is not profitable	- Taxation or ban on single-use products such as discardable plastic bags and straws
Ch 5. Lack of institutional capacity to apply regulations and policies on waste management	- Review and reform of Nepal Solid Waste Management Act [38] to assign responsibility to public administrations according to their capacities
Ch 6. Public tenders for waste management services focus solely on costs	- Review and reform of the Nepal procurement act [55] to include environmental and social factors
Ch 7. Taxation on materials' transport (scrap tax) discourages and decreases the profitability of waste collection for recycling	- Elimination of the scrap tax for the informal sector

Discussion

This section presents a set of recommendations to promote the participation of IWS in circular economy in Nepal based on the interaction between waste actors and the challenges identified in previous sections.

The Need to Integrate the Informal Sector

The relevance of the informal sector for the current recycling markets in Nepal is validated by analysing interactions between waste management actors. Although this is acknowledged in existing literature [7, 29, 41], this particular case of household waste management's disproportionate dependence on IWS in Nepal makes a strong case for integration. The role and impact of the IWS in increasing environmental awareness, establishing waste segregation, and implementing circularity in the waste management system are recognized by all the stakeholders. However, these positive impacts have not triggered any form of transition in favour of informal waste workers, who are currently unable to claim or collect social security and health benefits provided by the government.

In line with Saidón et al. (2022), the heterogeneity of the informal sector in Nepal is supported by the identification of two profiles under the kabidawala umbrella: cyclists and scavengers. Their differences in terms of logistics, capacity, and interactions must be considered in the integration process. The characteristics of cyclists' labour can be harnessed to promote more sustainable consumption and source separation in generators. Scavengers are closer to sorting and classification activities of household waste which are activities that are essential for the success of a circular economy. The circular economy ambitions in Nepal must include the full capacity and diversity of the informal sector, without which proper integration may be ineffective. Any effort to exclude them can affect the availability of material needed to maintain the circular markets in Nepal.

A novel finding from the description of the waste management actors in Nepal is the classification of the collection centres in terms of their formality. So far, this degree of formality is not recognized either by literature or by the other waste management actors in this country context. The formalization process in Nepal is a unique opportunity for not only cyclists and waste pickers, but all the stakeholders that form the waste management sectors because it can have an enormous potential to improve the standards of informal waste actors.

Reforms to Promote a Circular Economy in Nepal

The increase in the institutional capacity to apply waste management regulations and policies (challenge 5) and reform of these regulatory mechanisms are pivotal, as these are barriers for the development of circular economy in Nepal. These regulations include the Nepal Solid Waste Management Act [38] and the Nepal procurement act [55]. The scrap tax (challenge 7), the ban on the export of materials (challenge 2) and the high impact of costs in the tenders for waste management services (challenge 6) must be reviewed with special attention for the IWS's profitability. Independent of the strategy to stimulate treatment and recovery markets, authorities must also consider that changing the current rules can introduce new actors with access to capital, which could exclude IWS even more [9].

This trade-off can be addressed through an integration process that prioritizes the formalization of cyclists and waste pickers over other actors.

Association Schemes to Empower the Informal Sector

As they are at the bottom of the waste management hierarchy, cyclists, and scavengers do not have negotiation power when interacting with other actors and selling the collected material. The informal workers are profoundly affected by the volatility of the material price (challenge 1) and are affected by the consumers' behaviour and negative attitude towards the IWS (challenge 3). Unlike others, these challenges can be addressed by the informal sector itself. Collection centres formed as cooperatives and small/medium businesses led by waste pickers have the potential of improving their profitability [56]. These configurations allow IWS to store materials, increase volumes, and, therefore, augment their negotiation power when selling the materials to aggregators. As they have the knowledge but not the capital to invest in this solution, social entrepreneurship models can be explored as organisation schemes [57]. Working groups and collective associations facilitate the training of recyclers as environmental agents, the development of protection networks and the standardization of services [58]. These effects add value to IWS's labour and can improve the perception of generators and other formal actors.

Extended Producer Responsibility Scheme

Extended producer responsibility (EPR) is a principle under which producers are given a significant responsibility — financial and/or physical — for the treatment or disposal of post-consumer products. This principle is identified by scholars [24, 59] and institutions [60, 61] as a transformative approach to promote a circular economy and the participation of all the actors that compose the production and waste management systems. The effect of the EPR was proved in the European Union, which adopted it as a central principle for their circular economy ambition and allowed them to reach never-before-seen recycling rates [12]. Developing countries with a high presence of informal recyclers such as China and Brazil are also implementing the EPR to increase recycling rates and improve the efficiency of their industry [62–64]. In the context of Nepal, an EPR scheme has the potential to integrate circularity upstream and address the excessive use of discardable and short-lifespan products whose collection and treatment are not profitable (challenge 4). The definition of goals and mechanism to implement an EPR scheme must be seen as an opportunity to bring ideas and explore cooperation efforts from both formal and informal sectors. In Chile, for example, the EPR law recognizes the relevance of grassroots recyclers and explicitly acknowledges that collective waste management systems must be created to reach the country's goals [65].

Conclusion

This study identified the interactions between the formal and informal actors that compose the waste management systems in Nepal and the current challenges of the IWS. The direct participation of stakeholders from the formal and informal sectors allowed

an analysis of first-hand information. This methodological approach is essential to obtain a deep understanding of the complexity that characterizes informality in waste management systems. In particular, the identification and characterization of the different waste management actors were possible due to the methodological nature of interviews, which offers space for the actors who are usually excluded to reflect on their own circumstances.

Theoretical Contribution

This study contributes to the characterization of informality in waste management. The identification of cyclists and scavenges under the informality profile supports the conceptualization of the heterogeneity of informal waste management as a counter to the generalization of waste picking activities [20]. The results of this study also support the idea that recognition and integration of the informal sector into the waste management systems are essential to promote a circular economy [13]. In Nepal, this is not only based on the dependency of current markets on the informal waste sector, but on the possibility that integration offers to address many of the current challenges of the informal workers. In addition, informal workers belong to the most vulnerable socioeconomic groups and are exposed to health risks due to the nature of their job. From a just transition perspective, the integration into formal waste management systems has the potential to improve their livelihood.

Practical Implications

The challenges and respective solutions identified by waste management stakeholders from Kathmandu and Lalitpur (Table 2) offer a solid starting point to promote a circular economy in Nepal. In Nepal, the role of the government in creating an enabling environment for a circular economy is crucial. A reform of current waste management and tendering regulations are seemingly critical to decrease the barriers that are harnessing formal and, mostly, informal actors. In line with that, a Nepalese EPR scheme can respond to unsustainable production and consumption patterns. If this scheme includes the voice and experience of the formal and informal sectors, its implementation can also address the lack of recognition that is a characteristic of integration efforts.

Current Study Limitations

Research limitations are related to the geographic scope and the survey size used for the interviews and questionnaires. Our results should be considered as a basis for the design of integration initiatives in Nepal. Notwithstanding the aforementioned, Kathmandu and Lalitpur reflex the conditions of the informal sector found in literature, so we encourage the interpretation of the results using a comparative and generic approach. In particular, the interactions and challenges found in this study have the potential to represent other regions and can be useful to understand similar contexts in the Global South.

Future Research

This research provided a characterization of the stakeholders that compose waste management in Kathmandu and Lalitpur as a representation of the Nepalese context. Further research should quantify the current and potential capacity of those stakeholders who collect and treat waste in Nepal. This information is necessary to deliver more in-depth recommendations for policymakers. In particular, the development of an effective EPR scheme for Nepal lies in identifying waste collection and treatment capacities.

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Declarations

Ethics Approval and Consent to Participate and for Publication The methods for this study were approved by the University Research Ethics Committee (UREC) of the University of Manchester (UK) (Reference number: 2021–10481-17781). Written informed consent was obtained from all individual participants included in the study, including the consent for publication.

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