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MEASURING INFORMALITY?

CHALLENGES IN QUANTIFYING INFORMAL RECYCLING SECTOR ACTIVITIES

A doctoral thesis

by

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“Where there's muck there's brass” [1]

[1] *A 20th century expression which originated in Yorkshire, England where brass is still used as a slang term for money. By 'muck' any form of dirt or manure may be implied, depending on context. Where there are dirty jobs to be done there is money to be made. Link: http://www.phrases.org.uk/meanings/408900.html (Last accessed: 27.10.2015).*

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Dedicated to my daughters Ida, Yara and Anna.

Abstract

The informal sector plays a crucial role in waste management systems around the globe. This “unofficial” and “not authorised” sector consists of waste pickers and other stakeholders constituting an informal recycling value chain and make a living out of the collection, processing, recycling and trading of different recyclables. Waste and recyclable materials provide a livelihood for millions of people in low-income and transition countries, but due to economic crises and increased migration, the informal waste recycling sector becomes also more and more visible in Central and Eastern Europe. As the informal sector closes the gap where formal systems (run by private enterprises or public utilities) cannot provide waste collection, processing and recycling services to a sufficient extent, informals have to be considered as an integral part of the existing systems. Despite this, it happens that informal and formal systems are competing for recyclables, this is the case when formal systems start with separate collection and recycling activities in order to generate revenues from selling recyclables. In all these cases it is necessary to have information on the performance and the values and attitudes towards waste attached by the informal recycling sector.

Waste management systems are characterised by the involvement and interactions of various stakeholder groups – often with different interests. There are different reasons, depending on local specifications, why certain parties intend to obtain data on informal sector performance. It is important that the results of examinations aiming at displaying informal sector performance are not stand-alone but have to be considered in the context of the whole waste management system. Especially the interfaces between formal and informal systems are of particular interest.

On the one hand this cumulative thesis deals with the elaboration of methodological approaches in order to obtain data on the performance of informal systems directly at the level of informal stakeholders. On the other hand, it is reported how these findings may be related to other elements of the overall waste management system. Estimates regarding the contribution of the informal sector to waste recycling (based on the developed methods in this thesis) have to be considered as approximate values due to several uncertainties that are explained. However, this thesis presents the concept of triangulation that enables a cross-verification of the estimates by using different methods in order to quantify informally diverted recyclables.

This thesis shall provide a methodological framework for practitioners in order to estimate the contribution of informal systems in low-income and transition countries to waste collection and recycling as important prerequisite for waste management monitoring and planning activities.

Keywords

Low income countries, informal recycling sector, waste recycling, waste picking, waste collection, municipal solid waste, waste generation, significance, modelling, measuring

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I(R)S	Informal (recycling) sector
SWM	Solid Waste Management
EPR	Extended Producer Responsibility
MSW	Municipal Solid Waste
WEEE	Waste Electrical and Electronic Equipment
EEE	Electrical and Electronic Equipment
PAYT	Pay-As-You-Throw
C & I	Commercial and Industrial
C & D	Construction and Demolition
IWBs	Itinerant Waste Buyers
UBCs	Used Beverage Cans

1 Introduction

According to a resolution concerning decent work and the informal economy the General Conference of the International Labour Organisation (ILO) describes that ‘‘informal economy’’ refers to all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements. Their activities are not included in the law, which means that they are operating outside the formal reach of the law; or they are not covered in practice, which means that – although they are operating within the formal reach of the law, the law is not applied or not enforced; or the law discourages compliance because it is inappropriate, burdensome, or imposes excessive costs (ILO, 2002). Beside the fact that the informal economy in general is responsible for a considerable amount of the Gross Domestic Product produced in low-income and transition countries, informal work realities affect the predominant share of the global workforce.

This also holds true for waste management: millions of people worldwide earn their livelihoods from picking consumption residues, i.e. waste and recyclable materials. Waste is seen as income opportunity but the involved people usually live in difficult situations regarding occupational health and safety issues. Informal workers (no matter if related to waste picking or other activities) usually have in common that they do not record their activities. Therefore, it is difficult to assess how and in what quantities informal waste pickers contribute to collection, processing, recycling and resource recovery.

On the one hand this cumulative thesis deals with the elaboration of methodological approaches in order to obtain data on the performance of informal systems directly at the level of informal stakeholders. On the other hand, it is reported how these findings may be related to other elements of the overall waste management system. Estimates regarding the contribution of the informal sector to waste recycling (based on the developed methods in this thesis) have to be considered as approximate values due to several uncertainties that are explained. However, this thesis presents the concept of triangulation that enables a cross-verification of the estimates by using different methods in order to quantify informally diverted recyclables.

This thesis shall provide a methodological framework for practitioners in order to estimate the contribution of informal systems in low-income and transition countries to waste collection and recycling as important prerequisite for waste management monitoring and planning activities. This work was developed and written in the time period from 2011 to 2015.

Chapter 1 deals with an introduction to the topic and reveals how informal sector activities emerged in literature and increasingly gained interest of research. Several definitions of informal work are presented and discussed, especially with the link to waste management it is described what the typical locations are prevailing where informals are active.

Chapter 2 outlines the research objective of this work and what are the typical needs of stakeholders involved in waste management to obtain data on the informal sector performance.

Chapter 3 digs into details regarding the methodological approaches that might be used for estimating informal sector performance. At the beginning it is explained how a “value chain approach” supports the integral approach to obtain data on the informal sector. It is important to assess the existing data basis and to find out what sources of information might be

available in order to generate data on the informal sector contribution to waste management. This different sources of information and the related availability and quality of data are described in Chapter 3, leading to the deduction of different methodological approaches. The concept of triangulation is introduced in order to provide a methodological concept to verify results of estimating informal sector performance. This concept is amplified by presenting three case studies.

Chapter 4 is dealing with the illustration of three research articles of which to were published in SCI ranked journals. Chapter 5 presents the main findings of this thesis.

1.1 Different perspectives of waste management in low-income countries

The following introductory remarks are published in a briefing article of a themed journal issue on waste management in low-income countries (Linzner and Ali, 2013).

Solid waste management was not even considered to be an essential basic service in many countries before 1970. Most of the solid waste management activities existed under the departments of public health, usually led by a health professional, with a strong focus on waste collection to reduce the disease risks.

The concepts of considering solid waste as a resource, reducing waste generation for environmental reasons and reducing long-term adverse environmental impacts of waste disposal did not exist in practice in those days. The World Health Organization (WHO) supported the publication of the first text book on solid waste management in low-income countries in 1984 (Flintoff, 1984). It is still a very popular text book, strongly focused on waste collection, waste transportation and basic disposal practices, in a systemic way. At the same time in industrialised countries solid waste management focused more on further supporting the emerging environmental priorities.

In the mid- to early 1990s only a few well-known books on solid waste management had been published, such as Tchobanoglous et al. (1993) on integrated solid waste management, with the inclusion of chapters on policies, legislation and institutions. The role of informal actors, especially the waste pickers and workers, was not fully recognised in the multitude of published books on solid waste management until the 1990s. Since 2000, solid waste management has received more attention on the back of the environmental agenda, especially its relationship with climate change. In addition to the environmental perspective, employment, income generation and livelihoods perspectives continue to receive attention, for example the United Nations Human Settlement Programme's book Solid Waste Management in the World's Cities (UN-Habitat, 2010).

Globally, when it comes to framing waste issues the literature and practice take various positions depending on their role. For example, there is a dominant set of literature which regards the waste issue from an access to a service perspective dealing with service gaps, poor local capacity, institutional reforms, public participation and cost recovery, and concludes with the need for more financial investment. The other group of literature may regard the waste issue from a 'waste as a livelihood for the poor' perspective. This includes livelihoods, informal pickers undertaking recycling, urban poor earning income from providing a waste service etc. The growing interest of research and practice in social protection is also a component of this group. In addition, other narratives exist, for example, the emerging narrative on climate change mitigation, which is talking about greenhouse gas

reduction, capturing landfill gases, waste to energy and waste reduction. This perspective sees reforms in carbon trading and market systems as the way forward to address challenges of poor waste management. There is little global reconciliation on these different perspectives.

1.2 Parallel worlds

One common driver for resolving solid waste management problems and their related impacts is rapid urbanisation. It is expected that the urban population will reach 60% of the total population in 2030, with strong growth rates in low-income countries (United Nations, 2012). Cities represent engines of growth and attract people from rural areas, which leads to concentrated and steadily increasing waste amounts. In parallel the low-income areas with no service provision are also increasing. Therefore, one approach to counter this problem has been by using financial resources, machinery, strategic planning and international institutions; this is also evidenced from a similar stream of institutional developments in industrial countries during the approach to modernisation (Mol and Sonnenfeld, 2000).

Examples from the past have proven that this large-scale approach failed for a multitude of reasons. The rapid modernisation approach in waste management did not disappear completely. It is still on the agenda of governments, donors and private investors. Most of the programmes to improve / modernise waste management and / or to enhance recycling suggest that the service coverage and service levels need to be improved with large-scale investments. Thus it is perceived that local capacity is poor, policies are inadequate and it is believed that training and toolkits can build skills in entrepreneurship.

It is important to recognise that in low-income countries existing systems achieve most effective outcomes for primary collection and recycling through a number of unofficial (informal) activities. It is important to note that these different actors have a ‘non-governmental’ perspective about waste and different values attached to it. This informal waste recycling sector as part of this existing system is often the only group serving poor areas and generates considerable recycling rates. This sector sees waste as an opportunity, a valuable material which could be collected, separated, traded and recycled for an income. This view may be similar to that held by large global waste collection and recycling companies about the waste in high-income countries.

The informal activities are large-scale in terms of number of income opportunities they create for very poor people, provision of additional income to households and the number of customers they reach. Approximately 0.5 to 2% of the world´s urban population in low-income and transition countries is active in the informal waste recycling sector (Linzner and Lange, 2013). Most of these stakeholders make their own investments and have their own systems of technology development and innovation. A significant proportion of this makes use of technologies that are locally rooted, mostly small-scale, socially accepted and of low cost – all properties that are subsumed under the term ‘appropriate technologies’ (van de Klundert and Anschutz, 1999). This situation creates parallel worlds in waste policies and practice.

1.3 Definition of the informal sector

Feige (1990) states that „the informal economy comprises those economic activities that circumvent the costs and are excluded from the benefits and rights incorporated in the laws and administrative rules covering property relationships, commercial licensing, labour contracts, torts, financial credit and social security systems."

"Informal economy" refers to all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements. Their activities are not included in the law, which means that they are operating outside the formal reach of the law; or they are not covered in practice, which means that – although they are operating within the formal reach of the law, the law is not applied or not enforced; or the law discourages compliance because it is inappropriate, burdensome, or imposes excessive costs (JICA, 2008).

The term informal sector itself was "born" in the Mission Report to Kenya for the International Labour Organisation (ILO, 1972); concepts reach back to economic and social sciences from the 1950s and 1960s. Basically the research on informal sector was embedded in development studies pointing out that dualistic labour structures emerged and a major share of the labour force is relegated to a marginal existence (Jolly et al., 2004). Beside this there is still no clear definition of the concept of informality and "informal activities are persistent, universal and increasing, occurring in countries and regions with very different levels of economic development" (Chi et al., 2011).

The concept of informality and the related school of thoughts changed over time and informal work did not disappear but persisted. Controversial discussions towards the reality of informal economic activities include measurement and proxies of the size of informal work, whether to include agricultural employment, gender and informality, poverty, the heterogeneity of affected groups and the impacts on pro-poor related policies and strategies.

Direct and indirect methods are used to estimate the size of informal economies (Alderslade et al. (2006) and Schneider et al. (2010)). Recent studies estimate that "informal employment today accounts for up to 47 percent of total non-agricultural employment in West Asia and in North Africa, 70 to 90 percent in sub-Saharan Africa, more than 50 percent in Latin America, nearly 70 percent in South and Southeast Asia and 24 percent in transition economies" (Jütting and de Laiglesia, 2009). It is also stated that informal wage employment in the developing world constitutes 30 to 40 percent of the informal employment outside of agriculture (Flodman Becker, 2004). The drivers to conduct studies related to assess the informal share of a countries´ GDP are twofold: on the one hand data are generated from the point of view of social cohesion and to support "pro-poor" activities and on the other hand studies intend to show tax losses due to activities related to the shadow or hidden economy.

An Organisation for Economic Co-operation and Development (OECD) study shows that the financial crisis has adversely affected the employment situation of many people and, in low-income countries with no unemployment insurance, they are forced to take informal jobs with low pay, no protection and high risk exposure. The study found that 1.8 billion people, or more than half of the global labour force, were working without a formal labour contract and social security (Jütting and de Laiglesia, 2009) and this number continues to grow.

The economic recession may be the reason for additional growth of the informal economy. Estimates show that globally in 2009 there were over 200 million more informal sector workers displaced from formal work, due to rising unemployment (Chambwera et al., 2011).

A survey on 1,500 migrant workers in Shandong (China) showed that “the informal sector is not necessarily a transit camp”. Migrant workers in China consider informal self-employment as more stable job than compared to the formal sector, though the informal wage-earner group does seem to attract those who have less city work experience (Meng, 2001).

1.4 Informal sector and waste management

Informal activities performed in waste management in low-income countries are well known regarding the diversity of activities (Wilson et al., 2006). People earn their livelihoods by collecting, (pre-)processing, recycling and selling waste at different levels along the (informal) value chain (informal recycling hierarchy). Informal, meaning “non-authorised” activities may contribute significantly to extend waste management services, e.g. collection in poorer areas or the provision of cheap secondary raw materials for local economies. In other regions informal activities are seen as problem, reasons mentioned are for instance competing interests for marketable secondary raw materials or clearance costs for the formal (official) waste management sector due to unorganised, sloppy work.

Scheinberg et al. (2010) define the informal solid waste sector as referring

> “*to individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognised, supported, organised or acknowledged by the formal solid waste authorities, or which operate in violation of or in competition with formal authorities*.”

Recycling activities usually take place in all stages of a waste management system and are widely undertaken by people working in the informal sector. As displayed in Figure 1, it is possible to segregate the following main categories of informal waste activities depending on where and how the material recovery takes place:

- Doorstep (household) waste pickers;
- Itinerant waste buyers moving around the streets buying (or bartering for) clean reusable and recyclable materials;
- Street waste picking (household bins, bags or municipal collection points);
- On route / truck waste pickers (municipal collection crew or informal truck pickers);
- Waste picking from dumps / landfills.

Beside the individual pickers (waste reclaimers) at the bottom of the informal “recycling value chain” (see Figure 3) other activities are involved in this hierarchy, such as sorting, processing (e.g. cleaning, crushing, bailing etc.). Usually the value of the recyclables increase, the higher they are traded within this hierarchy. The recycling trade hierarchy consists of individual waste pickers (or family type units) at the lowermost levels, ascending to recycling small and medium-sized enterprises (SMEs), craftsmen and middlemen, brokers, wholesalers and manufacturing industries as the final destination of informally collected recyclables. Beside differences in the framework conditions, this informal hierarchy looks similar around the globe.

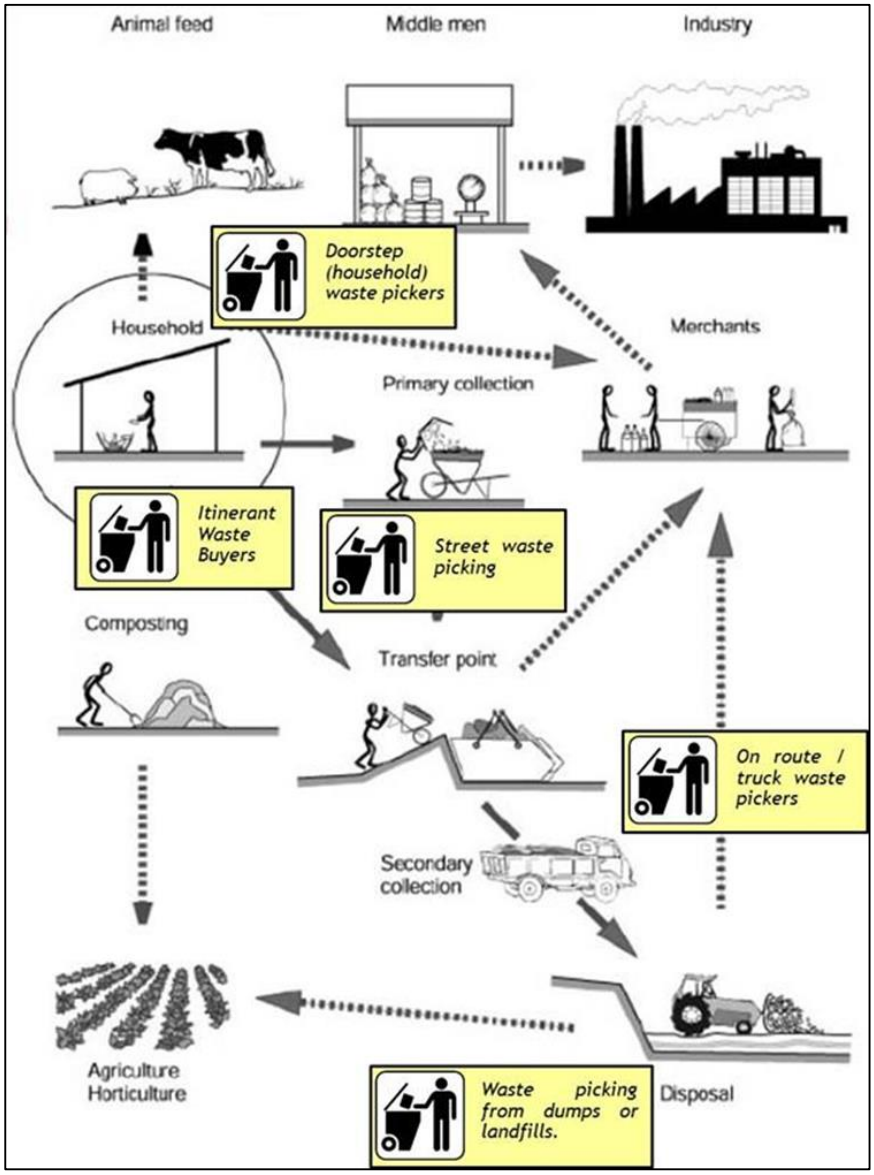


Figure 1: Typical elements of a waste management system in low- or middle income countries (Zurbrügg, 2003), modified

1.5 Limited to low-income countries only?

Beside the “typical” pictures of informal waste recyclers in low-income countries it has to be stated that informal recyclers are also active in Europe. Though the existence of informal waste recycling activities in Europe has generally been neglected to date, but such activities are greater than an issue that affects merely the homeless. In Central and (South)-Eastern European countries, informal practices are visible in the streets and on landfills. Informal collectors pick potentially recyclable wastes out of the municipal waste stream e.g. at household level or out of municipal bins, with the goal of earning an (additional) income by selling them.

In the European context, literature data on the size of the IRS are hardly available. Scheinberg and Nesic (2014) present the results of a consultation process on the informal

waste recycling sector in Europe. The authors point out that most European waste pickers are men, between 20 and 60 years old and that waste picking and recycling is an individual entrepreneurial activity, not (primarily) a family activity. It is also expressed that informal work is carried out seasonally or part time. The authors also estimate the numbers of informal recyclers in Europe of more than 60,000 second-hand and reuse operators in Italy; 20,000 in Greece; Serbia has an estimated 10,000 waste pickers; approx. 5,000 in the Western Hungarian city of Devecser and thousands of informal recyclers documented in virtually all Balkan countries. Hence the estimate of one million persons supported by informal recycling within or at the gates of the European Union does not seem far-fetched. Moreover the authors stress that most waste pickers in the European Union belong to one, or in some cases to two extremely vulnerable groups: (1) persons of Roma ethnicity, who have very low educational levels and are the targets of a range of social exclusion measures; and (2) pensioners, elderly persons without family, and older women heads of household, who are excluded from the labour market for a number of other reasons. Table 1 displays the total population and the urban population of Italy, Greece and Serbia. These numbers are related to reported sizes of the IRS (Scheinberg and Nesic, 2014), the share of the IRS in percent of the urban population lies between 0.15 and 0.25 % - yet it has to be stated, that the Italian numbers relate to the second hand and reuse sector.

Country	Total population	Urban population[2]	Size of the IRS[3]	IRS [% of urban pop]
Italy	59,830,000 (2013)	41,282,700	60,000 in the second hand and reuse sector	0.15
Greece	11,030,000 (2013)	8,603,400	20,000	0.23
Serbia	7,164,000 (2013)	3,940,200	10,000	0.25

Table 1: Population sizes and size of IRS in Europe (Scheinberg and Nesic, 2014).

Problems occur in regions where EPR-schemes have been established and costly infrastructure was set up in order to separately collect recyclables. This led to competitive issues between formal and informal systems especially in Eastern Europe. Informal collectors pick out of the bins provided for separate collection or pick the materials before they reach the formal system. Against the background of recycling targets to be fulfilled, EPR-schemes fear that they cannot reach the targets set out by the EU. According to EXPRA et al. (2014), due to informal recyclable picking the EPR-schemes face problems with decreasing quantities of incoming valuable materials, littering around the collection bins, damages to the established collection infrastructure, increasing operating costs and demotivation of the inhabitants to separate the waste. The reason for this is considered to be the increased value of certain recyclables, social problems and poverty, lack of legal

[2] http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

[3] *Scheinberg, A., Nesic, J., 2014. Engaging Informal Recyclers in Europe: Status and Report of a Consultation, ISWA World Congress 2014. International Solid Waste Association (ISWA), Sao Paulo, Brazil.*

provisions regarding the ownership of waste, lack of actual enforcement of existing legislation and no clear definition of the responsibilities and scope of action for different stakeholders. The authors also state that there is a need to collect more data on informal collection.

A specific variety of informal activities, namely the “waste-brigades”, have evolved in recent years, becoming more and more visible in Central Europe by performing informal collection activities at household level or at civic amenity sites / recycling centres / waste collection centres (WCCs) in Western European countries. They collect reusable items such as furniture, kitchen equipment, household effects, toys etc. and transport it to their home countries where the items are sold at flea markets. Common target countries for these informal collectors are Austria and Germany, but may include Switzerland and The Netherlands. The members of the “waste-brigades” originate in Slovakia, Hungary, Poland and other Eastern European countries. At flea markets in these countries it has been observed that informal traders buy and transport some of those items further e.g. to Serbia, Ukraine and Belarus.

Outside Europe, informal waste recycling activities are also visible in countries that are not considered as being of a low- income. According to UNEP (2015) informal activities “tend to intensify in times of economic crises when employment is difficult to find and in cases where imported raw materials are relatively expensive due to inflation or currency depreciation. (…) One example is the informal activities increasing after the currency depreciation in Argentina in the early 2000s.” Parizeau (2013) reports that the “financial crisis in 2001−2002 marked a decisive shift in informal recycling work. With the overnight crash of the peso, the importation of raw materials for industrial use became prohibitively expensive. For example, the price of paper increased by more than ten times in a matter of months. This crisis created an increased demand for recyclable materials from local markets and also gave rise to soaring unemployment rates. Therefore, informal recycling work during this period was both a personal response to labour insecurity for workers and a source of affordable inputs for local industry.”

In Annex 1 some example photos from informal sector realities around the world are presented.

1.6 Research and the informal recycling sector - the times they are a-changing'

A discourse on informal activities should mention how informal waste workers are perceived, by formal waste management practitioners, local authorities, non-governmental organisations (NGOs), and by society in general. Medina (1997) compiled an overview of common characteristics of informal waste management systems using generalisations, for example that involved individuals are relatively poor; of low ascribed social status; that “scavenging” can provide economic and environmental benefits and is an adaptive responsive to poverty in low-income countries and that these activities supply (secondary) raw materials to local trade and industry. Nas and Jaffe (2004) criticise generalisations as they “do not represent the great variety of scavenger systems throughout the world.” Moreover the authors support a statement by DiGregorio (1994) saying that “there are only two common characteristics of scavenging. The first one is that waste is recognised as a resource and the second one that throughout the world these activities are related to a varying degree of social opprobrium”.

Scheinberg et al. (2010) discuss the development of the relationship between solid waste management practitioners and waste pickers. It is stated that “informal activities were formerly seen as a de-contextualised, social problem without considering the economic activities carried out. Reactions were thus welfare based, focusing mainly on improvement of the working conditions and disregarding the enabling environment, meaning ‘the political and social forces that influence their position’”.

In addition, more development oriented approaches gave rise to ‘social and economic interventions such as education, credit and income generation to enable pickers to exit to other occupations’, ignoring significant issues related to the importance of waste picking as a means of generating income. Other approaches were more rights-based, including ‘supporting pickers to form organisations and lobby for rights and social status, but still without acknowledging the economic importance of picking.

More and more the informal recycling sector and its contribution to waste collection, processing and recycling services became part of research. On the one hand papers and reports published described local case studies in terms of activities, estimated size of the informal sector and its contribution to recycling, socio-demographic data of the participants (age, sex, gender etc.), health issues and income-related data (achieved market prices of recyclables). Over time an increasing number of projects were described in literature that dealt with implementation projects. These projects focussed on options and possibilities to partly or fully include the informal sector into existing systems; the main keywords were “formalisation”, “integration”, “legalisation”, “inclusion” or “professionalization” of informal waste systems.

Nowadays a few publications provide information on comparing informal activities in different regions and derive possibilities for successful inclusive approaches. Velis et al. (2012) state that “increasingly, incorporating the informal recycling sector as a legitimate stakeholder and functional part of solid waste management (SWM) is attempted, further building recycling rates in an affordable way while also addressing the negatives.” The authors developed “a systematic framework - or typology - for classifying and analysing possible interventions to promote the integration of the informal recycling sector in a city’s MSW system.”

In any case, it is asserted that early approaches were driven mainly from a social point of view, but are more changing towards recognising the informal waste sector and the involved individuals as an integral part of waste management systems. Figure 2 outlines the number of publications listed in the scientific search engine Scopus[4] using the terms “informal” and “waste management”. In the mid of the 2000s the number of scientific papers on the topic increased from around five articles per year to more than twenty-five in the years 2012 to 2014. The year 2015 includes just information until November of this year.

[4] Link: http://www.scopus.com

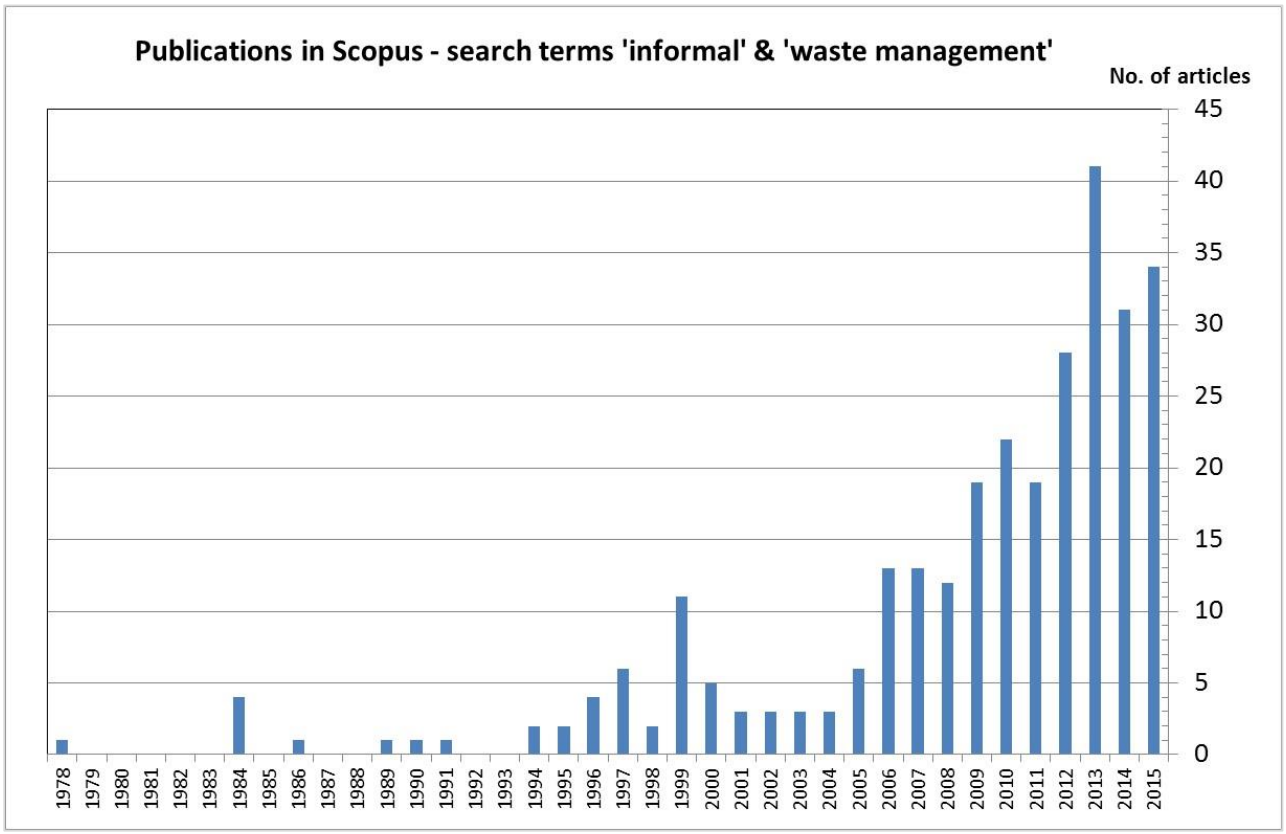


Figure 2: Number of scientific journal publications including the terms „informal“ and „waste management“

2 Research objective

As the informal recycling sector is usually not recording its activities, it is fairly difficult to estimate its contribution to the collection and recycling performance of a waste management system. Velis et al. (2012) identify four primary interfaces that are important for successful integration / inclusion of the IRS:

- between the IRS and the existing solid waste management system;
- between the materials and value chain;
- society as a whole and
- the dimension which is focused on organisation and empowerment.

In order to “edit” the interfaces between formal and informal systems, it is necessary to obtain reliable data on their performance. In the following the need for data on IRS performance and the deduction of the research objective of this thesis are displayed.

2.1 The need for data

Waste management systems are characterised by the involvement and interrelation of various stakeholder groups – often with varying roles and interests. Different stakeholders are characterised by differing values, attitudes and beliefs towards waste. The informal sector cannot be seen as stand-alone, but furthermore showing a range of interactions (e.g. voluntary, unintended, planned or accidental) with formal stakeholders (public or private). In this setting, also other stakeholder groups might occur, having an interest to obtain data on informal sector performance.

However, this interest is highly dependent on local specifications. For example, motivations might differ in a low-income country compared to middle- or high-income countries or stakeholder groups claiming to have a stake may vary depending on the region. One example is that formal waste management stakeholders in some cases simply ignore the existence of the informal sector in low-income countries, whereas in high- and middle-income countries where the waste management system is more advanced with respect to the recovery of recyclables, and therefore informal workers are a competitive threat, the opposite is true. However, it still happens that typical reactions towards informal workers range from oppression, negligence, ignorance, mistrust to relocation.

Data on informal recycling sector performance are important in policy making and enforcement, for example in the development and implementation of national / regional environmental (and / or waste management plans) or in monitoring the achievement of recycling goals. Furthermore, informal recycling sector performance data are prerequisite for the monitoring and planning of waste management systems and influence issues related to cost efficiency, recycling rates, environmental performance, collection coverage and efficiency, capacities of treatment and disposal plants, city master plans etc. Certain stakeholder groups might have interest in performance data as well, when they deal with issues around advocacy and visibility of informal systems. For example, data are needed for improving the efficiency or to display unique selling points of informal systems such as contribution to waste collection, recycling, hygiene or when describing environmental

benefits / cost savings. In addition, the quantity and quality of collected materials are important for negotiations with the manufacturing industry or when describing livelihoods (income etc.) of informal workers in local / global advocacy etc.

Furthermore, informal collection activities are more and more visible in the European context.

Table 2 displays a compilation of different stakeholders and their different needs for obtaining / using data on the informal recycling sector.

Stakeholder	Data required
National level authorities (e.g. ministry of environment, labour or social affairs)	Policy making and enforcement e.g. national environmental plans, achievement of recycling goals; tax circumvention due to informal activities, transfer payments and minimum wage policies etc.
Local level authorities (regional governments, city administrations, municipal waste departments)	Monitoring and planning of waste management systems: cost efficiency, material balances / recycling rates, environmental performance, collection efficiency, capacities of treatment and disposal plants; city master plans etc.
Waste management enterprises / recycling industry, EPR-schemes, manufacturing industry	Competitive issues (amount and quality informally collected), inclusivity issues (amount and quality of materials that can be purchased from informal sector); material prices etc.
Individual pickers, waste picker associations (local, regional, global), NGOs acting as advocates for informal workers	Data needed for improving efficiency or to display unique selling points of informal systems, e.g. contribution to waste collection, recycling, hygiene; describing environmental benefits / cost savings; amounts and quality of collected materials are also important for negotiations with manufacturing industry; describing livelihoods (income etc.) of informal workers in local / global advocacy etc.
Others e.g. labour unions, chambers of commerce, banks, insurance companies, customs offices etc.	Minimum wage enforcement, industry support, loans, warranty issues, transboundary shipment of waste / reusable items etc.

Table 2: Stakeholders and the interconnection to informal recycling sector

2.2 Research objective: Measuring informality

Informal activities are per definition difficult to assess as this sector has no inherent reason, obligations or simply not the capabilities to keep records on its activities, e.g. on the quantities of recyclables collected. The motivation to obtain information regarding its activities is different. Informal activities closely related to the “shadow economy” are interesting for authorities regarding tax losses and other economic issues. Therefore several methodologies for estimating the magnitude of informal work were developed based on direct and indirect estimations and calculations (Alderslade et al. (2006); Ruiz Rios et al. (2009) and Schneider et al. (2010)). These studies mainly aim at determining the percentage

of GDP that is informally produced, thus giving hints on tax circumvention, how “regulated” labour markets are and also on social security issues (e.g. health and unemployment insurance). In addition, official performance data usually do not cover informal systems; official waste statistics do not reflect the big picture in low- and middle-income countries. Therefore, for waste management planning or monitoring purposes it is of paramount importance to obtain data on informal systems.

This doctoral thesis aims at providing different methodological approaches on measuring informal waste recycling sector performance.

3 Methodological approaches

The following chapter describes methodological approaches on how to measure (estimate) the performance of the informal waste recycling sector. At the beginning it is explained how a “value chain approach” supports the integral approach to obtain data on the informal sector. It is important to assess the existing data basis and to find out what sources of information might be available in order to generate data on the informal sector contribution to waste management. This different sources of information and the related availability and quality of data are described in this chapter, leading to the deduction of different methodological approaches. Subsequently, the concept of triangulation is introduced in order to provide a methodological concept to verify results of estimating informal sector performance. This concept is amplified by presenting three case studies.

3.1 Approaching the value chain

As the main items of interest for formal and informal waste management systems are wastes, the methodological approach to assess their performance is to consider the value chain alongside the collected items are traded. It is important to understand formal and informal flows of wastes and products and to display the interfaces between formal and informal systems.

It is differentiated here between “wastes” and “products” as the definition of what has to be considered as waste is on the one hand not defined in the same way around the globe and on the other hand there is a lack of international standards, definitions and classifications. In addition, law enforcement is varying from region to region, having also influence on what items can be traded as products and for what items waste management regulations apply. The distinction between waste and product is not necessarily related to a market value. One example are the difficulties occurring in the border zone of the waste and product term: reusable items can be sold on internet platforms, despite one can assume a certain “intention to dispose of” – which is already fulfilling waste definitions set out in laws, e.g. in Austria. Thus recyclables have a market value, in many countries they are nevertheless considered as waste when they are collected. This shows that there is still room left for (legal) interpretation of what is waste and what not. Beside this definition of waste in the following the term “waste” to a certain extend may also include items that have product-status and is subject of interest for informal collectors.

The (informal) waste recycling value chain (see Figure 3) is characterised by a broad base of waste pickers active at different locations (see Figure 1). This group consists of individual pickers, family type units and cooperatives that collect, (pre-)process and trade recyclables, organic waste and reusable items etc. Besides the typical “waste picking” activities, other activities are involved such as sorting, processing (e.g.: cleaning, crushing, bailing etc.). As next step in this value chain the collected wastes and materials are sold to buyers (e.g. junk yards, scrap yards, craftsmen, middle-men, brokers, etc.) before they reach their final destination, i.e. the manufacturing industry. Usually the market value of the traded wastes and materials increase alongside the value chain. Ruiz Rios et al. (2009) calculated the profit margins for each step in the recycling value chain in Peru. The price for one kilogram of material increases along the value chain. Certain paper and cardboard products increase by a factor of 1.3 to 3.0, PET plastics by 2.0 and for some metals by a factor of between 1.4

and 2.5. Prices of recyclable materials at different recycling levels for Delhi (India) are presented in Agarwal et al. (2005) showing that the value added along the value chain ranges from 19% to 121%.

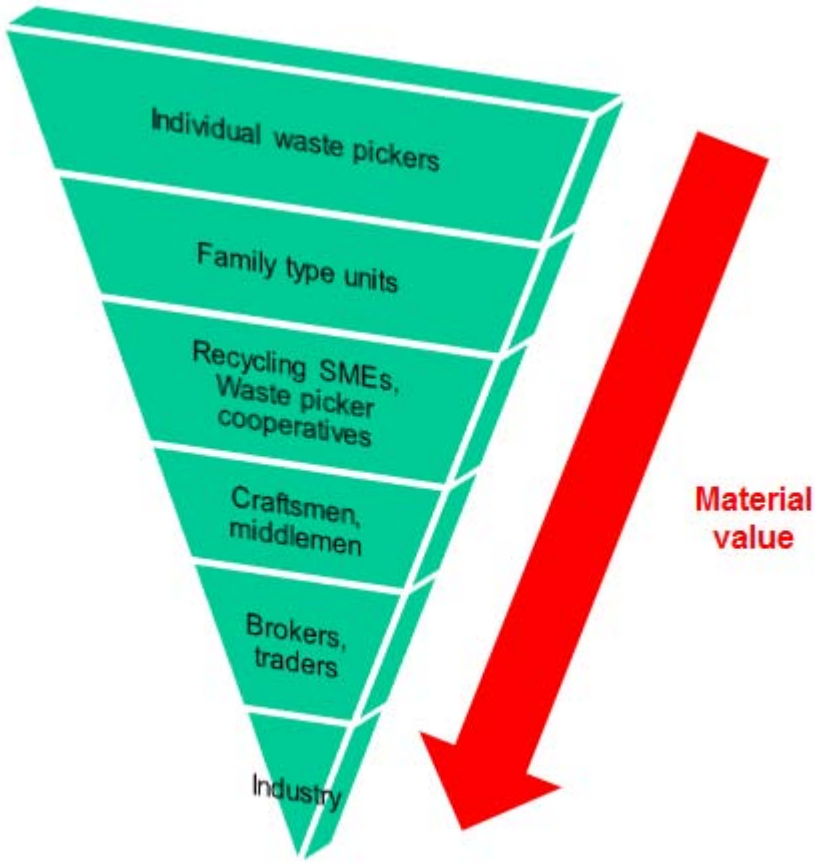


Figure 3: Stakeholders of the informal recycling value chain (Wilson et al., 2009)

In order to understand the formal and informal flows of wastes and products it is useful to map the stakeholders of the (informal) value chain and the corresponding flows of wastes / products.

3.2 What goes in - must come out

In a next step the flows have to be complemented with quantities - which is a challenging task. At each step of the value chain the law of mass conservation applies, meaning that "what goes in must come out" (Brunner and Rechberger, 2004). As displayed in Figure 4, on the one hand this allows conducting control calculations (left part of the Figure) and on the other hand it is possible to determine unknown flows (right part of the Figure).

It is possible to use process flow diagrams (PFD) or material flow analysis (MFA) software to display the flows.

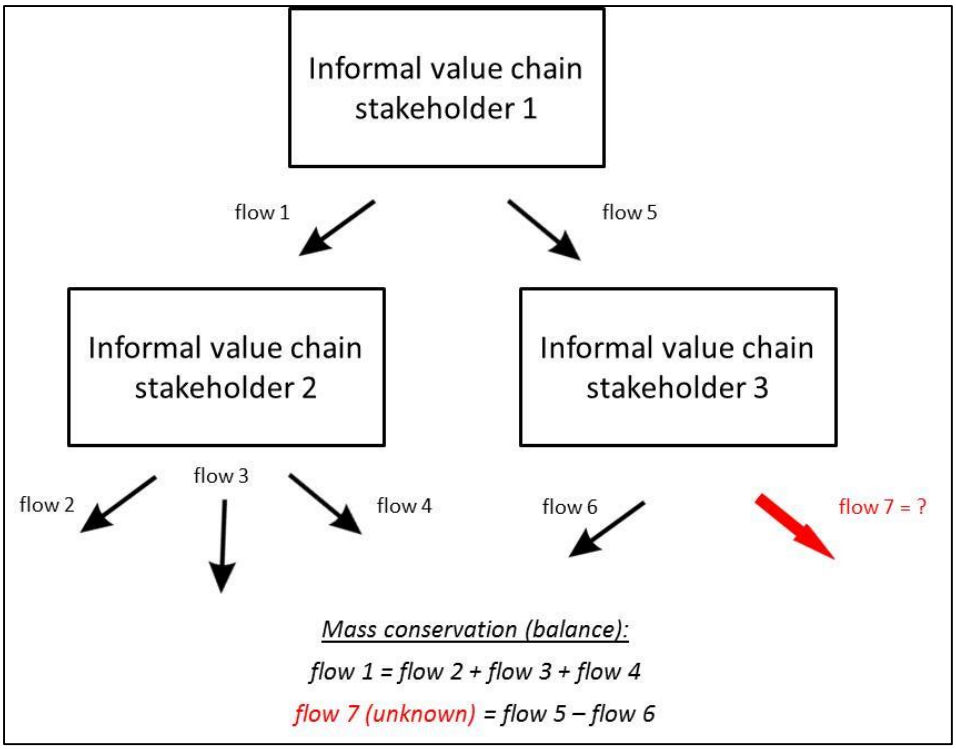


Figure 4: Material flows and mass conservation (modified from: Brunner and Rechberger (2004))

A combined methodology was used by UN-Habitat (2010). In this study twenty cities worldwide were researched and compared. The aim was to provide a PFD of the different waste types from the point of generation until the final point of disposal or recycling / re-use – both for formal as well as for the informal system. As a first step a person for each city was designated who has worked in the city (knowing culture, language and the waste management system), the so called “city profiler”. The profilers draw on their own practical knowledge of the city, in addition to consulting key stakeholders, newspapers, reports, plans, photos and / or using records of stakeholder meetings or other events. In the end a city profile is generated, which can also be a data form and a written “city presentation”. The city´s formal and informal solid waste management system is diagrammed in a PFD as exemplarily displayed in Figure 5. As it can be seen in this Figure, the informal recycling value chain may be quite complex, but to begin with mapping the stakeholders and (potential) flows is a good starting point. Process flow diagramming, when combined with material balances are even more powerful.

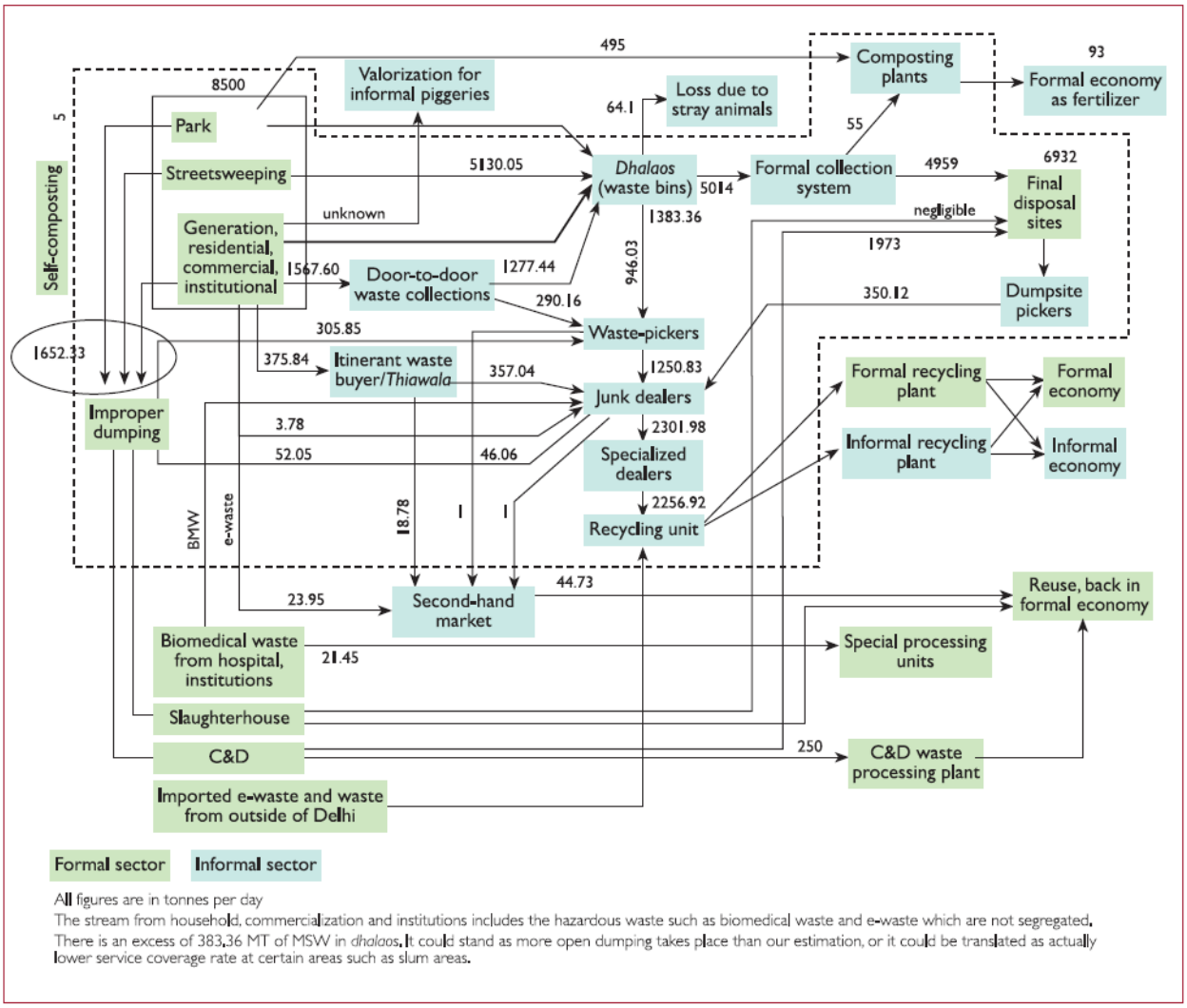


Figure 5: Process flow diagram for the city of Delhi (India); Source: UN-Habitat (2010)

3.3 Waste-related data

Figure 6 outlines a simplified waste management system that is constituted of formal and informal stakeholders. Wastes are produced at the point of generation (“waste generators”), in the case of municipal solid waste (MSW) this waste stream consists of residual waste, recyclables (at this point it doesn´t matter whether they are collected separately at the point of generation or if they are part of the residual (mixed) waste stream), organic waste, bulky waste, WEEE, hazardous (household) waste. Sources for MSW generation are households, small businesses (shops, banks, insurance companies etc.) and markets – industrial wastes are out of scope in this work.

The “waste potential” at the level of waste generators is the quantity of waste that is generated in total. Only a part of this waste potential ends up in a formal collection system, another part is collected informally but also other practices occur that reduce the amount of waste collected formally, e.g. animal feeding, home composting, illegal dumping (“fly tipping), waste burning etc. In Figure 6 this often unknown share of MSW is displayed as “other” disposal activities. Wastes that are collected in a formal system (the wastes formally handled or “collected and transported”) do in terms of quantities therefore not equal the

"real" waste generation (the waste potential). The left part of Figure 6 outlines the formal way and the right part the informal way of waste flows from generators to industry using recyclables as secondary raw materials. The green pyramid again displays the informal recycling value chain stakeholders that might be involved.

On the contrary to the definition of the informal recycling sector (as set out in Chapter 1.4) the "formal" waste management system is the one who has the official assignment to carry out waste collection, treatment, recycling and disposal activities, no matter what legal entity the formal stakeholders represent. This means that formal stakeholders can be private sector (companies), associations, public utilities etc.

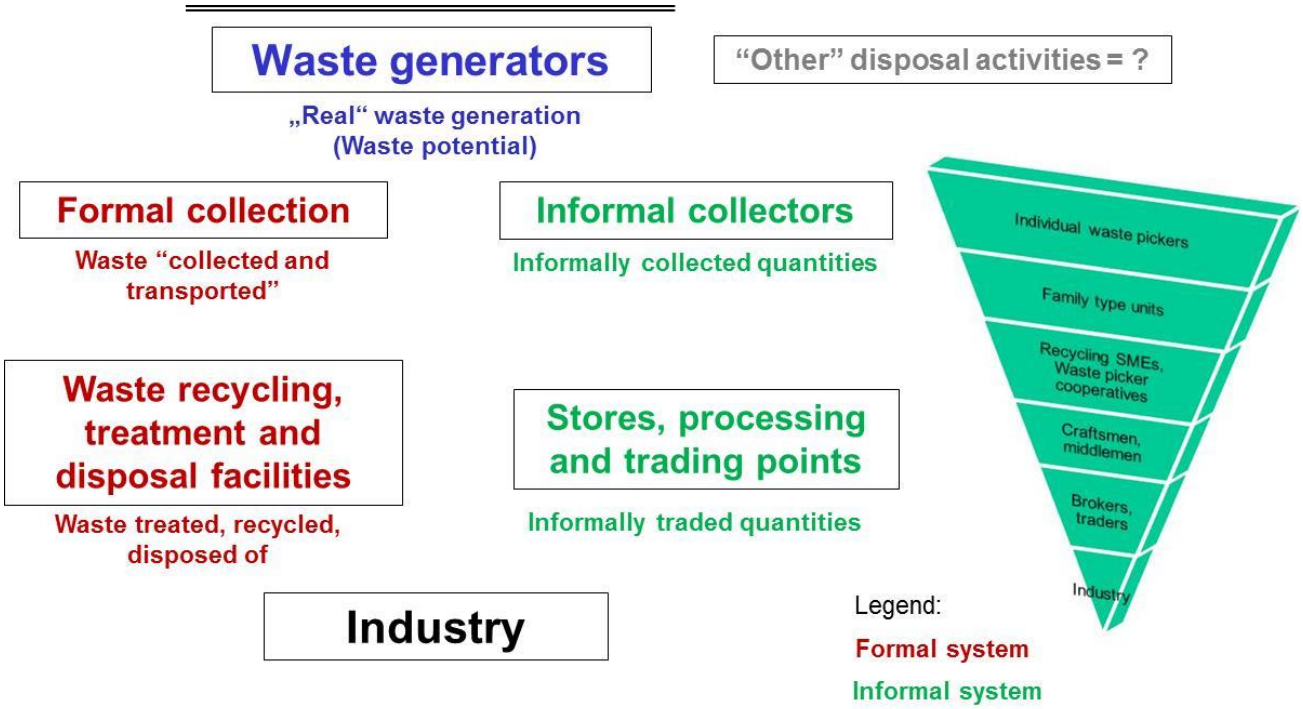


Figure 6: Simplified system sketch of a MSW management system

In the following some thoughts on both data availability and quality as well as sources of information alongside the informal recycling value chain are presented.

3.3.1 Availability and quality of waste-related data

Waste-related data are an important prerequisite for waste management planning and monitoring activities. Good quality data on waste quantities and composition serve as input for planning and adapting waste collection, treatment and recycling infrastructure and therefore have influence on the costs. The fulfilment of waste prevention and recycling targets as well as the capacity planning of treatment and recycling facilities require a sound and comparable database.

Unfortunately, the compilation of available and high-quality waste related-data has been a challenge for a long time. Several studies report that the commonly highlighted attributes of waste-related data are uncertainty and unreliability. Dahlén et al. (2009) for example report

sixteen sources of error and uncertainties in the interpretation of official waste collection data. The authors grouped these into:

(A) general data problems,

(B) data uncertainties related to specific waste categories;

(C) unreliable data from recycling centres; and

(D) household waste component analysis data not comparable.

Regarding waste-related data the Global Waste Management Outlook reports (UNEP, 2015):

"The available estimates are diverse, not verified or reliable, and often rather dated. Thus transforming waste data into reliable waste statistics has proven difficult." Furthermore, the authors describe the major areas of concern as following:

"1. Lack of standard definitions and classifications. The definitions of waste streams such as MSW, C&I waste, C&D waste, agricultural and forestry wastes and mining and quarrying wastes vary widely among countries, including within the European Union (EU). Arguably, it is unrealistic to suggest that a single global definition of waste could or indeed should be applied in all countries. At the same time, it is realistic to ask that each country's definitions be clear and applied consistently.

2. Absence of measurement and of standard methodologies for measurement. The weighing of wastes is both relatively recent and still not universally practised. Many cities in the developing world still rely on estimates of MSW based on the volume of the vehicles used for collection and disposal. Here, as with many other aspects of waste assessment, there is a lack of standard methodologies. For example, it is often unclear at what point estimates or measurements have been made and whether the data refer to MSW or to all waste in the city, or whether it is waste as generated, or as collected, or as delivered to a disposal site (has some separation of materials for recycling already taken place before the measurement was made?). Measurement and assessment also tend to be limited to the official or formal waste management system. Activities outside of that system, including uncontrolled (and often illegal) dumping or burning, as well as recycling by the informal sector, are neither measured nor reported. Waste composition data are even more uncertain, even in high-income countries, as measurement tends to be occasional and not carried out on a comprehensive or consistent basis.

3. Lack of standard reporting systems. Statutory reporting systems for waste management in a standard format are still the exception. While tracking systems for the transboundary movement of hazardous wastes are mandatory under the Basel Convention, data collection and reporting of total quantities generated are only advisory and thus patchy. National data collection systems do exist for MSW; however, for other waste streams including C&I and C&D wastes, the reporting systems are not uniform even among high-income countries. So although data are reported to and collated by both the EU (Eurostat) and the OECD, there are both gaps in the data and questions over their inter-comparability. Double counting is one issue, as often when waste is processed, the output from the treatment facility is counted again as a 'new' waste. As a result, not only tallying the total quantities but also tracking a particular item of waste from its origin to its final destination is difficult. For developing countries, the availability of any data beyond MSW, never mind reliable data, is rather uncommon. Given these many interrelated challenges, there is an urgent need for clear and consistent methodologies for waste assessment. Any approach

needs to be underpinned by carrying out as much fieldwork 'on the ground' as possible. It is also essential to gather information from as wide a range of 'actors' in the city's waste and resource management system as possible. Two additional pieces of advice would be to go as far as is practicable to establish at least a rough mass balance, including estimates of unmeasured 'losses' from the system, and to document carefully all of the assumptions and estimates made and the 'rules of thumb' used, so that the assessment process is transparent and able to be audited. Some guidance is already available on the more detailed 'how' of data collection in order to establish the baseline situation in a developing country city."

Similarly issues are reported by UN-Habitat (2010): "Solid waste data in many cities is largely unreliable and seldom captures informal activities or system losses. Some developed countries (…) support their city administrations to generate regular and reliable statistics on municipal solid waste, based on weighbridge records and regular monitoring; but many do not. And when waste data exists, it is difficult to compare even within a city due to inconsistencies in data recording, collection methods and seasonal variations in the quantities of waste generated. Systems for weighing or measuring wastes disposed of are rare in low- and middle-income countries, and small cities (…) have to estimate waste generation. They generally do this either by estimating based on the design capacity of the vehicles used in collection, or by extrapolating back to the household using imperfect information on what is disposed of. For cities that don't have their generation figures, the amount handled or disposed of is the basis for extrapolating to waste generated."

If data are obtained (options for this see the following chapters), Dahlén et al. (2009) suggest that waste flow data have to be converted to comparable units (kg/cap/yr.) and as far as possible grouped in comparable waste categories. The per capita amounts are based on the official number of inhabitants, i.e., registered residents, which is not necessarily the same as the actual number of people generating waste in the municipality. This is important in touristic areas or at the fringe of cities (affluent suburbs). Other related problems are occurring when total waste quantities are related to the population in the low-income countries context: census data on population size differ due to different geographical regions considered; sometimes population refers to a city core, in other cases to metropolitan areas.

3.3.2 Sources of information

Based on the simplified system sketch of a MSW management system (see Figure 6), Figure 7 displays sources of information for waste-related data alongside the recycling value chain. In the following chapters it is depicted, what options are available in order to obtain or generate waste-related data both for formal and informal waste management system parts. This serves as an entry point for "triangulating"[5] results and to verify informal collection / recycling rates.

[5] *see Chapter 3.4*

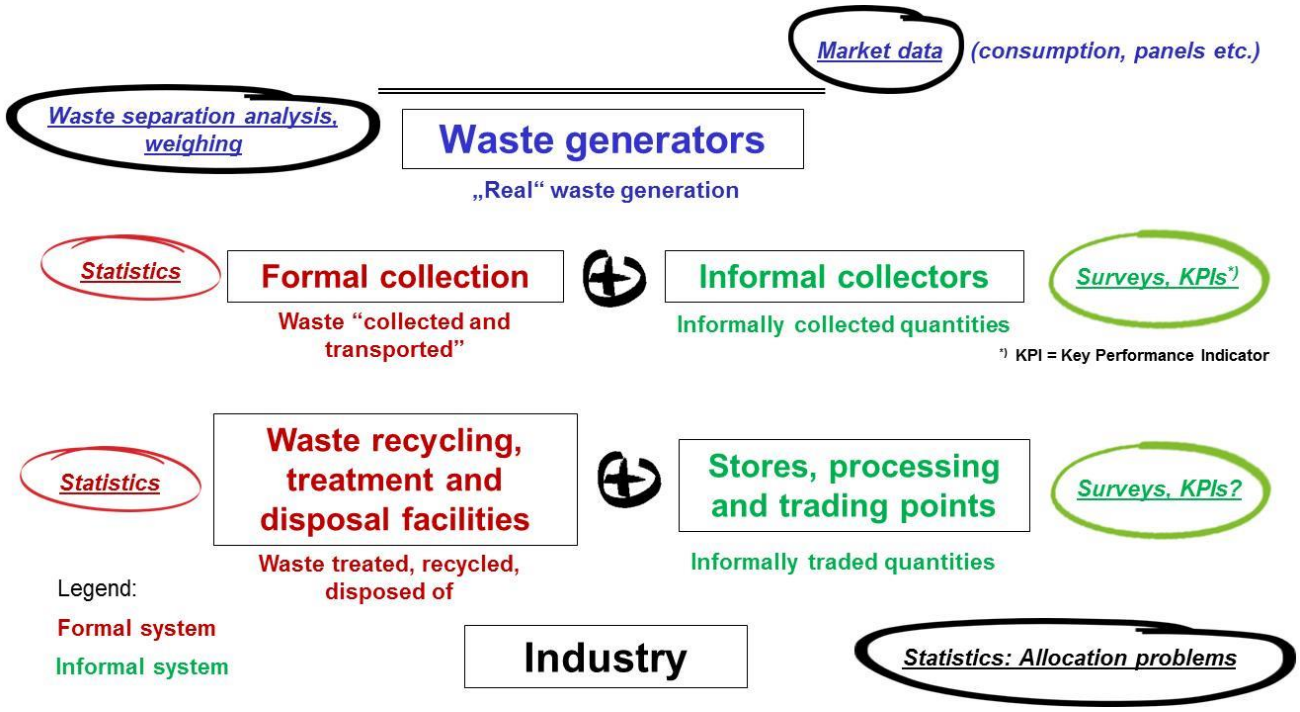


Figure 7: Sources of information in the (informal) recycling value chain

3.3.2.1 Waste-related data at the level of waste generators

One of the most important starting points in waste management planning activities is to obtain data on waste generation at the source. These data are scarcely available in low-income countries, and usually data provided by formal stakeholders (authorities, public utility companies, private companies) and statistical offices are usually not displaying the “real” waste generation, but rather data on waste formally “collected and transported”. The latter data are usually obtained at landfills, disposal sites, transfer stations and the like, and are available as “guesstimates” (as already described in Chapter 3.3.1).

At the level of waste generation, there are different options to obtain data related to the “real” waste generation (waste potential). On the one hand data might be available at “**market level**”, these are data related to consumption (e.g. at household level) and usually available as **household panels**. Several pieces of research aim at linking household consumption with waste generation at the source. On the one hand this is done with quantifying goods purchase and establishing the link to waste generation. On the other hand, analyses were carried out aiming at correlating household consumption expenditure with waste generation. The latter represents just a rough method; for both cases apply that in the low-income countries context both household panels and disposable household income data are not available. Harder et al. (2014) show a method aiming at collecting disaggregated data for **goods consumption and related waste generation** at the level of individual households. To this end, two data collection approaches were devised and evaluated: (1) triangulating shopping receipt analysis and waste component analysis and (2) tracking goods consumption and waste generation using a smartphone.

Beside data availability in low-income countries other shortcomings of this approach are the up-to-dateness of data, problems occurring due to the lifetime of products (the method is easier to be carried out for non-durable goods but more difficult for durable goods (e.g. EEE). For certain product (and the related waste) streams this method allows for a comparably

easy use: for example, for aluminium beverage packaging (aluminium cans) market data (what is put on the market per time unit) is available for different countries. Alu cans are very standardised, so the average weight of a can (for different volumes, but usually 0.33 l or 0.5 l) is known, allowing for estimating the waste potential per capita very easy. Usually these data are available country-wide but not at regional level.

Similarly for durable goods such as EEE a study was conducted by Baldé et al. (2015). The authors calculated the e-waste generated per country, year and product category by extracting statistical data from the United Nations Comtrade database. This was done for 175 countries for a time series of 1995 to 2012. By considering import and export at national level the sales data for different EEE were determined and the number of sold units were converted to weight using the average weight data per appliance type. In the end the e-waste generated by country was determined by applying the "Sales – Lifespan Distribution" method with empirical lifespan data. Lifespan data is obtained from the 28 EU Member States using the Weibull distribution. This modelling shows that it is possible to directly link sales data and calculate waste generation rates.

Beigl et al. (2008) describe 45 modelling approaches identified in a systematic literature review aiming at explaining or **estimating** the present or **future waste generation** using **economic, socio-demographic or management-orientated data**. The authors show a proposed relevance tree for appropriate methodology selection stating that "the main selection criterion is the type of waste streams to be investigated. In the majority of cases, correlation and regression analyses, as well as group comparisons, are the most beneficial modelling methods, both to test the relationship between the level of affluence and the generation of total MSW or a material-related fraction, and to identify significant effects of waste management activities on recycling quotas. The application of time series analyses and input–output analyses are advantageous for special information needs (e.g. assessment of seasonal effects for short-term forecasts) or for appropriate data availability. Sorting analyses are indispensable, if impacts on the quantity of separately collected waste streams (e.g. of recyclables) are to be quantified."

Waste separation (sorting) **analyses** (**waste composition analyses**) are standardised methods that allow for obtaining information on waste composition. Extensive reviews on the methodologies of waste composition studies are conducted by Sahimaa et al. (in press), Edjabou et al. (2015) and Dahlén and Lagerkvist (2008). The papers describe different methodologies and refer also to different error types, sample sizes and number of samples and stratification issues. Additionally the European Commission provides information on a methodology for the analysis of solid waste (SWA-Tool)[6] including practical execution and evaluation of waste composition analyses. In addition, the Austrian standard series S 2097 provides a standardised procedure for waste composition analyses.

Another option in order to generate data on the "real" waste generation at the source would be to use waste-related data obtained by PAYT systems (Dahlén and Lagerkvist, 2010), e.g. by the **weighing of waste bins** (Korhonen and Kaila, 2015) which of course means that this systems have to be established which does not hold true for the low-income country context.

As displayed in Figure 8, generally speaking from the above mentioned established methods for obtaining data on the waste potential at the level of waste generators, for municipal solid waste or household waste, the waste composition analyses are promising. Usually data at market level (e.g. household panels) are not available in low-income countries, time series

[6] https://www.wien.gv.at/meu/fdb/pdf/swa-tool-759-ma48.pdf *(last accessed 27.10.2015)*

analyses of waste data need reliable data in advance and PAYT systems are usually not installed.

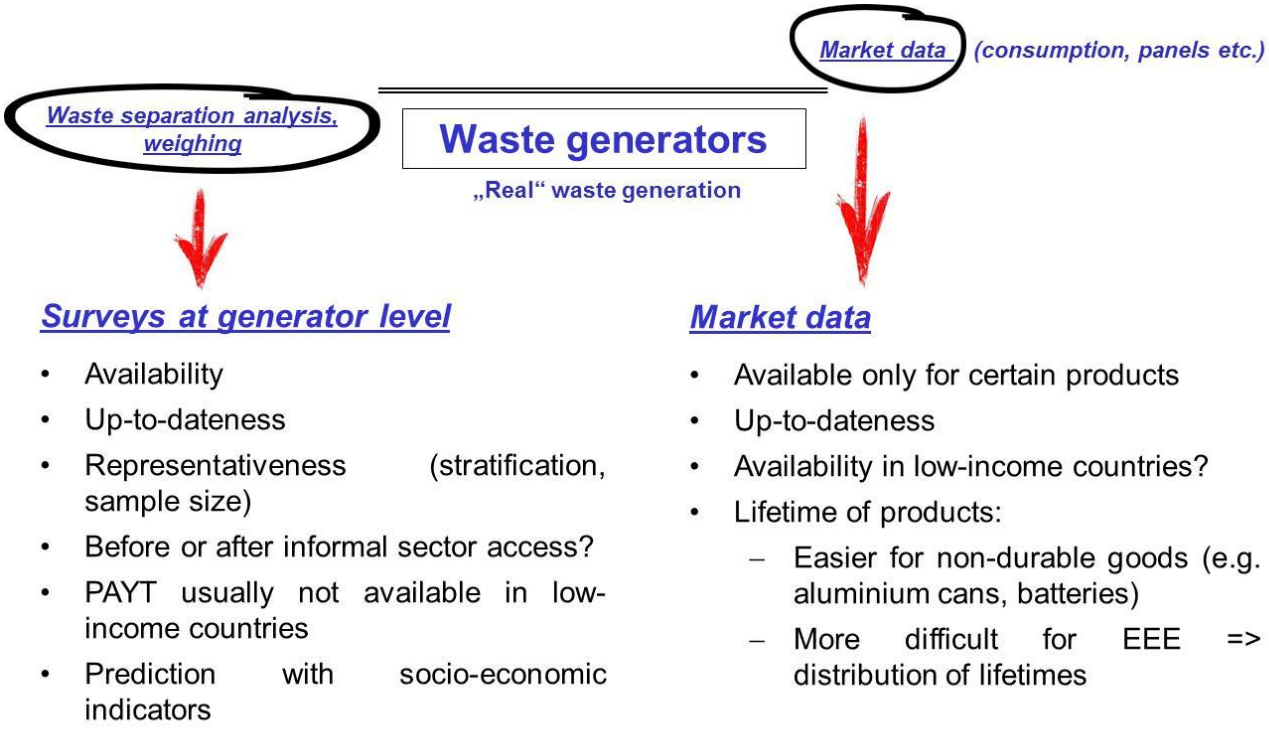


Figure 8: „Real“ waste generation data at the level of waste generators

3.3.2.2 Waste-related data from formal waste management systems

In order to obtain data on the formal part of waste management systems related to quantities collected, there a different information sources available (see Figure 9). Usually the data is related to waste statistics with inputs from records kept by the formal stakeholders. In industrialised countries there are obligations to record waste-related data as they represent an important source of information for waste management planning.

Waste quantities are usually recorded at the lowermost levels in waste management systems and reported bottom-up. In the end waste statistics at regional or national level are compiled and aggregated. Problems related to availability and data quality were already displayed in Chapter 3.3.1. A major problem in the low-income country context is that even formally handled waste quantities are only available as estimations.

Sources of information of formally handled waste quantities are for example:

- Official waste statistics issued by local authorities;
- Annual waste collection accounts of waste management companies;
- Public statistics from the EPR schemes;
- Annual environmental reports from public utility companies, private companies and treatment facilities;

- Weighbridge protocols of deliveries to waste treatment and disposal facilities;
- National and regional statistical offices;
- Interviews with local waste management operators.

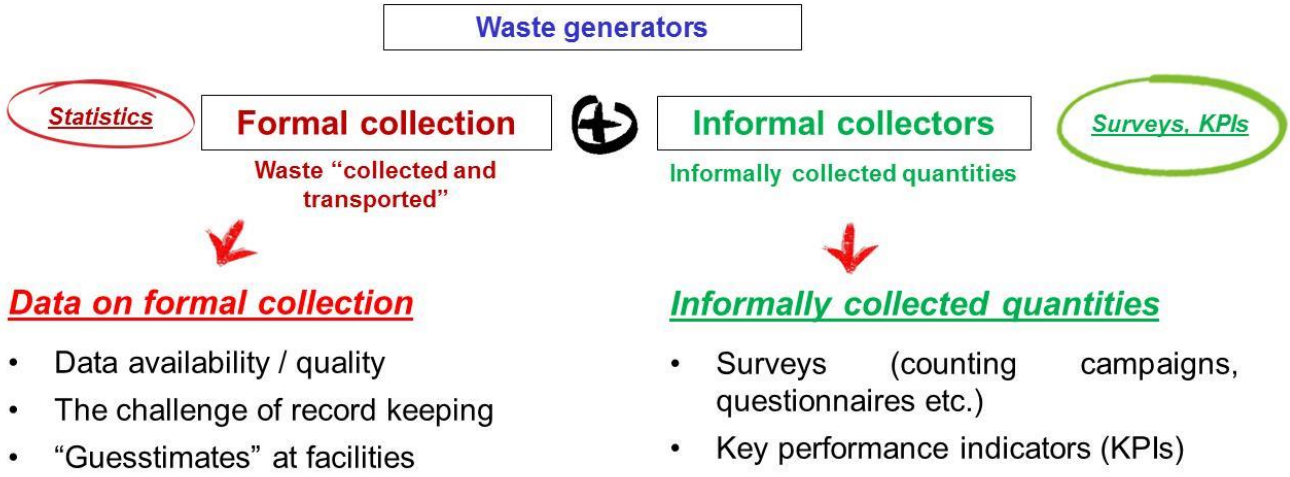


Figure 9: Waste-related data from formal and informal systems

3.3.2.3 Waste-related data from informal waste recycling systems

Assessing informal waste recycling systems in terms of quantities is somewhat complex (see the right (green) part of Figure 7). In the following it is shown what options exist in order to estimate informally collected quantities within a waste management system (see also Figure 9).

In general two options exist: on the one hand for rapid appraisals and initial estimates it is possible to use key performance indicators (see Chapter 4.1). The second option is to conduct surveys and approach the informal stakeholders and selected respondents directly via questionnaires and expert interviews. In the following both possibilities are described.

3.3.2.3.1 Key Performance Indicators (KPIs)

The KPIs for informal sector have been derived from an extensive literature research and can give first information on the magnitude of the informal contribution to waste collection and recycling services. KPIs include data on the size of the informal sector in different regions, quantities of wastes collected daily, estimates of the contribution of informal work to recycling rates and data on livelihood aspects such as income and job creation potential. KPIs are described in detail in Chapter 4.1 (Research article 1 - Role and size of informal sector in waste management – a review).

Using KPIs can be seen as "contact-free" method; despite it has to be clear that estimations based on these indicators lead to indicative estimates only. KPIs have to be further

researched and refined, especially related to quantities informally collected per time unit: this has to be extended with specific waste / recyclable types. In addition, it is necessary to collect more information on “generalists” vs. “specialists” as this has great impact on the quantities collected per time unit.

Informal waste sector realities vary from region to region; therefore estimates based on KPIs have to be cross-checked, e.g. verified via triangulation (see Chapter 3.4). With respect to this, KPIs cannot be seen as stand-alone approach, thus on-the-ground research is indispensable in order to obtain “real life” data and information.

A **research article** on the development of KPIs on the IRS is presented in Chapter 4.1 (**Research article 1 - Role and size of informal sector in waste management – a review**).

3.3.2.3.2 Surveys

Surveys are indispensable for obtaining information on the informal recycling sector on the ground. This is of paramount importance as informal sector “realities” vary from region to region. The differences in the personal living and working conditions may be characterised by:

- the services provided;
- waste / recyclable types collected;
- the quantities collected per time unit;
- the means of transport in use;
- full or part-time activities;
- “Generalists” (collecting all waste types) vs. specialists (focussing solely on selected waste streams);
- the places of activities (street picking, landfill picking etc.);
- the age and physical constitution of pickers and other
- socio-economic and cultural issues.

As the setting of IRS activities is very heterogeneous, the preparatory work for surveys is challenging. Yet surveys are adequate in order to obtain information on the prevailing realities and shall result in the generation of information that allows an estimation of quantities informally collected per time unit. In addition, questionnaire-based surveys may include additional information to be collected related to the age of involved pickers, problems faced, time-spent on activities, revenues generated and many more.

An important factor in survey planning is the extent of the survey in terms of time spent for this activity as the time and resources needed have impact on the costs. As described in Chapters 3.1 and 3.2 a good starting point is to conduct a **pre-survey** first and to map the places of activities first. On the one hand this can be done via a city map and a process flow diagram approach – it is important to have information what informal players are active, at which places and how the informal (recycling) value chain looks like.

The pre-survey can be done starting with an on-site inspection; additionally, city maps may be useful. Also it is recommended to carry out interviews with waste management experts, practitioners or NGOs involved in waste management and the IRS.

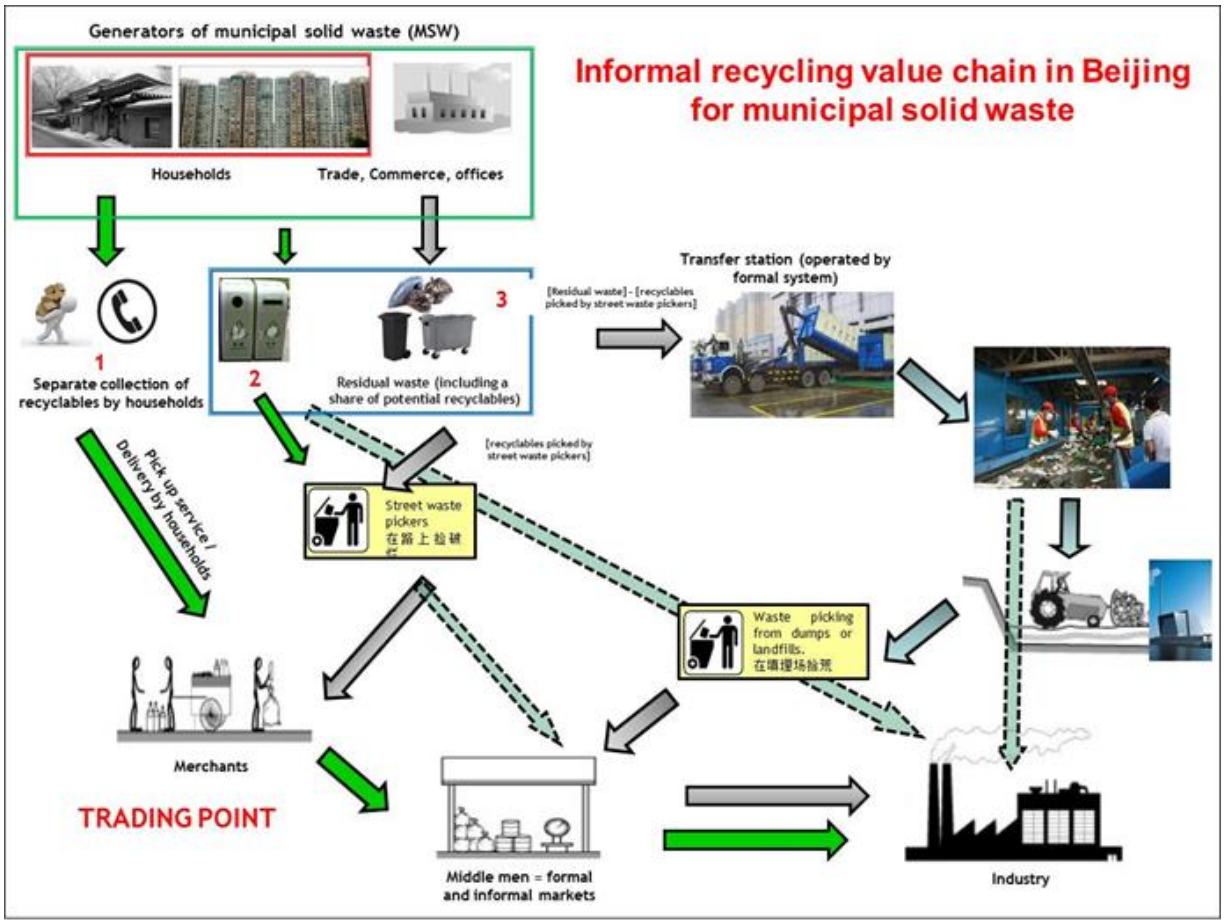
Figure 10 shows the results of a pre-survey carried out in Beijing (PR of China). The goal was to assess the size and contribution of the IRS in the district Haidian covering 3.3 million inhabitants and in total 29 sub-districts. Expert interviews and on-site investigations led to a first understanding how the informal value chain looked like. The upper part of Figure 10 shows the informal picker types and trading points that were observed, where collected recyclables are traded and then transported to larger informal recycling markets at the outskirts of Beijing. The lower part of the Figure shows the sub-districts that were assessed in-depth. Firstly, the trading points (TPs) in the sub-districts were spotted and plotted into a city map also indicating the size and “traffic” of the respective TP. This allowed a survey planning in terms of how many trading points to be observed and how many interviews to be carried out. In a next step questionnaires were developed in order to obtain information regarding informal work in waste management such as demographic characteristics, income (recyclables buying and selling prices), age distribution and gender, quantities and types of materials collected and means of transport used etc. In addition, it was possible to gain information on the informal recycling hierarchy (informal recycling chain) and on interfaces with formal stakeholders.

It is recommended to **pre-test the questionnaires** and the specific interview settings. This might lead to improved questionnaires, but also gives a strong indication on the **variation** of the answers which is influencing the necessary **sample size**, i.e. the number of interviews to be carried out. For example, assessing the informally collected quantities of a certain recyclable per time unit is important for extrapolating this to a certain region. Usually the estimation of the size of involved informal pickers in a region is difficult to assess, therefore the quantities should be better estimated.

A pre-survey with for example a sample size of n = 30 is a first starting point for statistical analysis. As the estimate of the average value is depending on the variation, it is necessary to lay down the level of significance which influences the necessary sample size that allows deriving statistical significant information. In some cases, also **non-probability sampling** technique are used where existing study subjects recruit future subjects from among their acquaintances. This sampling technique is often used in hidden populations which are difficult for researchers to access; example populations would be drug users or sex workers (Goodman, 1961).

In case that the size of informal workers is to be investigated, it is possible to carry out counting campaigns. Informally collected items and recyclables usually move through the recycling hierarchy. Depending on the activity and location informal collectors are moving or stationary. Generally spoken, informal workers picking recyclables at landfills are more stationary compared to street or doorstep pickers or IWBs. The latter groups’ mobility is furthermore dependent on age, physical condition, means of transport in use, geographical conditions and type of recyclables that are collected. It can be stated that landfill pickers are easier to count than people itinerant in the streets of a megacity.

Within surveys it is both possible to obtain **quantitative data** as well as **qualitative information**. Both closed and open-ended questions can be used in questionnaires, main focal points of questionnaires for both waste pickers as well as waste buyers (middlemen) are outlined in Medina (2007).



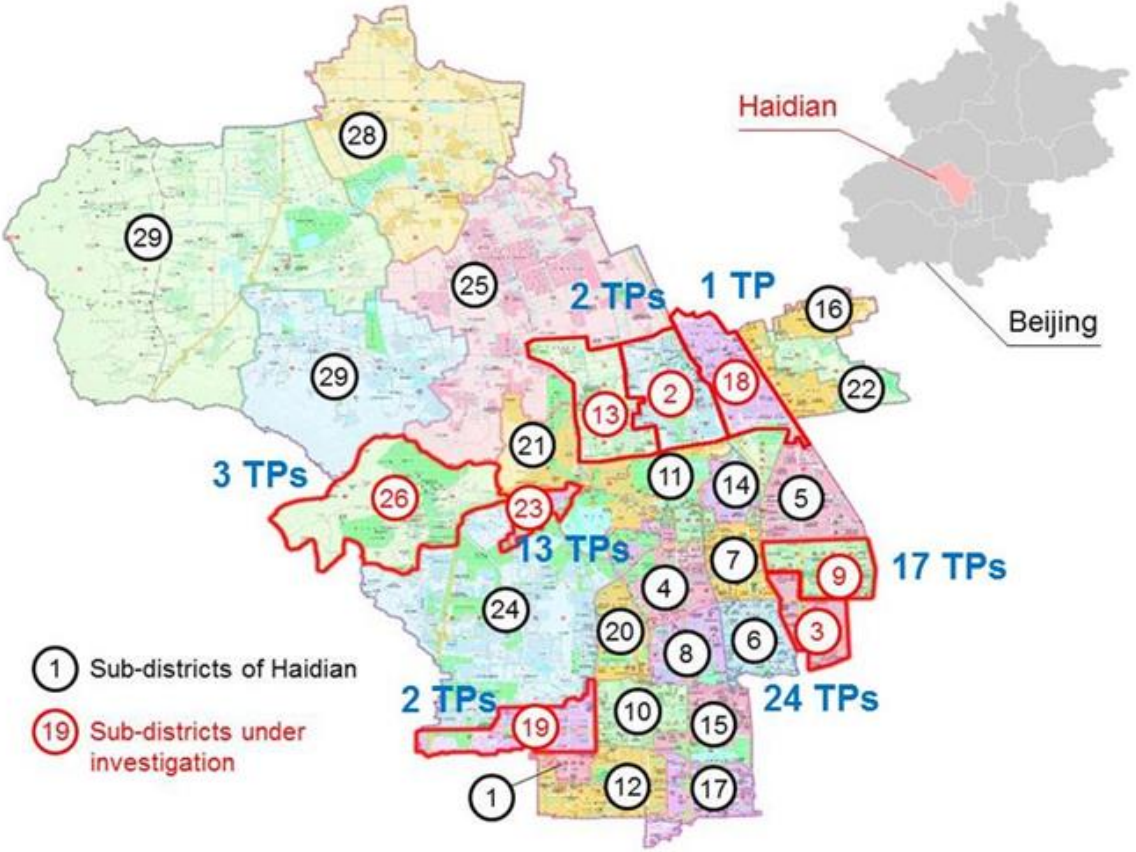


Figure 10: Results of a pre-survey for assessing the IRS in Beijing / district Haidian

For survey planning and conduction, the following issues have to be considered:

- Surveys might be time-consuming.
- Mobility of informal collectors and…
- …different locations of informal activities may lead to…
- …double counting.
- Different types of informal pickers namely generalists and specialists.
- Seasonal variations might occur in the activities.
- Prerequisite for surveys: “Understanding” the informal value chain (actors, material flows, locations).
- Waste pickers work informally, follow no schedules and sometimes they follow no collection route. They often cannot explain what they do in terms of the conventional units of measurement we know, i.e. kilograms, kilometres.
- Employees and owners of scrap yards are often reluctant to provide information on quantities of materials received and sold, fearing fiscal or legal audits.
- Street waste pickers may be either ashamed of sharing information about their work or fear that they may be persecuted for the information they provide. Awareness is needed in terms of that they don’t always have the time to answer too many questions.
- Waste pickers work informally and may not be registered. It can happen that a significant fraction of respondents consists of illegal immigrants, possessing no papers, no permit to live in the country and often have a very poor command of the local language.
- Language barriers between interviewers and interviewees; this occasionally caused some difficulty in understanding the questions of the questionnaire.
- When carrying out surveys it is recommended to have a local team that approaches the IRS with language and cultural knowledge of their background.

Counting campaigns include surveys aiming at determining mainly the size of the IRS, i.e. the number of individual pickers. These campaigns have to be carefully planned as double counts have to be avoided. In addition, these activities can be very time and staff resources consuming. One possibility is to count informal waste workers at the interfaces of the informal recycling hierarchy. This means at points where recyclables are handed over to other stakeholders in the value chain (street collection points, informal recycling markets, junk shops etc.) or stored might serve as points of investigation. Another possibility is to use geographical circumstances, such as main roads that pickers have to take or similar, in order to define suitable points of investigations. At these points pickers or other stakeholders of the informal chain can easily be counted without movement of the surveyors. Of course it is necessary to define certain areas where to carry out counting in advance, in order to identify significant regions (could be at district level etc.) that allow an extrapolation to other districts.

3.3.2.4 Waste-related data from industry using secondary raw materials

The use of data from industry using secondary raw materials as input material is difficult. On the one hand this data probably is reluctantly circulated to third parties and on the other hand allocation problems occur (Figure 7). It might be difficult for the industry to estimate the share of recyclables originating from informal collection activities. In addition, larger companies obtain recyclables from different regions which leads to problems when informal activities are assessed in a specific geographical location – problems occur, when enterprises have to allocate informally collected input material to different geographical regions.

3.4 Excursus: Triangulation

Triangulation, a concept used in social sciences, intends to facilitate the validation of data through cross-verification from two or more sources (Bogdan and Biklen, 2006). It refers to the application and combination of several research methods in the study of the same phenomenon. Originally this method evolved in nautical navigation and is widely used in surveying.

The assessment of informal sector contribution in terms of informally collected quantities needs verification, especially estimates based on KPIs, but also survey results (see Figure 11).

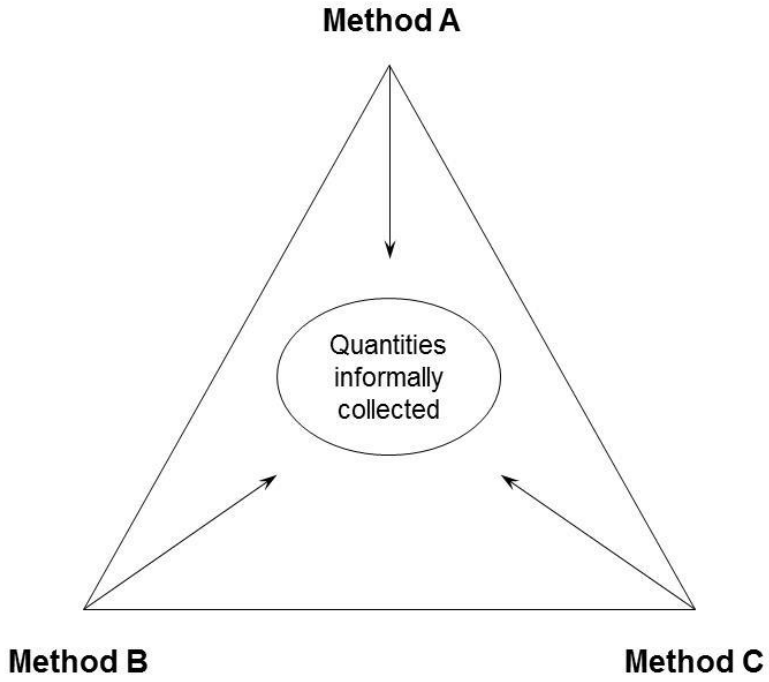


Figure 11: Concept of triangulation to verify results from different methodological „starting points“

In the case of assessing IRS activities there are different options to “triangulate” (verify) results of different methodological approaches. In the following, three options for verification are presented.

The first option presented deals with the opportunity to verify IRS assessment results at different levels of the informal recycling value chain regardless of the type of methodology used for the assessment. This means based on the law of conservation of mass at each step (interface) of the value chain “what goes in – must come out”. This allows for comparing results of quantities collected by the IRS with quantities entering for example an informal recycling market or storage point. The second option is to compare results of different methodological approaches, e.g. results of KPIs are compared with survey results. The third possibility to verify data is to compare whether formally and informally collected quantities fit with estimates on the waste that is generated at the source.

Estimates on the IRS can be improved; the more “triangulation options” are available. This means the higher the number of triangulation options in a system, the better the options of cross-checking results. But this is highly dependent on availability and quality of data (see Chapter 3.3.1).

3.4.1 Triangulation at different levels of the (informal) value chain

One option to verify results is to carry out analyses at different levels of the informal recycling value chain (see Figure 7), no matter what methodologies are used for this. Figure 12 displays the possibility to assess informally collected quantities via KPIs or surveys at the level of the individual collectors. In addition, it is possible to estimate quantities at the next level of the value chain, e.g. at storage points, informal recycling markets, scrap yards, junk buyers or other intermediary locations where informally collected recyclables are traded.

This means that at such an “interface” the number of involved stakeholders and the amounts collected / traded per time unit are observed from “both directions”. E.g. at a recycling market it is possible to record incoming informal collectors and get an estimation of the number of involved individuals. Using questionnaires of a sample of these collectors gives information on quantities and types of recyclables collected per time unit. The receivers of the delivered recyclables can also be observed via surveys; this leads to additional information obtained that can be compared with collector’s information. Another possibility to clarify quantity-related data collected from waste pickers is to evaluate pay-slips or bills (in case available) that might be used to define the prices for recyclables handed over at a certain informal recycling value chain interface. Taking into consideration mass balances (see Figure 4) it is possible to compare quantities delivered and received at different trading points.

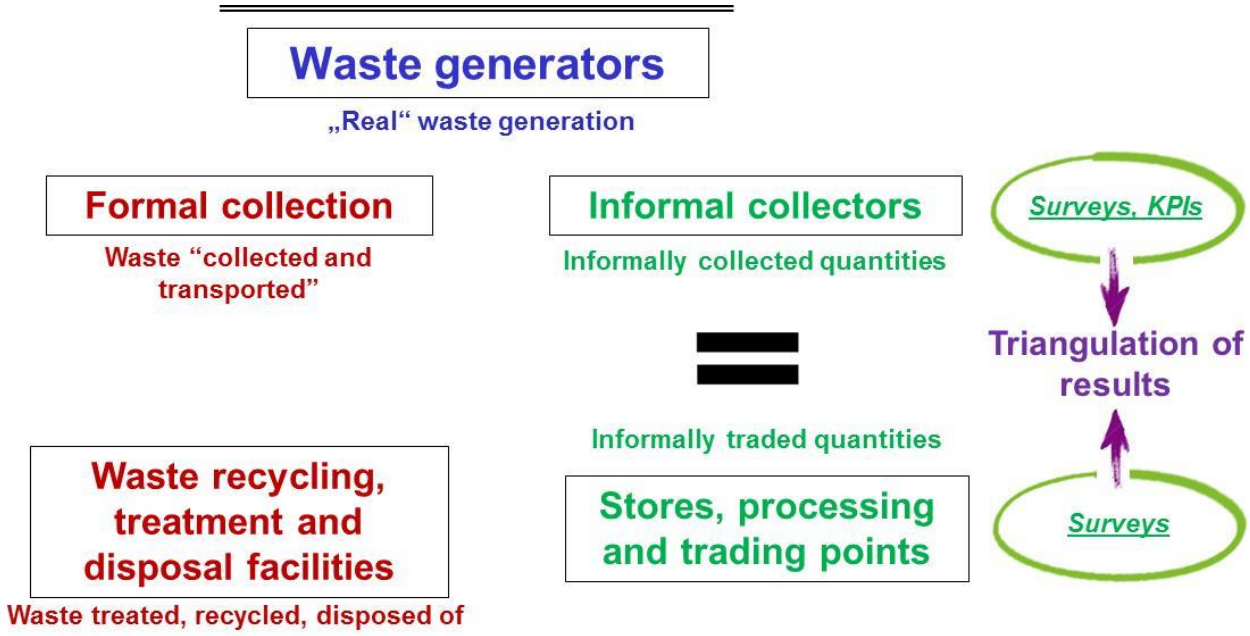


Figure 12: Triangulation at different levels of the informal recycling value chain

Case 1: Assessing the informal diversion of aluminium beverage cans in selected Eastern European cities

The following case described is related to an ongoing project carried out at the Institute of Waste Management. The aim of the project is to estimate the quantities of informally diverted aluminium beverage packaging (alu cans) in three Eastern European Cities.

Figure 13 displays the set-up of the available data of this case study. At the level of waste generators market data are available in terms of the numbers of aluminium cans that are put on the market per year. Aluminium cans can be considered as non-durable products, meaning that what is put on the market per year is considered as consumed (and therefore also entering the waste stream) in the same year. One problem that occurs is that these market data are available at national level but informal diversion is considered at local level. As the research scope is at city level, it has to be clarified how to recalculate national consumption data to city level. One possibility is related to GDP or income diversion, assuming that in urban areas more cans per capita are consumed.

Data on the formal collection of used beverage cans (UBCs) is available at local level and provided by EPR-schemes. In addition, in some cases also data might be available on UBCs ending up non-separated in the residual waste stream or can be recovered out of incineration slags. Regarding the informal diversion of UBCs a rough estimation was carried out via KPIs, whereas the size of the IRS was calculated with 0.2% of the urban population and daily collected quantities with 1.7 kg per collector based on literature data.

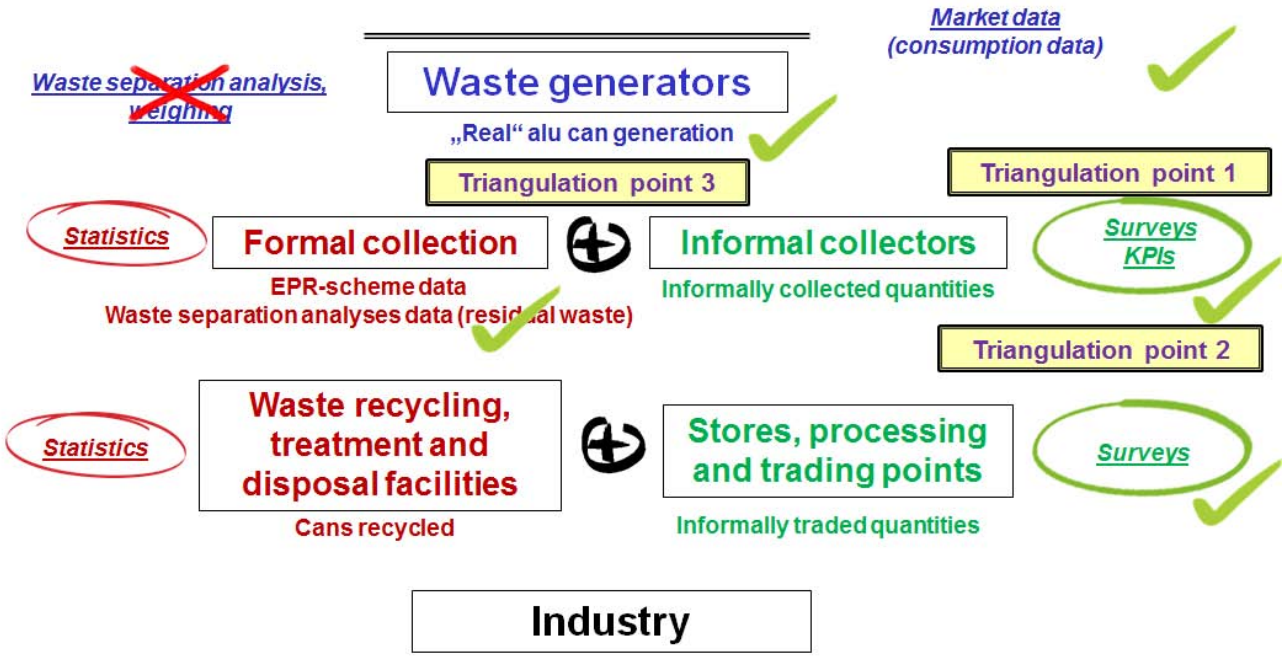


Figure 13: Set-up of available data sources for estimating the informal diversion of alu cans

For each case study city questionnaires were used for surveying the IRS. On the one hand interviews were carried out at individual picker level, but in some case study cities it was also possible to interview scrap yard owners. In total it was (in the best case) possible to use one triangulation point between results at individual picker level and survey results, a second one by using KPIs and a third one by comparing the formally and informally collected quantities with the quantities of UBCs put on market (see Figure 14). This allows for estimating an upper limit for UBCs informally collected by subtracting the formally collected UBCs and the informal estimates from the UBCs put on market.

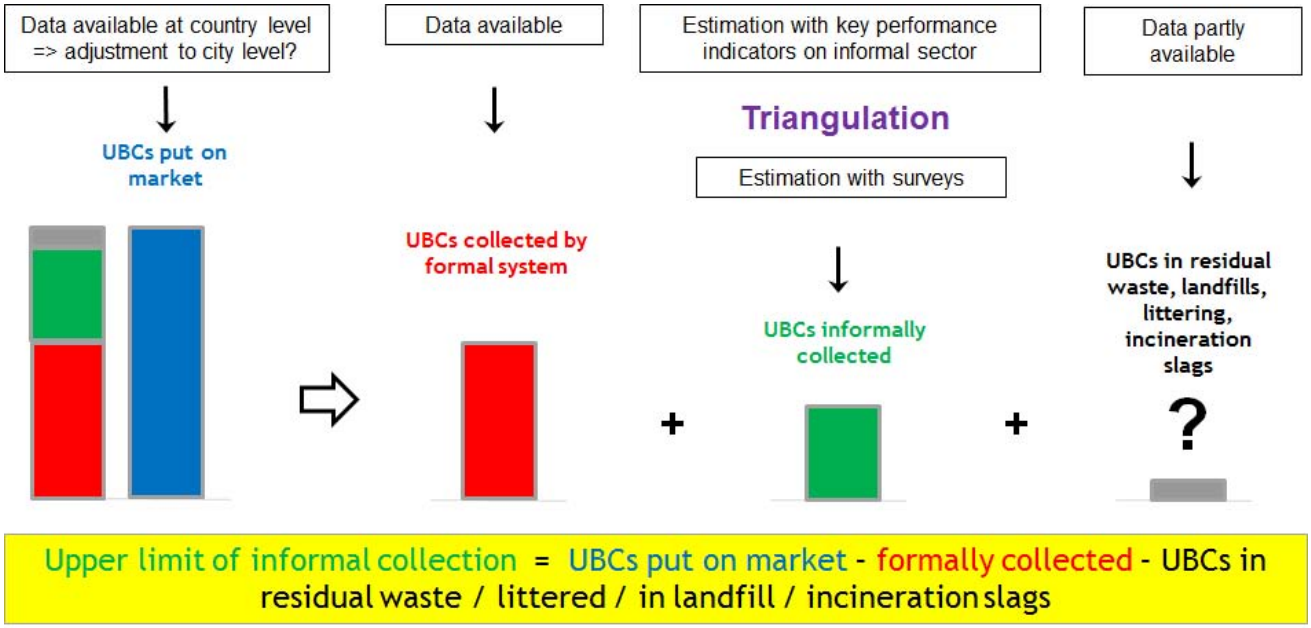


Figure 14: Estimation of informally diverted UBCs

3.4.2 Triangulation of “real” waste generation with “collected & transported” and informally collected quantities

The third possibility is outlined in Figure 15, showing the option to verify results by triangulating information of the real waste generation at the source (possibilities to obtain data are presented in Chapter 3.3.2.1) with the summed up quantities that are handled (“collected and transported”) by the formal system (see Chapter 3.3.2.2) and the informally collected quantities (see Chapter 3.3.2.3).

In the low-income country context usually problems occur, as the amount of wastes generated at the source is widely unknown. In addition, there might be other ways of disposal where quantifiable data are lacking and can be summarised under the term of “fly-tipping”, animal feeding, backyard burning of waste etc.

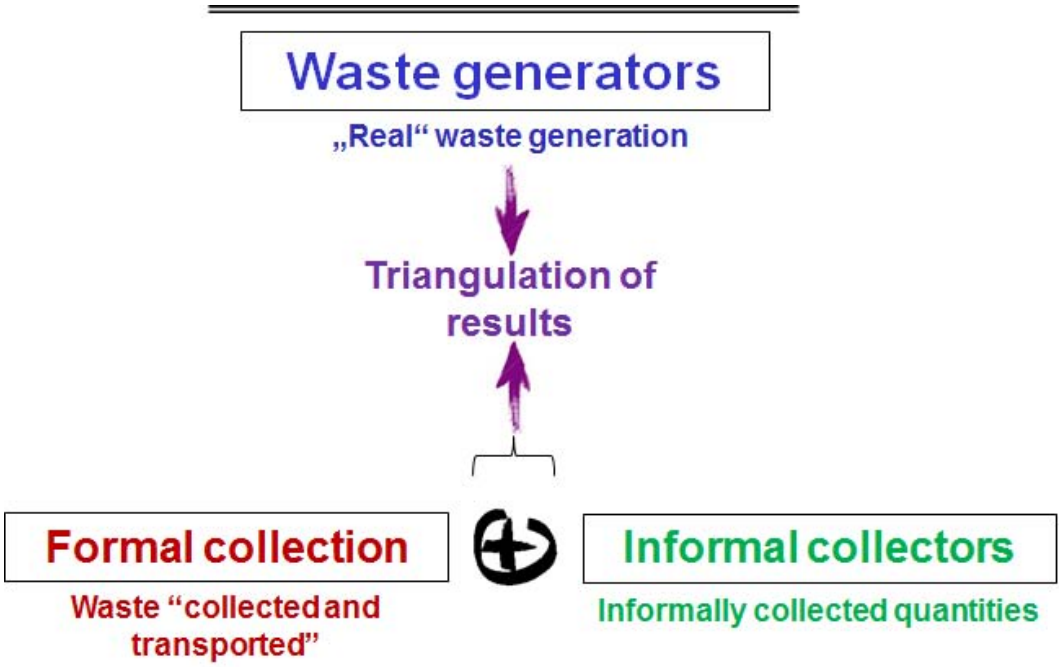


Figure 15: Triangulation of “real” waste generation with “collected & transported” and informally collected quantities

Case 2: Estimating informal recycling contribution in urban China

The informal sector is active in the collection, processing and trading of recyclable materials in urban China. Formal waste management organisations have established pilot schemes for source separation of recyclables, but this strategy is still in its infancy. The amounts of recyclables informally picked out of the municipal solid waste stream are unknown as informal waste workers do not record their activities. A majority of the reviewed literature detects that official data is displaying mainly “municipal solid waste collected and transported”, whereas less information is available on “real“ waste generation rates at the source. Based on a literature review the variables, the “number of informal waste workers

involved in collection activities", the "amounts collected daily per informal collector"' and the "number of working days" are used to estimate yearly recyclable amounts that are informally diverted from municipal solid waste.

As it can be seen in Figure 16 for the estimation of informal quantities KPIs were used at individual picker level. The next level of the informal recycling value chain was not possible to use as triangulation point, as huge informal recycling markets in the outskirts (of e.g. Beijing) were too large and could not be observed in detail.

The basic source of information regarding Chinese waste data used widely in literature and waste management practice is that provided by statistical offices. There is a lack in describing the methodology how data in official statistics are generated - there is growing evidence that waste data is derived from transfer stations (or estimated at landfills) and therefore does not reflect informal sector access and the associated removal of recyclables. In addition, there are literature estimates on the MSW that is generated at the source.

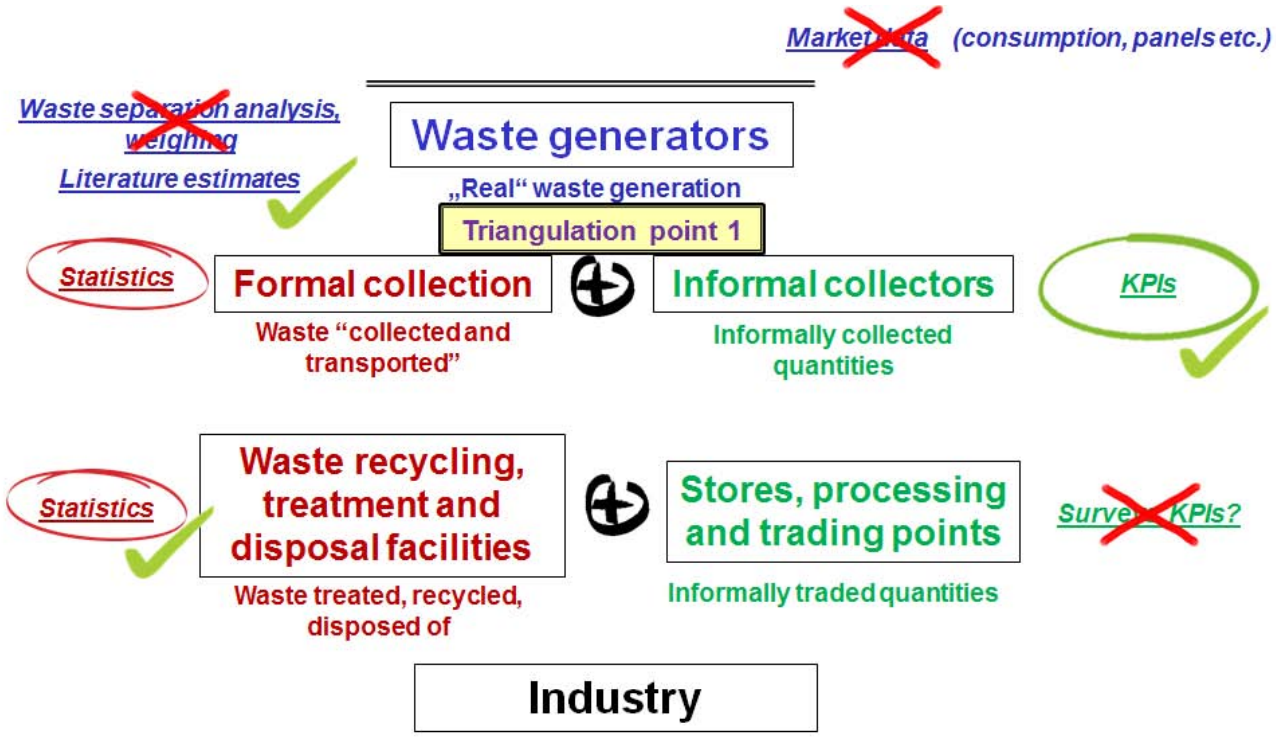


Figure 16: Set-up of available data sources for estimating the contribution of IRS to recycling activities in urban China

On the one hand, the difference between "MSW collected and transported" and "MSW generated" indicate the amount of recyclables diverted informally (see Figure 17). This might also include fly-tipping, incineration at household level or illegal dumping. On the other hand, informal sector recycling rates are calculated via the number of informal collectors and daily collection rates (KPIs). The number of informal waste workers given in literature is cross-checked with data on migrant worker studies (which can be considered as additional triangulation point). The estimates are compared with results from literature in order to approximate informal recycling rates for urban China.

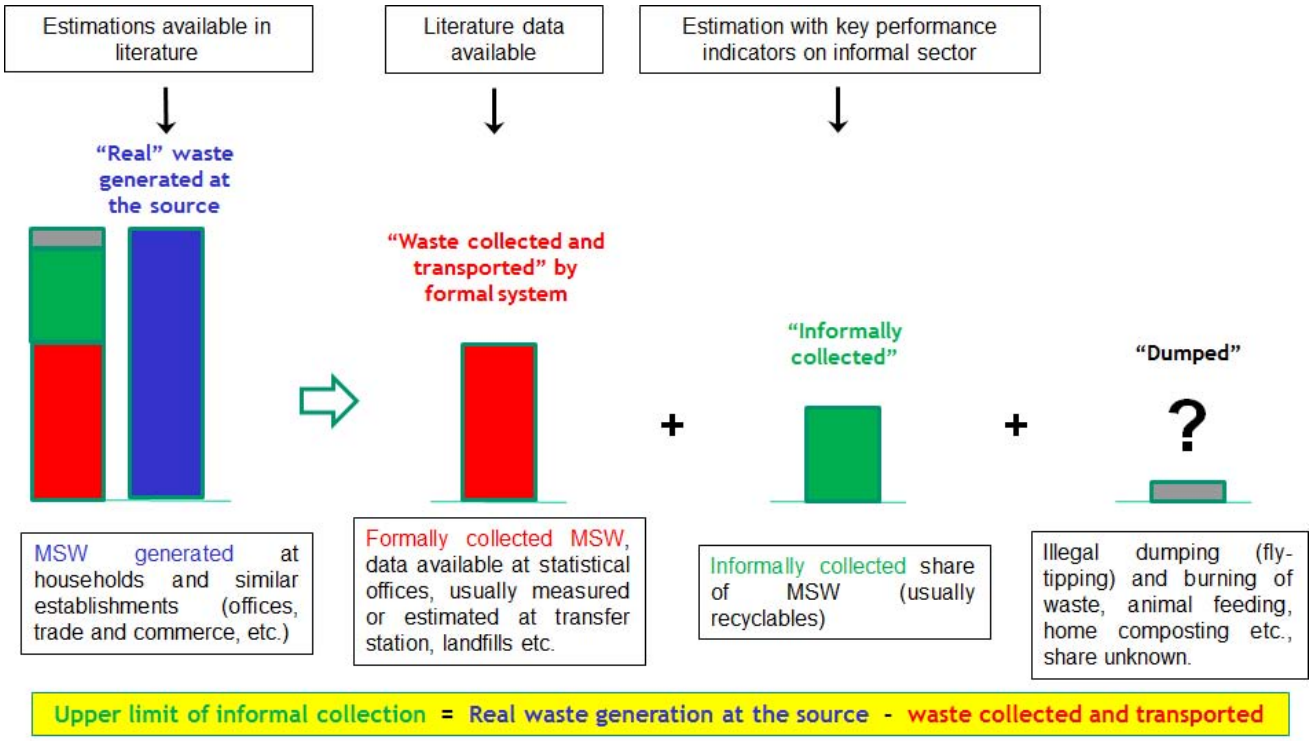


Figure 17: Estimation of an upper limit of informal collection in urban China

A **research article** on the estimation of IRS contribution to recycling in urban China and Beijing is presented in Chapter 4.2 (**Research article 2 - Municipal solid waste recycling and the significance of informal sector in urban China**).

3.4.3 Triangulation of different methodologies to estimate informally collected quantities

Another possibility to cross-check results is by applying different methodological approaches in order to quantify informally collected recyclables. The example set out in Figure 18 shows that there is the option to carry out counting campaigns. These campaigns are surveys aiming at determining mainly the size of the IRS, i.e. the number of individual pickers, but usually this makes sense if there are for example geographical bottlenecks informal pickers have to pass on their way to trading or storage points (see Figure 18). Such bottlenecks could be bridges, tunnels, border crossings or other main traffic routes that allow the counting of informal pickers, e.g. on a daily base. Besides estimating the number of pickers passing by per time unit, it is important also to obtain information on the means of transport in use and to estimate quantities they transport. These results of counting campaigns can be triangulated with KPI estimations, surveys carried out at individual waste picker level or surveys at the final destination of the transported wastes / recyclables (e.g. informal recycling markets or storage points).

Counting campaigns have the advantage that the observation of informal transports can be carried out at a stationary point, avoiding the usual problem of double counting.

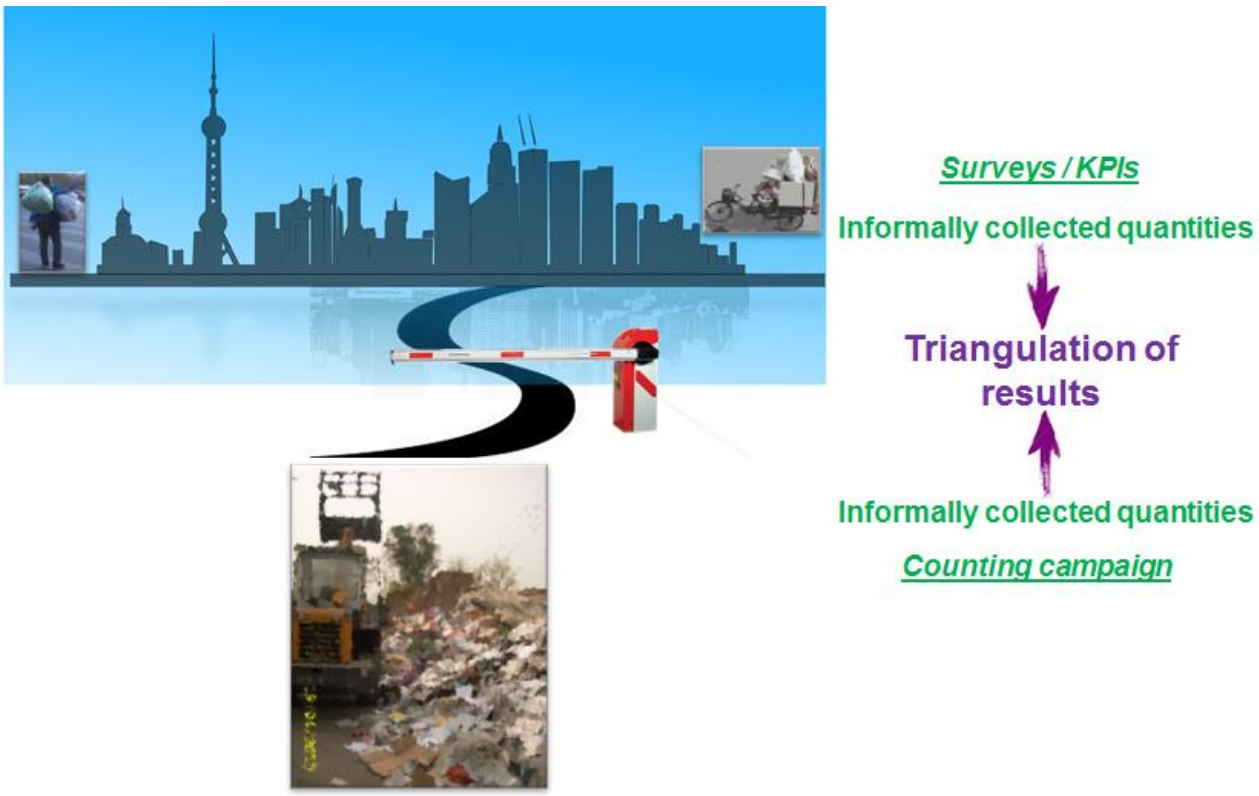


Figure 18: Triangulation of different methodologies to estimate informally collected quantities

Case 3: Modelling informally collected quantities of bulky waste and reusable items in Austria

A specific variety of informal activities, namely the ‘‘waste-brigades’’, have evolved in recent years, becoming more and more visible in Central Europe by performing informal collection activities at household level or at civic amenity sites/recycling centres/waste collection centres in Western European countries. Common target countries for these informal collectors are Austria and Germany, but may include Switzerland and The Netherlands. The members of the ‘‘waste-brigades’’ originate in Slovakia, Hungary, Poland and other Central and Eastern European Countries; at flea markets in these countries it has been observed that informal traders buy and transport some of those items further e.g. to Serbia, Ukraine and Belarus. From a geographical point of view, the research project “TransWaste” focussed on estimating the quantities of reusable items informally collected in Austria and the transboundary movement of these items from Austria to Hungary.

Different types of waste and reusable items such as Waste Electrical and Electronic Equipment (WEEE), household metal scrap and bulky waste (especially useable and saleable goods like furniture, household effects, textiles, sports equipment or toys) are gathered by non-authorised (informal) collectors without any statutory permit. The items are subsequently transported to countries whose waste management is in the process of being modernised – mostly to (South)-Eastern Europe (see Figure 19).

The informally collected quantities of reusable items in Austria were determined by using two methodological approaches. On the one hand a survey was carried out in Austria in order to estimate the number of municipalities affected by informal collection activities. In

addition, the municipalities were observed and interviews carried out with municipal officers and 83 informal collector groups in order to determine the number of groups active per municipality and the frequency of their activities. In addition, a traffic counting campaign was carried out in the course of one year at the main border crossings from Austria to Hungary in order to estimate the number of informal vehicles crossing the border. The results of the traffic counting and the surveys were used as triangulation of the results (see Figure 20).

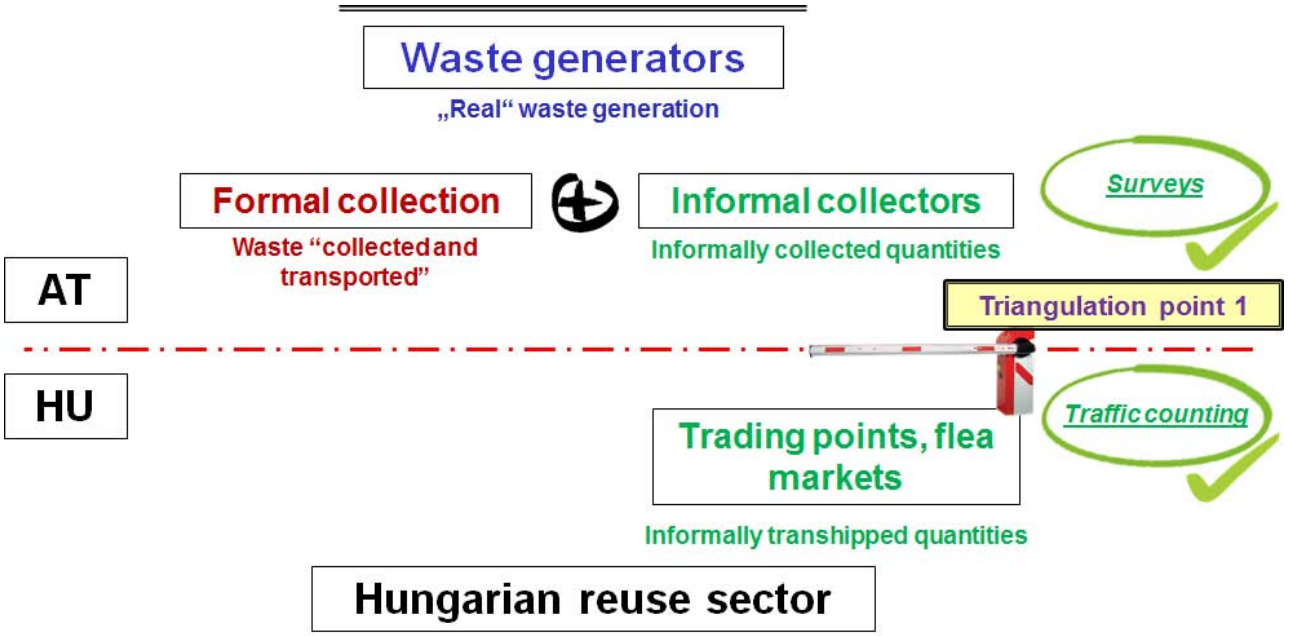


Figure 19: Methodological approach in the project “TransWaste“

A **research article** on the modelling of informally collected quantities of bulky waste and reusable items in Austria is presented in Chapter 4.3 (**Research article 3 - Modelling informally collected quantities of bulky waste and reusable items in Austria**).

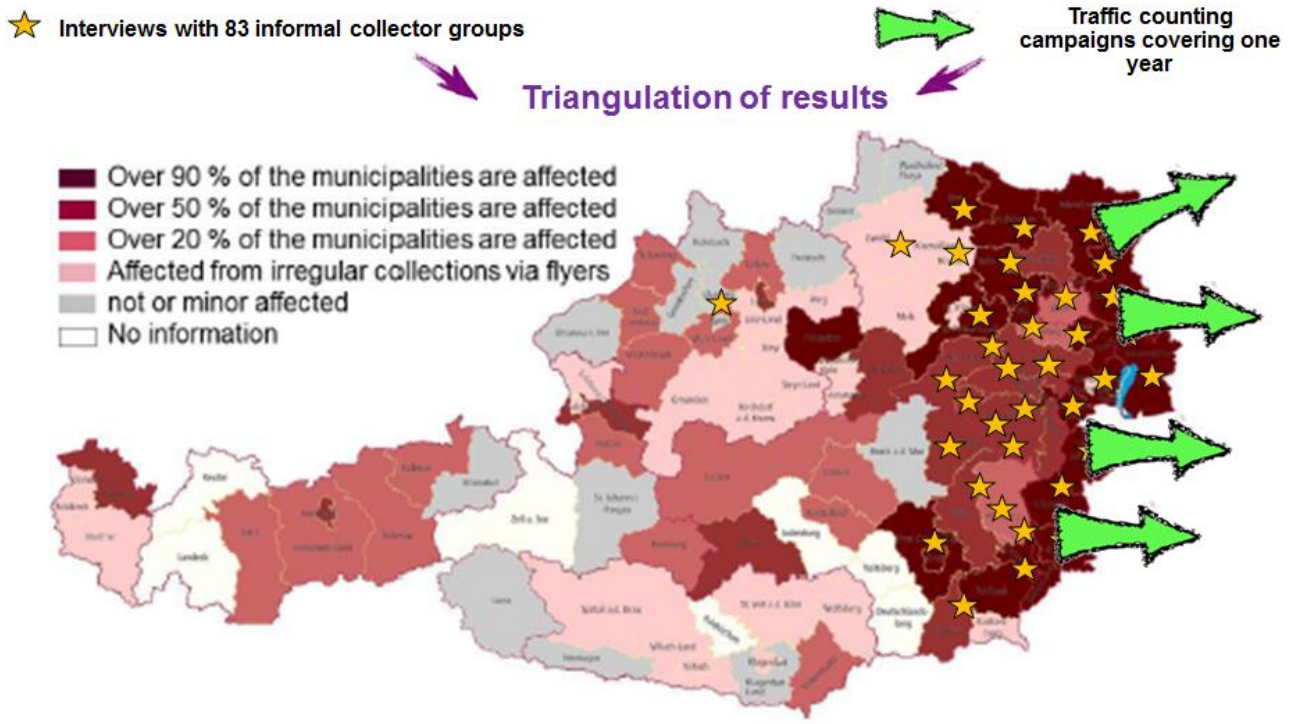


Figure 20: Methodological approaches to triangulate results in the case of “TransWaste”

4 Outline of research articles

In the following section three research articles are presented, that were published in international, peer reviewed journals. Research article 1 contains extensive research on suggested Key Performance Indicators (KPIs) on informal waste sector activities. Research article 2 displays the application of KPIs in practice, i.e. an estimation of informal collection activities in Beijing and urban China. Research article 3 focusses on presenting a somewhat different methodology on modelling informally collected quantities of bulky waste and reusable items in Austria.

4.1 Research article 1 - Role and size of informal sector in waste management – a review

The contribution of informal activities is per definition difficult to estimate as informal waste reclaimers have no inherent reason, obligations or simply not the capabilities to keep records. As 'formal' (official) performance data do not usually cover informal systems, official statistics (if even available) do not reflect the bigger picture of waste management in low-income countries.

Data on informal sector waste management performance is important in policy-making and enforcement but also with respect to advocacy and visibility of informal systems. In many cases the informal workers are not recognised in having a key role in waste management systems and are running the risk of losing their livelihoods in modernisation processes.

This paper aspires to bring together a large amount of research in this area and to compile research outcomes, mainly from the last decade, aimed at providing key performance indicators (KPIs) for initial appraisals in waste management planning or monitoring purposes. KPIs include data on the size of the informal sector in different regions, amounts of materials collected daily, estimates of the contribution of informal work to recycling rates and data on livelihood aspects such as income and job creation potential.

Locally generated data have been compiled and analysed in this paper, giving rise to data ranges and to national and global average values that can serve as rapid appraisal input data in waste management planning. Nevertheless, it is important to consider specific city context data requirements as outlined in the examples above.

The main results of this paper can be summarised as follows:

- The proportion of informal waste workers can be estimated at approximately 0.6% (0.5 - 2%) of the total population.
- Depending on the means of transport, daily collection rates amount to approximately 40 - 2,000 kg.
- Informal systems may recycle up to 45% of the generated waste (in some specific cases even more).
- Per kg prices of materials collected may increase by a factor of 3 up the recycling hierarchy.

- Daily incomes of informal waste reclaimers can be assumed to be between US$ 1 and US$ 15 (in some cases higher) and the ratio of income to minimum wage may be in a range from 0.7 up to 5.0.
- A rough estimate is that informal waste management systems generate 10 to 40 times more jobs than systems in an industrialised country.

Journal: **Waste and Resource Management**

Issue: Volume 166, Issue WR2, May 2013, Pages 69-83

Title: *Role and size of informal sector in waste management – a review*

Authors: **Linzner Roland** and Lange Ulrike

DOI: http://dx.doi.org/10.1680/warm.12.00012

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Role and size of informal sector in waste management – a review

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The contribution of informal activities is per definition difficult to estimate as informal waste reclaimers have no inherent reason, obligations or simply not the capabilities to keep records. As 'formal' (official) performance data do not usually cover informal systems, official statistics (if even available) do not reflect the bigger picture of waste management in low-income countries. Data on informal sector waste management performance is important in policy-making and enforcement but also with respect to advocacy and visibility of informal systems. In many cases the informal workers are not recognised in having a key role in waste management systems and are running the risk of losing their livelihoods in modernisation processes. This paper aspires to bring together a large amount of research in this area and to compile research outcomes, mainly from the last decade, aimed at providing key parameters for initial appraisals in waste management planning or monitoring purposes. Key parameters include data on the size of the informal sector in different regions, amounts of materials collected daily, estimates of the contribution of informal work to recycling rates and data on livelihood aspects such as income and job creation potential.

1. Introduction

The current paper is an up-to-date review of the role of the informal sector in waste management. The goals of this paper are to gather a large amount of research in this area, and to compile research outcomes, mainly from the last decade, with the aim of providing key parameters for waste management planning or monitoring. Accordingly, any results presented stem from published journal papers, reports and case studies, rather than original research based on primary data. The objective is to set out the data on the informal sector comprehensively, focusing on the following points

- the size of the informal sector in different regions
- the amounts of materials collected daily and methods of transport
- estimates of the contribution of the informal sector to recycling rates
- information on livelihood aspects such as income and job creation.

Because the informal sector is active in almost all parts of the waste management chain, this paper mainly looks at data related to the collection and processing within municipal waste management systems, that is activities connected with the collection and processing of potentially valuable recyclables. Material streams, special wastes such as industrial waste, e-waste or waste ships are not considered.

An Organisation for Economic Co-operation and Development (OECD) study shows that the financial crisis has adversely affected the employment situation of many people and, in low-income countries with no unemployment insurance, they are forced to take informal jobs with low pay, no protection and high risk exposure. The study found that 1·8 billion people, or more than half of the global labour force, were working without a formal labour contract and social security (OECD, 2009). The economist Hans Singer once expressed astutely, 'The informal sector is like a giraffe, difficult to describe but easy to recognise' (Cacciamali, 1983).

This paper provides information compiled on informal waste management activities and in particular the size and contribution to overall waste management systems in low-income countries. The data collected may assist waste management practitioners making initial assessments, in planning stages or even during monitoring processes on location. The following

data are approximate and if more precise data on informal workers are needed, the sector should be more closely investigated using the methodologies presented by Medina (2007), Scheinberg *et al*. (2010), Sembiring and Nitivattananon (2010) and Wilson *et al*. (2009).

1.1 Informal activities in waste management

Scheinberg *et al*. (2010) define the informal solid waste sector as referring

> to individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognised, supported, organised or acknowledged by the formal solid waste authorities, or which operate in violation of or in competition with formal authorities.

Informal sector activities cover a diverse range and are described in many reports and papers. Wilson *et al*. (2006) and Women in Informal Employment: Globalising and Organising (WIEGO, 2013) segregate the following main categories of informal waste recycling, depending on where and how the material recovery takes place

- doorstep (household) waste pickers
- itinerant waste buyers moving around the streets buying (or bartering for) clean reusable and recyclable materials
- street waste picking
- en route/truck waste pickers (municipal collection crew or informals)
- waste picking from dumps/landfills.

The recycling trade hierarchy consists of individual waste pickers (or family type units) at the lowermost levels, ascending to recycling small and medium-sized enterprises (SMEs), craftsmen and middlemen, brokers, wholesalers and manufacturing industries (Scheinberg *et al*., 2006; Scheinberg, 2011). The value of materials usually increases up the chain.

A discourse on informal activities should mention how the workers in such waste management systems are perceived, by formal waste management practitioners, local authorities, non-governmental organisations (NGOs), and by society generally. The value given to informal sector activities is reflected in the local and international names bestowed on the workers involved. Chi *et al*. (2011) and Medina (2007) provide some examples from different countries. One very common term used for such people is 'scavenger'. Scavenging often describes animal activities and discussions at, among others, the International Waste Management and Landfill Symposium in Sardinia 2007 or the First World Conference of Waste Pickers in Bogotá 2008 led to the use of the expressions 'waste pickers' or 'waste reclaimers', because these terms are preferable to derogatory words such as 'scavengers'. Samson (2009a) points out that 'waste picker' does not capture the nature or importance of the labour being performed and that 'the term reclaimer emphasises that, through their labour, people are reclaiming items cast aside by others, and are also reviving dead commodities and reclaiming the value inherent within them'.

Scheinberg *et al*. (2006) discuss the development of the relationship between solid waste management practitioners and waste pickers. Informal activities were formerly seen as a decontextualised, social problem without considering the economic activities carried out. Reactions were thus welfare based, focusing mainly on improvement of the working conditions and disregarding the enabling environment, meaning 'the political and social forces that influence their position'. In addition, more development-oriented approaches gave rise to 'social and economic interventions such as education, credit and income generation to enable pickers to exit to other occupations', ignoring significant issues related to the importance of waste picking as a means of generating income. Other approaches were more rights-based, including 'supporting pickers to form organisations and lobby for rights and social status, but still without acknowledging the economic importance of picking.

In any case, as well as the professionals involved, it is important to acknowledge those informal individuals as an integral part of waste management systems.

1.2 The need for data

Waste management systems are characterised by the involvement and interactions of various stakeholder groups – often with different interests. Table 1 gives an overview of selected stakeholder groups and the need for data on informal sector performance.

Table 1 is not comprehensive and the interest of certain stakeholder groups to obtain data on informal sector performance is highly dependent on local specifications. For example motivations might differ in a low-income country compared to middle- or high-income countries or stakeholder groups claiming to have a stake may vary depending on the region. One example is that formal waste management stakeholders in some cases simply neglect the existence of the informal sector in low-income countries, whereas in high-income countries where the waste management system is more advanced with respect to the recovery of recyclables, and therefore informal workers are a competitive threat, the opposite is true. Locally generated data have been compiled and analysed in this paper, giving rise to data ranges and to national and global average values that can serve as rapid appraisal input data in waste management planning. Nevertheless, it is important to consider specific city context data requirements as outlined in the examples above.

The major development drivers for change in waste management in low-income and emerging countries are public health,

Stakeholder	Data required
National level authorities (e.g. ministry of environment, labour or social affairs)	Policy making and enforcement, for example, national environmental plans, achievement of recycling goals, tax circumvention owing to informal activities, transfer payments and minimum wage policies etc.
Local level authorities (regional governments, city administrations, municipal waste departments)	Monitoring and planning of waste management systems: cost efficiency, material balances/recycling rates, environmental performance, collection efficiency, capacities of treatment and disposal plants; city master plans etc.
Waste management enterprises/recycling industry, manufacturing industry	Competitive issues (amount and quality informally collected), inclusivity issues (amount and quality of materials that can be purchased from informal sector), material prices etc.
Individual pickers, waste picker associations (local, regional, global), NGOs acting as advocates for informal workers	Data needed for improving efficiency or to display unique selling points of informal systems, for example, contribution to waste collection, recycling, hygiene; describing environmental benefits/ cost savings; amounts and quality of collected materials are also important for negotiations with manufacturing industry; describing livelihoods (income etc.) of informal workers in local/global advocacy etc.
Others (e.g. labour unions, chambers of commerce, banks, insurance companies, customs offices etc.)	Minimum wage enforcement, industry support, loans, warranty issues, transboundary shipment etc.

Table 1. Stakeholders and the interconnection to informal sector waste management

the resource value of waste and environmental protection (Wilson, 2007). Changes to waste management systems, which are assumed to be more resource oriented might also interest other stakeholders, for example the private sector may be interested in setting up a value chain to procure recyclables. In these cases, datasets on informal activities should be extended to include more information about the reliability of the informal systems, viability and quantities amassed over time, quality of materials collected, prices and so on. This may be different from conventional solid waste management planning data (M. Ali, personal communication, 2010).

It is by definition difficult to estimate the contribution of informal activities, because waste reclaimers have no inherent reason or obligation to keep records, or may simply not be capable. In addition, official performance data do not cover informal systems; statistics do not reflect the big picture in low-income countries. Therefore for waste management planning or monitoring purposes it is of paramount importance to obtain data on informal systems.

2. Methodology of the literature review

Data obtained from an extensive literature review are presented. The main focus is a compilation of data that might serve as entry points for waste management planning in modernising waste management systems in low-income countries. The datasets presented include: the reported size of the informal sector in different regions; amounts of materials collected daily with respect to the means of transport; estimates of the contribution of the informal sector to recycling rates; and information on livelihood aspects such as income and job creation.

More than 100 international journal papers, reports, studies, books and policy papers were examined and classified into a total of five sections and 35 categories including 204 different characteristics. In this paper only a part of the information collected is presented.

The information has been divided into five sections.

- Characterisation of the informal sector: this section classifies by region and type (e.g. ranging from individual waste reclaimer to broker or middlemen), the number of people or families involved, gender and if they are registered/organised.
- Informal waste picking activities: this section mainly refers to materials and specialised types of activities, prices of materials, income generation, working hours, access to

materials and the material flow (i.e. information about the value chain).
- Environmental and health problems caused by informal activities: deals with potential health and other risks, disturbances and environmental impacts associated with informal activities.
- Measures against informal sector: displaying potential types of measures against informal sector activities and the initiating stakeholders.
- Formalisation of and support for the informal sector: deals with formalisation ideas applied and their degrees of success.

3. Results of the literature review

3.1 Size of the informal sector

Table 2 shows a compilation of 43 datasets on the reported sizes of the informal sector in different regions. Different literature sources give contrasting data on the size with respect to the same geographical region. Accordingly a minimum to maximum size range is displayed whereby the source first mentioned in the last column always refers to the minimum number of reported workers. The same holds true for the population sizes in the corresponding regions; the respective census years are given in brackets. The percentage of informal workers related to the population was calculated and is displayed in a minimum to maximum range. The abbreviations in brackets refer to the ISO 3166 country codes (ISO, 2006).

Table 2 gives a rough estimate of the percentage of informal workers in relation to the population size. The comparison of datasets should consider the following aspects.

- Differences in the given population sizes result from both varied census years and reported geographical regions. Sometimes population refers to a city core, in other cases to metropolitan areas.
- As far as possible, data from similar time periods were used to calculate the number of informal workers, as well as census results.
- In almost all of the cases the reported number of informal workers are estimates and difficult to verify; these figures are indicative, rather than exact. The methodologies used for those estimates (if available at all) have not been questioned. In addition, in many cases it is not revealed if the number refers to all the informal workers or just the parts related to certain activities, for example dump pickers only, or geographical areas, such as a certain municipality within a city. Apart from these uncertainties, the vast majority of datasets used contained no information on precision or reliability and the search criteria used focused on municipal solid waste and not special waste streams.
- Regions written in bold type display country data. Because informal sector activities are mainly linked to urban areas, the total urban population was used to calculate the population data (UN, 2010).

On average, informal workers (all regions except the country data) account for approximately 0·6 % of the population. Sources in literature present figures of between 0·5% (in ten reference cities, UN-Habitat (2010)) and 2% (Bartone, 1988; Medina, 2000). Based on a database provided by the UN (2010) the urban population was calculated at 2·49 billion people for selected countries. In addition the UN (2010) provided population data for 'less developed regions' at 5·6 billion people. Assuming an urbanisation rate of 50% the urban population can be calculated at 2·8 billion people. Applying the informal sector range of 0·5–2% to the urban population ranges (2·49–2·8 billion people) leads to an estimated size of roughly 12·5–56 million people worldwide working in the informal sector in waste management. This is the equivalent of the populations of Cambodia and Italy respectively. Medina (2008) as well as Binion and Gutberlet (2012) report 15 million informal workers worldwide.

In the three largest countries where informal activities can be observed (China, India and Brazil), it is possible to calculate average values based on the available city data in Table 2. Together with the available country data (Table 2, bold entries) and by applying these ranges of the percentage of informal actors to the urban population, the total estimated number of informal workers in China, India and Brazil extends to approximately 6–12 million people; Medina (2008) reports approximately 8 million for the three countries.

Scheinberg *et al.* (2006) state that the

> numbers of waste pickers fluctuate because of population growth and economic conditions. If economic conditions worsen, the numbers tend to grow. Waste picking can (re)appear during particularly stressful situations such as war and severe economic crisis that lead to extraordinary circumstances and scarcity.

Besides the reported numbers of informal waste workers (see Table 2) it may be assumed that the number of people dependent on these activities is even higher.

It is possible that a concentration of informal waste workers exist with respect to certain waste streams. Prominent examples are transboundary shipments of e-waste to low-income countries such as Ghana (in particular Accra), China (especially Guiyu) or to Nigeria or India. Hicks *et al.* (2005) present data on Guiyu, estimating 100 000–120 000 informal workers in e-waste recycling out of a population of 130 000–150 000. In China it is estimated that 660 000 people work informally in the e-waste sector, equating to 0·11% of the urban population.

City/country	Population range (year)	No. of reported informal workers (range)	Calculated percentage of informal actors of population: %	Source
Asia				
China (urban)	635 839 000 (2010)	2 500 000–6 000 000	0·39–0·94	World Bank (2005); Liu (2008)
Beijing (CN)	11 716 000–19 600 000 (2010/2011)	130 000–300 000	0·66–2·56	Zhou and Xiong (2010); Li *et al*. (2009)
Guangzhou (CN)	6 181 000–11 070 654 (2001/2010)	100 000	0·90–1·62	Medina (2011)
Shenzhen (CN)	8 000 000–10 357 938 (2010)	200 000	1·93–2·50	Liu (2008)
Suzhou (CN)	2 000 000–4 074 000 (2010)	40 000–50 000	0·98–2·50	Mo *et al*. (2009)
Wuhan (CN)	6 144 000–9 100 000 (2010)	20 000	0·22–0·33	Li (2002)
Ulaanbaatar (MN)	760 000–824 700 (2000/2003)	5 000–7 000	0·61–0·92	World Bank (2004)
India (urban)	364 459 000 (2010)	1 500 000	0·41	Chaturvedi (2010)
Ahmedabad (IN)	4 800 000–5 570 585 (2003/2011)	20 000–50 000	0·36–0·42	Salahuddin and Shamim (1992); Medina (2005b)
Amritsar (IN)	1 132 761–1 183 705 (2011)	3 000–3 500	0·25–0·31	Sandhu (2012)
Bangalore (IN)	5 000 000–8 425 970 (2000/2011)	25 000–70 000	0·30–1·40	Van Beukering *et al*. (1999); Medina (2007)
Delhi (IN)	11 007 835–18 680 000 (2011/2010)	80 000–300 000	0·43–2·73	Chintan (2009); Medina (2007)
Kanpur (IN)	2 767 031–2 920 067 (2011)	15 000–20 000	0·51–0·72	Zia and Devadas (2008)
Kolkata (IN)	4 486 679–15 100 000 (2011/2010)	20 000–80 000	0·13–1·78	Medina (2005a, 2007)
Mumbai (IN)	12 478 447–19 200 000 (2011/2010)	85 000–135 000	0·44–1·08	Singh and Chari (2010); Medina (2007)
Pune (IN)	3 000 000 (2001)	6000–8850	0·20–0·30	Chikarmane *et al*. (2001); Scheinberg *et al*. (2010)
Bandung (ID)	2 000 000–2 393 633 (2010)	2915	0·12–0·15	Sembiring and Nitivattananon (2010)
Jakarta (ID)	9 588 198 (2010)	6000–37 000	0·06–0·39	Borongan and Okumura (2010); Medina (2008)
Manila (PH)	1 700 000–11 600 000 (2007)	12 000–13 413	0·10–0·79	Medina (2005a) and (2007)
Quezon City (PH)	2 487 098 (2007)	10 105–14 028	0·41–0·56	Scheinberg *et al*. (2010); UN-Habitat (2010)
Dhaka (BD)	7 000 940–10 979 000 (2008/2010)	120 000	1·09–1·71	UN-Habitat (2010)
Lahore–Allama Iqbal Town (PK)	120 000 (na)	400	0·33	Asima *et al*. (2011)
Ho Chi Minh City (VN)	7 396 446 (2010)	20 000–30 000	0·27–0·41	Scheibe (2006)
Phnom Penh (TH)	2 234 566 (2008)	3000	0·13	Chintan (2005)

Table 2. Population range, number of reported informal workers and percentage share in terms of population

City/country	Population range (year)	No. of reported informal workers (range)	Calculated percentage of informal actors of population: %	Source
Central and Latin America				
Mexico City (MX)	8 873 017–20 000 000 (2010)	15 000–20 000	0·08–0·23	Medina (2005a, 2005b)
Monterrey (MX)	1 130 960–4 080 329 (2010)	1000	0·02–0·09	Medina (2005b)
Peru (urban)	22 688 000 (2010)	100 000	0·44	Ruiz Rios *et al*. (2009)
Callao (PE)	813 000–876 000 (2011)	1500	0·17–0·18	Ruiz Rios *et al*. (2009)
Cañete (PE)	48 892 (2009)	176	0·36	UN-Habitat (2010)
Lima (PE)	7 765 151 (2005)	11 183–17 643	0·14–0·23	Scheinberg *et al*. (2010)
Brazil (urban)	169 098 000 (2010)	229 568–1 000 000	0·14–0·59	Crivellari (2008); Movimento Nacional (2006)
Belo Horizonte (BR)	2 452 617 (2009)	2685–5000	0·11–0·20	Dias *et al*. (2010); Gutberlet (2008)
Rio de Janeiro (BR)	6 136 652–11 470 644 (2010)	40 000	0·35–0·65	Do Carmo and de Oliveira (2010)
Santo André (BR)	660 000 (2004)	2000	0·30	Gutberlet and Baeder (2008)
São Paulo (BR)	11 316 149 (2011)	20 000	0·18	Scheinberg *et al*. (2006)
Bogotá (CO)	6 834 000–7 467 804 (2010/2011)	18 000	0·24–0·26	Schamber *et al*. (2007)
Buenos Aires (AR)	2 746 761–12 600 000 (2005/2004)	9000–25 000	0·07–0·91	Schamber *et al*. (2007); Medina (2005a)
Montevideo (UY)	1 338 408–1 968 324 (2009)	15 000	0·76–1·12	Schamber *et al*. (2007)
Africa				
Addis Ababa (ET)	2 757 729–3 384 569 (2007–2008)	5500–7000	0·16–0·25	Escalante *et al*. (2010); M. Maschal (personal communication, 2009)
Cairo (EG)	14 450 000–17 620 580 (2010–2011)	33 000–70 000	0·19–0·48	Scheinberg *et al*. (2010); Scheinberg (2011)
Dar-es-Salaam (TZ)	2 500 000 (2005)	600	0·02	Kaseva and Gupta (1996)
Lusaka (ZM)	1 238 227 (2005)	480	0·04	Scheinberg *et al*. (2010)
Europe				
Cluj-Napoca (RO)	309 136	3226	1·04	Scheinberg *et al*. (2010)

Note: na signifies 'not available'

Table 2. Continued

For Ghana's e-waste sector Amoyaw-Osei *et al*. (2011) present figures that can be transformed into percentages of the urban population. Ghana's informal e-waste collectors and recyclers account for approximately 0·06% and the refurbishing sector is estimated at 0·15% of the urban population.

Another example is ship breaking, where clusters in low-income countries play a major role in dismantling ships, providing employment for informal workers and also much needed re-usable materials for local economies (Khan *et al*., 2012). The motivation is similar to e-waste where significant occupational

and environmental health risks are shifted from the developed world to low-income countries. Ship breaking clusters exist, for example, in China, Bangladesh, Pakistan, India (virtually all shipbreaking in India is concentrated in Alang and a neighbouring site, Sosiya, located in Gujarat State, northwest of Mumbai), the Philippines, Vietnam and Turkey (Rousmaniere and Raj, 2007). A crucial topic in ship breaking is the development of guidelines focusing on occupational and environmental risks (e.g. how to deal with hazardous materials and substances) and on improving the low productivity of the activities. Rousmaniere and Raj (2007) report for Bangladesh that 'eighty percent or more of domestic consumption of steel is derived from ship breaking . . . some 200 000 workers were estimated in 2005 to be engaged directly or indirectly in ship breaking.' Both the European Union and the International Labour Organisation published guidelines for ship breaking (EC, 2007; ILO, 2003).

3.2 Amounts collected

The amounts collected by time unit are dependent on several factors

- location of activity and accessibility of materials (e.g. dump picking as opposed to itinerant waste buyers)
- means of transport (by foot, pushcarts, animal-driven, motorised vehicles)
- physical condition, age and sex of collectors
- type of materials (bulk densities)
- geographical conditions (length of trips to be made to collect materials, flat or hilly areas).

Table 3 shows the daily amounts collected by informal workers with respect to the means of transport in use. These approximate values do not consider the type of materials collected. It is not clear from the literature whether the figures display mixed recyclables or certain types of recyclables. Collectors on foot may collect a minimum of 9–17 kg/d (study for Delhi, whereas children collect 9 kg) or maximum 40 kg. Cyclists can collect 14–60 kg/d; rickshaw and pushcart use leads to increased collection rates from 40 to 200 kg/d, horse carts 200 kg/d and pick-up trucks 2–3 t/d (see Table 3).

The National Solid Waste Management Commission (NSWMC, 2009) presents data from three cities in the Philippines with respect to the daily amounts of certain materials collected at certain locations. Using the information provided it is possible to calculate that street collectors accumulate less, daily compared to landfill pickers. A landfill, which can be seen as a centralised source of potentially recyclable materials, contains a relatively high concentration of material, whereas households are a more decentralised source from which the collection requires mobility and consequent time loss. On the other hand, recyclables picked at households might be of better quality and achieve higher resale prices than materials from landfills. The Philippine study shows that for paper, aluminium and plastic, street gatherers collect approximately 30–40% of the amounts at landfills; for other metals and glass this share reaches approximately 70%.

A compilation of different sources reporting daily amounts of material collected is provided in Table 4, ranging from 15 to 70 kg and with an average value of 49 kg. The information provided does not consider material types, location or the means of collection.

UN-Habitat (2010) presents the numbers of materials collected in metric tonnes per worker and year for nine cities. Assuming

Means of transport	Daily trip: km		Time spent: h		Daily amount collected (min.–max.): kg		Source
On foot	6	7	–	–	40	–	Chintan (2003)
	–	–	–	–	9	17	Agarwal *et al*. (2005)
Pushcart	6	9	2	4	200	–	Medina (2007)
Horse cart	10	15	4	8	500	–	
Pick-up truck	–	–	–	–	2000	3000	
Cycle	20	25	–	–	40	60	Chintan (2003)
	–	–	–	–	14	25	Agarwal *et al*. (2005)
Tricycle	–	–	–	–	–	35·5	Agarwal *et al*. (2005)
Rickshaw	10	15	–	–	40	100	Chintan (2003)

Table 3. Means of transport, daily trip, time spent and collected amounts per day

Collected amounts: kg/d	Source
70	Chintan (2003)
47	Lange *et al*. (2011)
55	Khullar (2009)
38	Zia and Devadas (2008)
15	Sharholy *et al*. (2008)
25	Kaseva and Gupta (1996)
25	Medina (1998)
82	Lohani (1984)
62	GTZ (2008)
69	Chintan (2005)
Average value = 49	–

Table 4. Informally collected amounts

288 working days per year, the daily amounts collected per person range from 7 to 700 kg with a median value of 43 kg (average value 111 kg).

The contribution of informal collection and recycling activities within overall waste management systems has been calculated by different authors. Table 5 gives an overview regarding estimates of the percentage of waste recycled by the formal and informal sectors in terms of percentage of the total waste generated.

Wilson *et al*. (2009) state that recycling rates achieved by the informal sector can be quite high, typically in the range of 20–50 %. Table 5 also shows that informal workers are often the only stakeholders that provide recycling activities in low-income countries, whereas the formal waste management organisations carry out no recycling activities or have low rates of recycling. According to UN-Habitat (2010) Belo Horizonte has a strong and extensive tradition in municipal planning, including waste management services, and is known for its pro-inclusivity approach towards waste-pickers – therefore the amounts actually processed by the informal sector are minimal. Varna might have higher formal recycling rates owing to the post-socialist history; the informal sector is mainly active in street waste picking (UN-Habitat, 2010).

3.3 Livelihoods

The incomes of informal workers are illustrated in several studies. To calculate the net incomes it is important to consider not only revenues from materials sold. Incomes are volatile and highly dependent both on market prices and on the quality and quantity of materials collected. Case studies from literature also show that charges exist that are related to access to waste, or the

City (Country)	Mass percentage of waste recycled by informal sector: % of total waste generated	Mass percentage of waste recycled by formal sector: % of total waste generated	Source
Wuhan (CN)	21	0	Wilson *et al*. (2009)
Delhi (IN)	17–27	7	Agarwal *et al*. (2005); Scheinberg (2011)
Bangalore (IN)	13	1	Scheinberg (2011)
Dhaka (BD)	18	0	Scheinberg (2011)
Bandung (ID)	13	na	Sembiring and Nitivattananon (2010)
Manila (PH)	6	0	Wilson *et al*. (2009)
Quezon City (PH)	31	8	Scheinberg (2011)
Ormoc (PH)	22	na	Hetz *et al*. (2011)
Phnom Penh (KH)	9	na	Sengh *et al*. (2011)
Karachi (PK)	45	0	Wilson *et al*. (2009)
Ghorahi (NP)	9	2	Scheinberg (2011)
Lusaka (ZM)	2	4	Scheinberg (2011)
Moshi (TZ)	18	0	Scheinberg (2011)
Belo Horizonte (BR)	1	10	Scheinberg (2011)
Cañete (PE)	11	1	Scheinberg (2011)
Varna (BG)	2	26	Scheinberg (2011)

Table 5. Mass percentage of waste recycled by formal and informal sector

question is raised whether to include transaction costs for market participation in the considerations. Ruiz Rios *et al.* (2009) calculated the profit margins for each step in the recycling value chain in Peru. The price for 1 kg of material increases along the value chain. Certain paper and cardboard products increase by a factor of 1·3 to 3·0, polyethylene terephthalate (PET) plastics by 2·0 and for some metals by a factor of between 1·4 and 2·5. From a 'material price per unit' point of view, the Peruvian informal collectors have the highest profit margins for materials within the value chain as they do not pay for the materials they collect. They expend, however, a great deal of effort and a large portion of the material is too dirty to have a significant resale value. Although the 'higher' stakeholders in the recycling hierarchy have lower profit margins on a per unit basis than informal recyclers, they store larger volumes of material they buy from several informal recyclers (Ruiz Rios *et al.*, 2009). Prices of recyclable materials at different recycling levels for Delhi (India) are presented in Agarwal *et al.* (2005) showing that the value added along the chain ranges from 19% to 121%.

Care should be taken when calculating incomes, because in many studies only revenues from materials are considered but costs are neglected. This becomes especially discernible when formal and informal systems are compared. Material and capital costs are assets that are incorporated in cost calculations, but differences occur in the case of labour costs. Wages are comparably easy to define in the formal sector but not in the informal sector. This leads to the assignment of 'a disproportionate amount of 'benefit' to the informal sector activities when compared to the formal sector activities; specifically, this has to do with how wages were accounted for in the formal sector but not in the informal sector' (Simpson, 2007). Similarly, in the case of self-employed people, the 'entrepreneurial profit' (employer's salary) has to be taken into consideration. The scientific community is currently dealing with the question of how to ascribe notional wage costs to the informal sector – whether, for example, to use a minimum wage as a 'shadow labour price' (Simpson, 2007).

Table 6 cites informal waste reclaimers' incomes. The incomes, from a review of relevant literature, were converted to US$/d per person, with conversion rates from the respective period. In some cases monthly or weekly incomes were available and these were converted into daily rates by dividing by factors of 20 and 5, respectively.

Country/City	Waste picker income: US$/d	Source	Ratio of picker income related to minimum wage	Source
Mexico	9·0–15·0	Medina (2005b); Medina (2007)	3·0–5·0	Medina (2007)
Argentina	2·3	Medina (2007)	0·8	Medina (2007)
Argentina/Rosario	8·1	Spies *et al.* (2005)	–	
Brazil/Ribeirao Pires	2·7	Gutberlet (2008)	1·0–4·0	
Brazil/Rio de Janeiro	27·0–62·0	Gutberlet (2008)		Crivellari *et al.* (2008)
Brazil/São Paulo	13·8	na		
Thailand/Bangkok	1·2–12·0	Muttamara *et al.* (1994)	–	
Cambodia/Phnom Penh	2·5	Chintan (2005)	1·1	Chintan (2005)
India/Bangalore	0·3	Hunt (1996)	–	
India/Kolkata	0·8	Hasana and Khan (1999)	–	
India/Kanpur City	1·3	Zia and Devadas (2008)	–	
India/Delhi	4·6	Khullar (2009)	1·04	Medina (2007)
India	1·3–3·6	Samson (2009b)	–	
Philippines/Manila	8·5 (3·6–7·1)	Medina (2007); Chintan (2005)	1·07 0·7–1·3	Medina (2007) Chintan (2005)
China/Beijing	2·3	Zhou and Chi (2010)	–	
Tanzania/Dar es Salam	0·9	Kaseva and Gupta (1996)	–	
Egypt	2·2	Medina (2007)	2·47	Medina (2007)
Zimbabwe/Victoria Falls Town	1·5	Masocha (2006)	–	
Nigeria/Lagos	7·8	Afon (2007)	–	
Nigeria/Enugu	4·7	Nzeadibe (2009)	–	

Table 6. Waste picker income

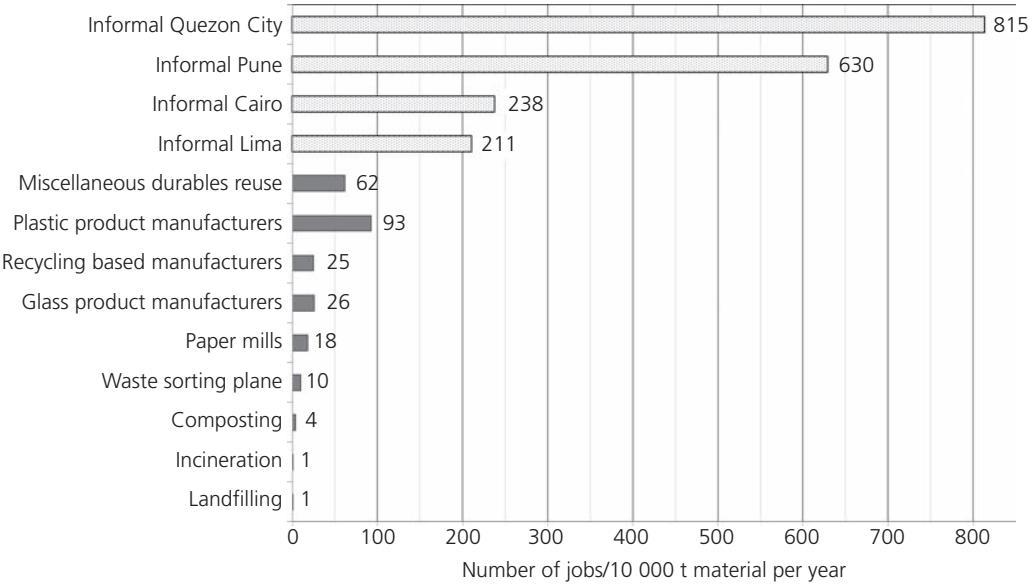

Figure 1. Jobs per 10 000 t of material per year (based on ILSR (1997) and UN-Habitat (2010))

Table 6 shows that the daily incomes range from approximately 2 to 15 US$ in Latin America, with higher incomes reported for Rio de Janeiro. Indian incomes are reported at 0·3–4·6 US$/d, although some information dates back to the 1990s. African daily incomes range from approximately 1 to 8 US$/d. UN-Habitat (2010) reports an average income of 4·3 €/d (approximately 6 US$/d) for six cities.

Daily incomes are relative and are therefore pegged to local minimum wages or poverty lines. For example, the ratio of picker income to minimum wage is reported by Medina (2007) for Delhi and Manila at 1·04 and 1·07; for Cairo at 2·47; for Mexico City at 3·0–5·0; and for Argentina at 0·8. Scheinberg *et al.* (2010) present ratios for the cities Pune, Lima, Cluj and Lusaka ranging from 1·1 to 2·4. Crivellari *et al.* (2008) give information on Brazil reporting a ratio of 1 to 4. Chintan (2005) proposes the ratio of 1·1 for Phnom Penh and 0·7 to 1·3 for Manila. It can clearly be assumed that waste reclaiming activities are an important revenue factor in low-income countries. The available data on waste reclaimer incomes related to minimum wages shows that the informal workers may even reach incomes that are a multiple of the minimum wage, for example in Mexico, Brazil or Cairo. In other cases the incomes are around the minimum wages or lower.

Labour-intensive informal activities are also important from the perspective of job creation. The Institute for Local Self-Reliance (ILSR, 1997) in Washington D.C. conducted a survey on the job creation potential in waste management based on interviews with selected facilities around the USA. The authors calculated the jobs involved in disposal, recycling and reuse activities per 10 000 t yearly. The results are shown in Figure 1.

The lower part of Figure 1 shows that disposal activities like landfilling and incineration provide 1 job per 10 000 t, whereas in sorting for recycling ten times more jobs are generated and recycling based manufacturers provide approximately 20–90 jobs per 10 000 t. The upper columns display informal jobs in waste management in selected cities based on the number of informal sector workers (see Table 2) and tonnes recovered by informal recycling as presented in UN-Habitat (2010). Figure 1 shows the magnitude of difference between labour-intensive informal systems in low-income countries compared with mechanised systems in the USA. It is not clear whether the data from ILSR involved collection activities, nevertheless a rough estimation is that informal waste management systems generate 10–40 times more jobs than systems in an industrialised country.

3.4 Working conditions

Informal occupational activities in waste management are closely related to difficult working conditions. Working times and the working environment are linked to health problems, exacerbated by the handling of waste and insufficient working protection. Health issues are discussed in Chikarmane and Narayan (2009); Gutberlet and Baeder (2008) and Binion and Gutberlet (2012). Table 7 compiles information on daily working times.

The working times displayed range from 5 to 12 h/d and work is usually carried out on 5 d/week, in some cases more. In the

Country	Working time per day: h/d	Source
Colombia	12	Birkbeck (1978)
Thailand	6–10	Chikarmane and Narayan (2009)
India	9–12 (6 d/week)	Chikarmane and Narayan (2009)
Mexico (1998)	8–10 h/d	Medina (1998)
Brazil (2008)	8	Gutberlet (2008)
Philippines (2009)	8 (7 d/week)	Samson (2009b)

Table 7. Working time per day

literature it is also reported that the working hours are not consecutive, but are split into certain periods during the day, for example early morning, noon, late afternoon and evening (Chikarmane and Narayan, 2009). According to Chintan (2005), 90% of the informal workers observed within a year-long survey work 8–10 h/d.

4. Conclusion

4.1 The need for data

Different stakeholder groups with varying interests have diverse motivations with respect to obtaining data on informal sector activities in waste management. These motivations might be driven by rational considerations, for example a local authority might be interested to know the amounts informally collected in order to obtain a complete picture on waste generation. On the other hand, motivations could have emotional components rooted in competition, fear or compassion. In addition, the enabling conditions vary in different geographical regions meaning that the motivation to obtain data on informal sector performance can be different between low- and high-income countries.

Data on informal sector waste management performance are important in

- policy making and enforcement, for example development and implementation of national/regional environmental plans or monitoring the achievement of recycling goals
- monitoring and planning of waste management systems: cost efficiency, material balances/recycling rates, environmental performance, collection efficiency, capacities of treatment and disposal plants, city master plans and so on
- advocacy and visibility of informal systems: for example, data needed for improving efficiency or to display unique selling points of informal systems, such as contribution to waste collection, recycling, hygiene; describing environmental benefits/cost savings; amounts and quality of collected materials are also important for negotiations with manufacturing industry; describing livelihoods (income etc.) of informal workers in local/global advocacy and so on.

4.2 Data availability

It is by definition difficult to estimate the contribution of informal activities because waste reclaimers have no inherent reason, obligation or possibly ability to keep records. In the past, an increasing number of projects and research studies were undertaken aimed at describing the activities of the informal sector and to provide insights and data on the size and potential contribution to waste management systems. The present paper aspires to bring together a large amount of research in this area and to compile research outcomes, mainly from the last decade, with the aim to provide key parameters for initial appraisals in waste management planning or monitoring purposes. The important contribution of the informal sector should not be underestimated, because a major share of waste recycling activities are carried out informally, providing secondary raw materials to local markets. In many cases the informal workers are not recognised as having a key role in waste management systems and are running the risk of losing their livelihoods in modernisation processes (Scheinberg *et al.*, 2006).

4.3 Key data

The main results of this paper can be summarised as follows.

- The proportion of informal waste workers can be estimated at approximately 0·6% (0·5–2%) of the total population.
- Depending on the means of transport, daily collection rates amount to approximately 40–2000 kg.
- Informal systems may recycle up to 45% of the generated waste (in some specific cases even more).
- Per kg prices of materials collected may increase by a factor of 3 up the recycling hierarchy.
- Daily incomes of informal waste reclaimers can be assumed to be between US$1 and US$15 (in some cases higher) and the ratio of income to minimum wage may be in a range from 0·7 up to 5·0.
- A rough estimate is that informal waste management systems generate 10–40 times more jobs than systems in an industrialised country.

4.4 Future challenges

Changing waste management systems in low-income and transition countries needs planning that takes into account both the economic and the environmental impacts of informal activities. In addition, it is important to focus on the interfaces between formal and informal systems, because the two cannot be seen as operating in parallel but rather interacting. Inclusive planning activities should consider extended datasets on informal activities such as the reliability of the systems, viability and quantities captured over time, quality of the materials collected, achievable prices, necessary provision of sorting space, and so on. As well as focusing on legalising and professionalising informal activities, informal workers could be integrated into formal systems. Experiments in Latin America and Asia tried to integrate the workforce of informal workers under better working conditions. For example, people received proper equipment, identification documents, health insurance, working clothes and regular contracts. Together with data on the size and contribution of the informal sector, the first attempts are being made to demonstrate the economic and environmental impacts of informal workers. A very challenging task is to supplement this information by including social assessments in order to generate additional information and decision support about whether informal workers should be integrated, or supported within a parallel but professionalised system.

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4.2 Research article 2 - Municipal solid waste recycling and the significance of informal sector in urban China

The informal sector is active in the collection, processing and trading of recyclable materials in urban China. Formal waste management organisations have established pilot schemes for source separation of recyclables, but this strategy is still in its infancy. The amounts of recyclables informally picked out of the municipal solid waste stream are unknown as informal waste workers do not record their activities.

This article estimates the size and significance of the current informal recycling system with a focus on the collection of recyclables. A majority of the reviewed literature detects that official data is displaying mainly 'municipal solid waste collected and transported', whereas less information is available on 'real' waste generation rates at the source. Based on a literature review the variables, the 'number of informal waste workers involved in collection activities', the 'amounts collected daily per informal collector' and the 'number of working days' are used to estimate yearly recyclable amounts that are informally diverted from municipal solid waste.

The results show an interval of approximately 0.56% to 0.93% of the urban population or 3.3 to 5.6 million people involved in informal waste collection and recycling activities in urban China. This is the equivalent to estimated informal recycling rates of approximately 17 to 38 w/w% of the municipal solid waste generated. Despite some uncertainties in these assessments, it can be concluded that a significant share of recyclables is collected and processed by informal waste workers.

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Municipal solid waste recycling and the significance of informal sector in urban China

Roland Linzner and Stefan Salhofer

Abstract

The informal sector is active in the collection, processing and trading of recyclable materials in urban China. Formal waste management organisations have established pilot schemes for source separation of recyclables, but this strategy is still in its infancy. The amounts of recyclables informally picked out of the municipal solid waste stream are unknown as informal waste workers do not record their activities. This article estimates the size and significance of the current informal recycling system with a focus on the collection of recyclables. A majority of the reviewed literature detects that official data is displaying mainly 'municipal solid waste collected and transported', whereas less information is available on 'real' waste generation rates at the source. Based on a literature review the variables, the 'number of informal waste workers involved in collection activities', the 'amounts collected daily per informal collector' and the 'number of working days' are used to estimate yearly recyclable amounts that are informally diverted from municipal solid waste. The results show an interval of approximately 0.56%–0.93% of the urban population or 3.3–5.6 million people involved in informal waste collection and recycling activities in urban China. This is the equivalent to estimated informal recycling rates of approximately 17–38w/w% of the municipal solid waste generated. Despite some uncertainties in these assessments, it can be concluded that a significant share of recyclables is collected and processed by informal waste workers.

Keywords

Informal sector, recycling, waste collection, China, municipal solid waste, waste generation, significance, urban

Introduction

Over the past decades China has been facing an increase in population and immense economic development. This development is also linked to an enormous growth in solid waste generation. No other country has ever experienced as vast or as fast an expansion in total solid waste quantities that China is now facing (Zhang et al., 2010). Urbanisation, population growth and industrialisation accompanied by increasing gross domestic product (GDP) and higher standard of living are the key reasons behind the magnitude of China's growth in total waste generation.

In the last decade, the number of publications on Chinese formal waste management data has significantly increased within scientific circles. The reason for this might be that waste has become increasingly important politically. New regulations and policies have been implemented in the last few years, e.g. the Law on Circular Economy Promotion (effective from 1 January 2009). This law includes a legal framework on waste reduction, reuse and recycling (People's Congress, 2008). Additionally, the last two Five Year Plans (11th and 12th) put specific emphasis on ecological issues, including waste recycling.

Within the last few years a considerable number of scientific articles, studies and reports have been published on informal sector activities in waste management. These activities cover a diverse range and appear at almost every level of waste management systems in low income and emerging countries. Scheinberg et al. (2010) define the informal solid waste sector activities as 'referring to individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognised, supported, organised or acknowledged by the formal solid waste authorities, or which operate in violation of or in competition with formal authorities'. Formal (official) waste management activities on the other hand are performed by public authorities or private companies. In many cases, informal systems constitute the only part of waste management systems that provides appreciable recycling rates, as formal systems are often only involved in secondary collection and disposal. Although some pilot schemes for the source separation of recyclables have been established in China, they are still in their infancy (Chen, 2008).

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It is, by definition, difficult to estimate the contribution of informal activities to waste recycling, because informal waste reclaimers have no inherent reason or obligation to keep records, or simply may not be capable. In addition, official performance data does not cover informal systems; statistics do not reflect the larger picture in low income countries from waste generation to recycling and final disposal. For waste management planning or monitoring purposes it is, therefore, of paramount importance to obtain data on informal systems.

In Chinese cities, the informal sector, engaging mainly migrant workers, is active in the collection and processing (mainly sorting and cleaning) of recyclables. Literature provides data derived from case studies on the estimated numbers of informal workers, the amounts collected and the market value of recyclables (Li, 2002; Li et al., 2009; Medina, 2011; Wang et al., 2008; World Bank, 2005; Zhang et al., 2010; Zhou and Xiong, 2010). Official data on municipal solid waste (MSW) generation barely exists; data used in literature is cited from Chinese Statistical Offices, but it appears inconsistent and includes information obtained at transfer stations and treatment facilities such as landfills or MSW incineration plants.

The future design of Chinese urban waste management systems requires reliable planning data on quantities and composition of both formally and informally collected waste streams. This is of paramount importance because decisions on technologies to be implemented need a solid statistical basis in order to prevent technical problems, e.g. in sorting plants and waste incinerators (Dorn et al., 2012). In addition, to date it is only the 'army' of informal waste collectors who are currently capable of providing substantial amounts of recyclables for the growing demand of the local industry. Modernisation aspects of waste management systems thus have to include strategies on how to deal with the informal waste systems.

The goals of this article are to compile and evaluate existing research in this area, mainly from the last decade, with the aim of gauging the amounts of urban informal collection activities. Accordingly, any results presented stem from published scientific journal articles, reports and case studies, rather than original research based on primary data. The informal sector is active in almost all parts of the Chinese waste management chain, but this article mainly looks at data related to the collection of potentially valuable recyclables. Although contributing to recycling, sorting of recyclables at landfills is not considered in this article. Special waste streams such as industrial waste or waste electrical and electronic equipment (WEEE) are beyond its scope.

Materials and methods

The authors have been involved in research projects dealing with informal waste management systems and in other projects with the geographical focus on the People's Republic of China. The starting point for this appraisal of informal sector recycling rates in urban China are three projects; one already completed project deals with the circular economy and includes informal activities and their contribution to the recovery of secondary raw materials (Salhofer and Linzner, 2011), the second ongoing project includes informal systems in WEEE collection (http://www.rewin-china.net/en) and the final and completed project focuses on informal collection and processing of recyclables in Beijing/district Haidian (Salhofer et al., 2013).

A review of the available literature indicates that primarily two approaches concerning waste generation data were chosen. Whereas the majority of articles used figures from the Chinese Statistical Yearbooks, a few presented data from on-site observation at household level. These two approaches differ significantly regarding the magnitude of waste generation. The waste generation data taken from Chinese Statistical Yearbooks is lower compared with all data sources referring to waste generation (see Table 2 detailed later in this article). This leads to the question as to why this discrepancy exists.

The first part of this article reviews existing data on MSW generation in urban China and Beijing, including problems in data quality. Data from Statistical Yearbooks seem to reflect MSW quantities 'collected and transported', but do not represent 'real' waste generation at the source. These waste quantities, outlined for urban China and Beijing, are considered as MSW, but do not include the amount of recyclables that informal collectors pick out.

The second part provides an estimate of informal recycling rates based on the following underlying data and calculations: at first the size of informal collectors for urban China and Beijing is estimated based on literature data and augmented by studies available on migrant workers in China. In a second step, the estimated number of informal collectors is related to quantities collected per time unit; leading to ranges of recyclables that might be informally collected per year. The MSW 'collected and transported' plus the potential of informally collected recyclables result both in a calculated amount of MSW as well as an estimated recycling rate. Finally, the results are compared with national data on recycling from selected EU countries. These estimates only consider MSW (no other sources, e.g. from industry) and informal collectors in the streets and at household level (no landfill picking activities).

Results and discussion

In the following, data on formal and informal waste management activities related to MSW in China is presented. In addition, the concept of triangulation is used to estimate the magnitude of informal recycling activities for urban China and Beijing. Triangulation, a concept used in social sciences, intends to facilitate the validation of data through cross verification from two or more sources (Bogdan and Biklen, 2006). In this case this is done by calculating the amounts collected informally from different starting points. On the one hand, the difference between 'MSW collected and transported' and 'MSW generated' indicate the amount of recyclables diverted informally. This might also

include fly-tipping, incineration at household level or illegal dumping. On the other hand, informal sector recycling rates are calculated via the number of informal collectors and daily collection rates. The number of informal waste workers given in literature is cross-checked with data on migrant worker studies. The estimates are compared with results from literature in order to approximate informal recycling rates for urban China.

Data on formal waste management in China

Problems in data quality. The basic source of information used widely in literature and waste management practice is that provided by statistical offices. Zhang et al. (2009) state that certain information is available from government statistics, but call for improvement regarding data collection on waste management in order to be truly useful in waste management planning.

There is a lack in describing the methodology how data in official statistics are generated. First, local practitioners indicate that there are different locations where samples are taken frequently in order to 'guesstimate' waste amounts (Luo, 2013, personal communication; Zhang, 2013, personal communication). There is growing evidence that waste data is derived from transfer stations and therefore does not reflect informal sector access and the associated removal of recyclables. Both Chanchampee and Rotter (2007) and the World Bank (2005) state that the official information on MSW management in China is based on 'waste collected' rather than 'waste generated'. Zhang et al. (2010) state that waste generation data does not include any waste separated at source for recycling by private entrepreneurs. The reason is that the data is collected after source separation of recyclables, and therefore the amount of recycled waste is not included in the generation and compositional data.

Second, it is difficult to find out which authorities/institutions are responsible for this data collection, analysis and processing. In China, a fragmentation of responsibilities can be detected; several authorities are responsible for certain waste types and parts of the waste management system (OECD, 2007). This might also be the reason for difficulties in generating data with sufficient quality.

Another important issue in this context is related to definitions. In the literature assessed there are several terms in use. Some statistical data refer to 'urban waste', 'solid waste', 'household waste' or 'municipal waste'. In most of the cases, neither a clear definition of the types of waste researched nor of the methods of obtaining them was given. This makes a comparison of different sources of information or regions difficult. The World Bank (2005) also reports on inconsistencies in the definitions of waste types and on lacking references for data collection. In this article, MSW is defined by the sources of generation; typically ranging from waste arising from private households though similar wastes from sources such as commerce, offices and public institutions are included (Christensen, 2010; EU, 1999; Eurostat, 2014). Waste from larger industry is excluded, as it commissions waste haulers for collection individually.

In addition, the per capita waste generation rates might be influenced by the fact that Chinese cities include vast surrounding peri-urban and rural areas that are accounted for urban population but are not serviced by an official waste collection provider. On the other hand, truly urban areas are inhabited by a large number of non-registered migrant workers that contribute to waste generation but are not covered in population statistics. These two aspects were not considered when analysing per capita waste generation rates.

Waste generation in urban China. It is generally difficult to obtain reliable waste management data for China. This is also confirmed by Chinese authors Chen et al. (2010) and Xiao et al. (2007). The reason is that most underlying data is not published or not made accessible to the public. In addition, it was stated that many details on how data was generated were not explained in the published literature, such as sampling site setting, sample quantity, sampling time, etc.

The Chinese Statistical Yearbook presents data regarding the 'Volume of Garbage Disposal' from the years 2000 to 2008 (see Table 1). Huang et al. (2006) and Zhang et al. (2010) use the same data but term it 'Quantity of MSW collected and transported'. Many authors refer to this data in their published articles and reports, but a critical revision of the data origin is missing. It is not clear which waste types are included and how and where the data was obtained; the term 'garbage' is not meaningful in this context. The term 'disposal' may lead to the assumption that the mentioned amounts were landfilled, but this also remains unclear.

Zhang et al. (2010) reported the same data from the Statistical Yearbook, but added the years 1981 and 1990. From 1981 to 2000 a significant increase can be seen. The data on urban population that is provided by the Statistical Yearbooks seems inconsistent as within one year (2002–2003) the urban population increased by approximately 172 million people. Generally speaking, the Chinese system of urban demographic statistics is rather complicated. Inconsistencies are related to definitions and classifications of urban population and changes in the definition of urban areas (Chan and Xu, 1985). Consequently the per capita MSW rate shows huge differences as Dorn et al. (2010) compute 272 kg/cap/y, whereas the Statistical Yearbook data can be calculated at 388 kg/cap/y. According to Table 1, the data from 2002 to 2008 indicates an average MSW collection and disposal rate of approximately 269 kg/cap/y. (0.74 kg/cap/d) for China.

Another influence, both on composition and amounts of MSW, is the increase in the cooking gas supply rate and the collective heating areas in China. Chen et al. (2010) report an increase in the cooking gas supply rate in China from 19.1% (1990) to 82.1% (2005), substituting coal as a cooking and heating material and thus decreasing the share of inert materials (ash) in the MSW stream. Despite the changes in waste composition in urban China, in the last decades a continuous growth in the waste quantities can be detected.

The World Bank (2005) estimates a MSW generation rate at 1.0 kg/cap/d. This amount refers to urban waste generation that

Table 1. Urban population and MSW collected and transported in urban China.

Year	Urban population in China [millions]	Volume of garbage disposal/MSW collected and transported [million t]	MSW collected and transported [kg/cap/y]	Source
1981	144.00	26.06	181	Huang et al. (2006) Tai et al. (2011) Zhang et al. (2010)
1985	208.93	44.77	214	Huang et al. (2006) Tai et al. (2011)
1990	325.30	67.67	208	Huang et al. (2006) Tai et al. (2011) Zhang et al. (2010)
1995	377.90	106.71	282	Huang et al. (2006)
1996	na	107.68	na	OECD (2007)
1997	na	109.50	na	Tai et al. (2011)
1998	na	113.00	na	OECD (2007) Tai et al. (2011) Wang and Nie (2001) Zhang et al. (2010)
2000	388.24	118.19	304	China Statistics Press (2008)
2001	357.47	134.7	377	Dorn et al. (2010)
2002	352.20	136.5	388 (272)	Huang et al. (2006)
2003	523.76	148.57	284	OECD (2007)
2004	542.83	155.09	286	Tai et al. (2011)
2005	561.57	155.77	277	Zhang et al. (2010)
2006	577.06	148.41	257	
2007	593.79	152.15	256	
2008	606.67	154.38	254	

MSW: municipal solid waste; na: not available.
Multiple references for each entry mean that all sources report the same values.

Table 2. Waste data for urban China.

Waste data for urban China [kg/cap/d]	Source/remark
0.74	China Statistics Press (2008) (Average value 2002–2008) 'MSW collected and transported'; 'Volume of garbage disposal'
1.0	World Bank (2005); 'MSW generation'
1.18	Zhang et al. (2010); 'MSW generation rate'; Average value of six Chinese cities
1.15	Rissanen and Naarajärvi (2004); 'urban MSW generation'

MSW: municipal solid waste.

includes only 41% of the total population. The MSW generation in Chinese rural areas was estimated on the assumption of 0.4 kg/cap/d (World Bank, 2005). According to Zhang et al. (2010) Chinese waste generation per capita is about 0.8 to 1.0 kg/cap/d; the range of MSW generation in other cities in China (Beijing, Shanghai, Chongqing, Lhasa and Hangzhou) is reported between 0.85 to 1.51 kg/cap/d.

Chen et al. (2010) report a database from the Chinese Statistical Yearbook on 'MSW collected'. The data from 2004, 2005 and 2006 are the same as shown in Table 1, but it is stated that 'the data shown in the paper do not include recyclable wastes that were diverted by informal agents (e.g. scavengers)'. Rissanen and Naarajärvi (2004) report an urban MSW generation of between 0.79 kg/cap/d (1997) and 1.15 kg/cap/d (2003); Terazono et al. (2005) display a Chinese MSW generation at 1.70 kg/cap/d and that it is estimated that 60%–70% of MSW in mainland China is household waste, in that case calculated at 1.02 kg/cap/d.

The OECD (2007) presents figures on MSW generation in China from 1995 to 2004 (see Table 1). The source of information is the National Bureau of Statistics of China and the reported 'Volume of Disposal Garbage' for urban units is reported with 120 kg/cap/y (0.33 kg/cap/d). This quantity seems to be very low; it was probably calculated from the total population of China and not just from the urban population.

Table 2 sets out a compilation of waste generation rates for urban China; the Chinese Statistical Yearbook shows the lowest amount at approximately 0.7–0.8 kg/cap/d.

Waste generation in Beijing. The data situation on MSW in Beijing is also ambiguous. Several journal articles report time

Table 3. MSW for Beijing.

Year	'MSW generated' [kg/cap/y]	'MSW generated' [kg/cap/d]	Source
2006		0.85	Li et al. (2009) Zhu et al. (2012)
		0.96	Wang and Wang (2013) Zhao et al. (2011)
2007	380	1.04	Li et al. (2009) Wang and Wang (2013)
2008	396	1.09	Wang and Wang (2013) Li et al. (2009)
2009	381	1.04	Li et al. (2009) Wang (2010) Wang and Wang (2013)
2010	324	0.89	Wang and Wang (2013) Li et al. (2009)

MSW: municipal solid waste.
Multiple references for each entry mean that all sources report the same values.

series on MSW data. Li et al. (2009) present a time series on 'MSW generated' and 'urban population' data from 1992 to 2006. Wang and Wang (2013) display a time series on 'MSW generated' and 'resident population' from the years 2000 to 2010. Both time series show considerable differences in the waste data from 2003 to 2006, reaching a maximum in 2006 with a difference of 1.72 million tonnes. The population data also varies considerably, peaking by a difference of approximately 3.1 million inhabitants in 2003.

In the years 2006 to 2010 both authors use the same population and MSW data leading to per capita waste generation calculations as indicated in Table 3. A slight decrease from approximately 1.0 to 0.89 kg/cap/d in the period 2007–2010 can be distinguished.

Zhu et al. (2012) report that Beijing reached an urban population of about 19.61 million in 2010 and that MSW generation increased from 1.04 million tonnes (0.33 kg/cap/d) in 1978 to 4.134 million tonnes in 2006 (0.85 kg/cap/d).

As outlined in Table 1, the average urban Chinese MSW 'collected and transported' amounts to approximately 0.7 kg/cap/d (2008). This includes data from 654 cities that might be different in terms of GDP per capita, consumption habits and other factors affecting waste generation rates. As 'real waste generation' is assumed to be higher than MSW 'collected and transported', the urban Chinese MSW generation could be around 1.0 kg/cap/d. Data from Beijing show approximately 0.89 kg/cap/d 'MSW generated', but in the literature available, data on waste and population in use originate mainly from statistical offices. As with national data, it is not clear if these statistics are related to 'real waste generation' or only include waste that is measured at transfer stations, landfills or at incineration/mechanical biological treatment (MBT) plants. Real waste generation for Beijing, therefore, could be also somewhat higher, especially when taking into consideration that Beijing's GDP per capita is two times higher than the average Chinese level (Zhang and Wen, 2013). For the following calculations, the authors assume the quantities displayed in Table 3 as 'collected and transported' rather than 'generated'.

Waste composition in urban China. Numerous data on waste composition are available in literature. For Chinese cities, composition data are presented by Huang et al. (2006), Chen et al. (2010), Zhang et al. (2010) and Liu and Wu (2011). Salhofer and Linzner (2011) compile waste composition data from different sources and years for Beijing. Generally speaking the waste composition in Chinese cities is dominated by a high biodegradable material and moisture content. Biodegradables represent approximatelyh 60 w/w% of the MSW stream. Paper accounts for 8%–10%, plastics 10%–13%, glass 3% and metals approximately 1%–2% (all percentages by weight). Still ash and other materials are represented by approximately 10%–17% still reflecting coal or wood firing for heating and cooking, although the amount of this fraction has been significantly decreasing since the mid-1990s.

Assessing literature data on waste composition is difficult as in most cases no information is available at which stage the data were collected; at the point of generation, at disposal sites or somewhere in between. This is of importance as informal collection activities may influence the waste composition. Several journal articles obtained information on buying and selling prices of recyclables. Wang et al. (2008), Li et al. (2009), Zhang et al. (2010) and Zhou and Xiong (2010) present data on the price ranges for recyclables and materials in Beijing in the years 2007 and 2008 (see Figure 1). On the one hand, the recyclable prices from literature are designated collected by informal waste pickers. On the other hand, the prices were obtained at 'recycling service sites' or at informal trading hubs, where only informally collected recyclables are processed and traded. The highest material prices can be achieved in the category metals; waste paper, cardboard and books are about 0.1 €kg^{-1}, plastic bottles range

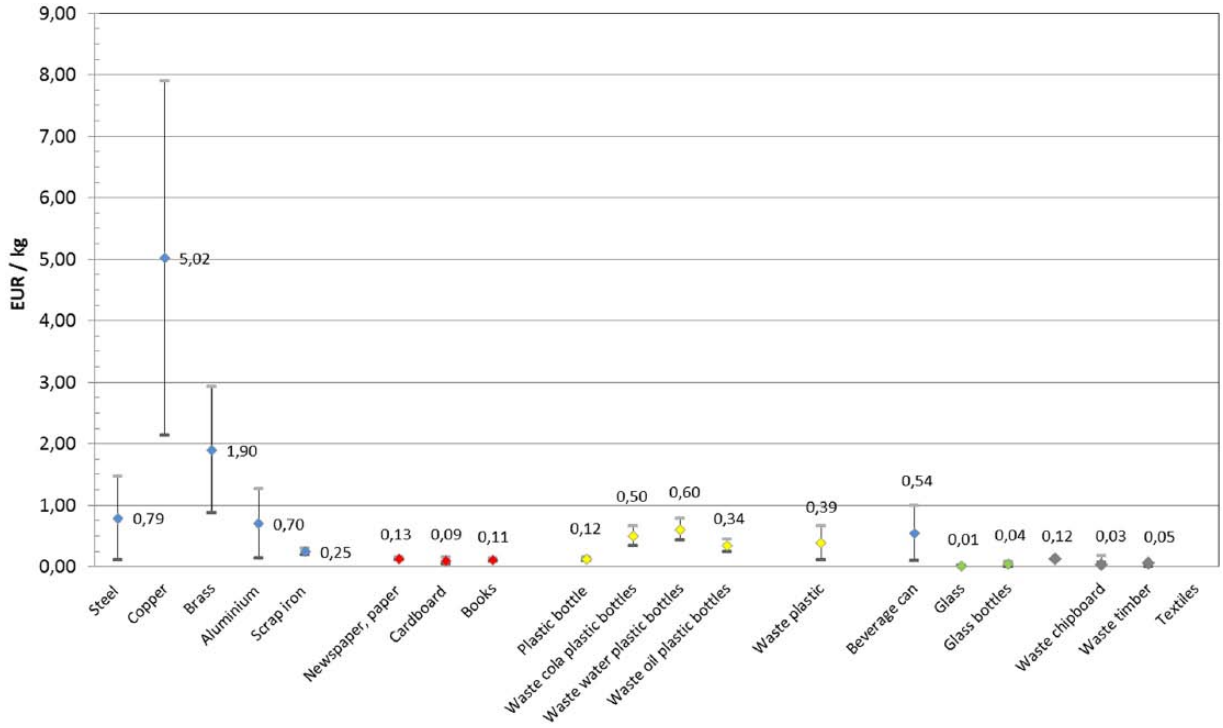

Figure 1. Material recyclable prices in Beijing (2007/2008).

from 0.1 to 0.6 € kg^{-1} and beverage cans approximately 0.55 € kg^{-1}. Glass and glass bottle prices are comparably low, ranging from 0.01 to 0.04 € kg^{-1}.

Information regarding prices of certain recyclables in literature and a visit to an informal trading hub in Beijing-Dongxiaokou gives ample reason to presume that the materials displayed in Figure 1 are removed from the waste stream informally.

Estimates of informal waste sector contributions to recycling

According to both literature and field visits on location in Chinese cities, a very active informal sector exists that is responsible for diverting recyclable materials away from waste being disposed of. Until the 1970s, recycling campaigns were routine and official redemption depots were available for citizens. Li (2002) states that owing to 'the initiation of social and economic reforms, Chinese governments at all levels have gradually been ignoring the recycling of MSW since the early 1980s'. Urbanisation has led to the redemption depots being relocated to city fringe areas, causing inconvenience and a lack of motivation for local residents to deliver recyclables, but leading to the emergence of informal waste collectors, pickers and itinerant waste buyers trying to fill this gap. In the following, an estimate of the contribution of informal systems to the collection of recyclables for urban China and Beijing is conducted.

Underlying data and estimates. In order to estimate the amount of recyclables that might be collected by the informal sector, some assumptions and estimates on underlying data have to be made based on the available data in literature.

The first underlying data relates to the number of informal waste workers involved in collection activities. Table 4 displays a compilation of data on reported sums of informal waste workers in urban China and five Chinese cities. The data calculated contains several uncertainties such as the following.

- Varying census years lead to differences regarding population sizes.
- Population sizes can be different owing to varying underlying geographical regions considered; sometimes the population refers to a city core, in other cases to metropolitan areas.
- The reported number of informal workers are, in most of the cases, estimates and difficult to verify as the underlying methodologies are not described in the literature. Therefore, these figures are indicative, rather than exact.
- In addition, it is often unclear whether the reported figures for informal waste workers are based on the total number of workers or just parts of the informal recycling value chain.

According to a compilation of Linzner and Lange (2013) based on 39 datasets, the average value of informal waste workers accounts for approximately 0.6% of the urban population. Other literature sources report figures of between 0.5% (UN-Habitat, 2010) and 2% (Medina, 2000). For the following estimates, it is assumed that the majority of informal waste workers are involved in collection activities according to the informal recycling hierarchy (Wilson et al., 2006). In Beijing, informal waste collectors (waste pickers and on-demand waste buyers) are selling collected recyclables to

Table 4. Population range, number of reported informal waste workers and percentage share in terms of population.

City	Population range	No. of reported informal waste workers (range)	Calculated percentage of informal actors of population [%]	Source
China (urban)	635,839,000 (2010)	2,500,000–6,000,000	0.39–0.94	Liu (2008); World Bank (2005)
Beijing	11,716,000–19,600,000 (2010/2011)	130,000–300,000	0.66–2.56	Li et al. (2009); Zhou and Xiong (2010)
Guangzhou	6,181,000–11,070,654 (2001/2010)	100,000	0.90–1.62	Medina (2011)
Shenzhen	8,000,000–10,357,938 (2010)	200,000	1.93–2.50	Liu (2008)
Suzhou	2,000,000–4,074,000 (2010)	40,000–50,000	0.98–2.50	Mo et al. (2009)
Wuhan	6,144,000–9,100,000 (2010)	20,000	0.22–0.33	Li (2002)

Table 5. Migrant workers and calculated share of informal waste collectors.

Region	Number of migrant workers	Source	Informal waste collectors (calc. with 3.1% migrant workers)
Urban China	111,000,000	Chan (2008)	3,400,000
	180,000,000	Han (2009)	5,500,000
	182,400,000	Liu et al. (2008)	5,600,000
Beijing	4,900,000–5,880,000	Assuming 25% to 30% is informal workforce, based on ILO (2012)	151,900 to 182,280

middle-men at 'street trading points'. The middle-men are transporting recyclables to informal recycling hubs in the outskirts, where they sort and process the recyclables and subsequently resell it to industry. Waste picking activities at landfills are not considered here as they do not constitute the main source of informally collected recyclables.

Table 4 indicates that the number of reported informal waste workers in urban China ranges from approximately 2.5 to 6 million in total or 0.39% to 0.94 % of the population. Newer data published reports 5 million informal waste workers for China and 170,000 for Beijing (Zhang and Wen, 2013). Based on this information, an estimate of informally collected amounts can be made, assuming that the workers reported are all involved in the collection of recyclables.

In order to verify the number of informal waste workers reported, a variety of studies on migrant workers can be consulted. Huang (2009) provides information that the size of the informal sector in China accounts for 168 million people. Meng (2001) reports on a survey conducted on a sample of 1500 migrant workers in Jinan City (Shandong province), revealing that 3.1% of the migrant workers are involved in 'collecting recycling goods'.

Table 5 displays the number of migrant workers for urban China and Beijing based on different studies and the given rate of 3.1% for waste collectors. For Beijing, the number of migrant workers was calculated by using the assumption from ILO (2012), stating that 25%–30% of Beijing's population is informally employed.

Assuming that informal waste collecting activities are carried out solely by migrant workers it can be estimated that for urban China 3.4–5.6 million migrant workers are active in waste collection. This number is in the range of other data used in literature (2.5–6 million). Similarly, in Beijing it is calculated there are 151,900–182,280 informal collectors, also within the range of 130,000–300,000 as displayed in Table 4.

To estimate informal recycling it is necessary to include the amounts of recyclables that can be collected by time unit. This is dependent on several factors, such as the location of activity and accessibility of materials; the means of transport; the physical condition, age and sex of collectors; the type of recyclables collected (bulk densities); and the geographical conditions. The amounts collected daily per informal collector are estimated at between 50 and 110 kg per day based on data presented by Linzner and Lange (2013) and UN-Habitat (2010), reflecting data from 10 and nine cities, respectively. A case study from Wuhan indicates a daily collection rate of 50 kg per collector (Li, 2002). The following calculations are based on the assumption that informal collectors work five or six days per week. Table 6 compiles the ranges of the three variables that are used for the estimations in the following sections.

Estimates of informal collection in urban China. The above assumptions make it possible to calculate yearly amounts collected by 2.5 and 6 million informal collectors (see Table 4) in urban China (see Figure 2). Based on the information from

Table 6. Summary of underlying assumptions for the estimations.

Variables	Urban China		Beijing	
	Minimum	Maximum	Minimum	Maximum
No. of reported informal waste workers	2,500,000	6,000,000	130,000	300,000
Daily collection rate [kg per informal collector]	50	110	50	110
Weekly working time [days per week]	5	6	5	6

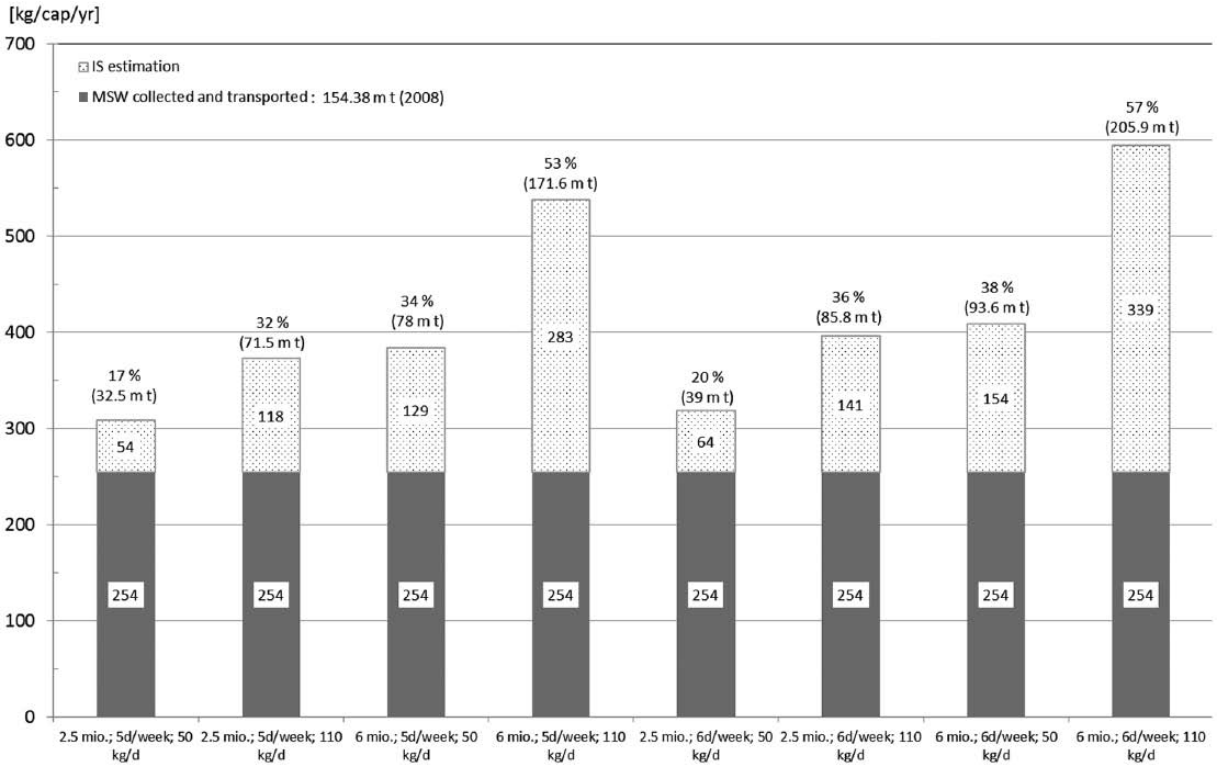

Figure 2. MSW collected and transported, and informal sector estimates for urban China (2008).
MSW: municipal solid waste.

Table 1 it is assumed that the 'MSW collected and transported' accounts for 154.38 million tonnes (254 kg/cap/y) in 2008, based on information from the Chinese Statistical Yearbook. The results of the estimates show that, depending on the underlying assumptions, 2.5 million informal collectors (working five days a week; collecting 50 kg per day) may collect from 32.5 million tonnes (54 kg/cap/y or 17% of the total MSW) up to 205.9 million tonnes (339 kg/cap/y or 57% of total MSW) based on 6 million informal collectors (working six days a week; collecting 110 kg per day).

In comparing these results with literature, it appears that Zhang et al. (2010) mention that the 'MSW generated' in urban China from the Year 2006 accounts for 212 million tonnes (367 kg/cap/y or 1.0 kg/cap/d), but without further information on how this data was obtained. The difference between MSW generated and collected in 2006 (see Table 1) can be calculated at approximately 63.6 million tonnes – or 110 kg/cap/y. It might be the case that this difference between 'MSW generated' and 'MSW collected and transported' can be seen as an upper limit of approximately 30% of the generated MSW that is informally collected; nevertheless it has to be stated that the difference might also include illegal dumping, disposal and burning of wastes.

In comparison, the World Bank (2005) uses an overall MSW generation rate for China at 190 million tonnes for 2004 (0.96 kg/cap/d). The difference with MSW collected and transported in the same year is approximately 35 million tonnes less and can be seen as an upper limit for an informal collection of 18%. Yang et al. (2012) estimate the 'actual production of urban domestic waste' 25% to 30% higher than waste 'collected and transported' in 2010.

Huang et al. (2006) state 'it is estimated that 10% to 20% of MSW is removed and recycled as recoverable materials in China'. The above figures estimate the informal recyclable collection roughly at between 17 and 57 w/w% of the generated MSW for urban China, however, 57 w/w% seems to be a rather high percentage of MSW diverted informally. This is probably an overestimation; more reasonable seems an upper limit of 38 w/w%, as this fits to the difference in the quantities 'generated' and 'collected and transported' in 2006.

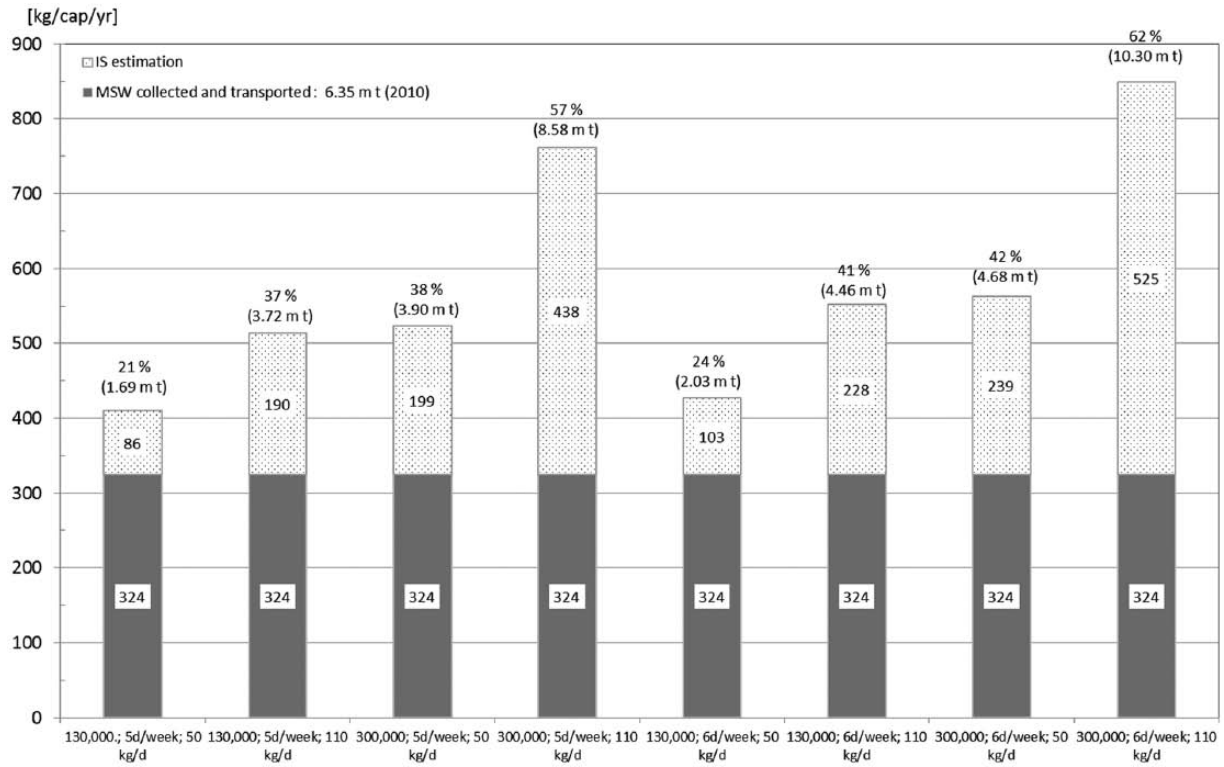

Figure 3. MSW collected and transported and informal sector estimates for Beijing (2010).
MSW: municipal solid waste.

Estimates of informal collection in Beijing. The estimate of informal recycling activities in Beijing has been made with the same underlying assumptions as indicated in the section 'Underlying data and estimates'. The number of collectors used is 130,000 to 300,000 (see Table 4). In addition, the amount of MSW collected and transported is 324 kg/cap/y (0.89 kg/cap/d) for 2010 (see Table 3). Practitioners in Beijing assume that this amount reflects waste data at transfer stations, but does not include informally collected recyclables.

The results of the calculation, as indicated in Figure 3, show that in Beijing 130,000 informal collectors (working five days a week; collecting 50 kg per day) may collect 1.69 million tonnes (86 kg/cap/y or 21% of the total MSW); and based on 300,000 informal collectors (working six days a week; collecting 110 kg per day), 10.30 million tonnes (525 kg/cap/y or 62% of total MSW).

Zhou and Xiong (2010) present data from the Beijing Statistical Yearbook. It is stated that the 'domestic waste discharged' in Beijing was 4.45 million tonnes for 1998. Using a growth rate of 8% per annum the authors extrapolate the domestic waste discharged at 8.9 million tonnes for 2007. The Statistical Yearbook provides data for 'MSW collected and transported' in 2007 at 6.01 million tonnes; this leads to a difference of 2.89 million tonnes (32% of waste discharged), that might be accounted for by informal collection activities. It is also reported that waste pickers can reduce about 1.50 to 2.0 million tonnes of MSW every year (Zhou and Chi, 2010). Wilson et al. (2009) calculate an informal sector contribution to recycling rates for Wuhan at 21% of the total waste generated. Finally, the range of informal recyclable collection in Beijing can be estimated at 21–62 w/w% of the generated MSW. Compared with the literature it seems that the maximum estimate of 62% seems to be rather high, more reasonable seems a range of informal collection rates of 21–42 w/w%, as this corresponds with estimations available in literature.

MSW generation and recycling rates in EU countries and urban China. Figure 4 displays MSW generation and recycling rates for selected EU countries based on data published in Salhofer and Linzner (2011). The yearly per capita MSW generation for the selected countries lies between 432 and 574 kg, with an average of approximately 500 kg/cap/y. The share of separately collected waste that goes into recycling is somewhat different within the EU, ranging from 43% to 54% in Luxemburg, Germany and Austria. Comparably low recycling rates can be observed in the UK (26%), France (24%) and Spain (10%).

The data for urban China refers to MSW collected and transported (254 kg/cap/y), adding further estimated informal recyclables collected in the range of 17 to 38 w/w% of the total MSW. Despite the fact that the EU-country data also includes rural areas, the Chinese MSW generation is lower compared with the EU. Nevertheless the informal recycling rates achieved in China are even higher when compared with some EU countries.

Conclusions

Waste management is gathering the growing attention of Chinese policy-makers as economic expansion and urbanisation leads to

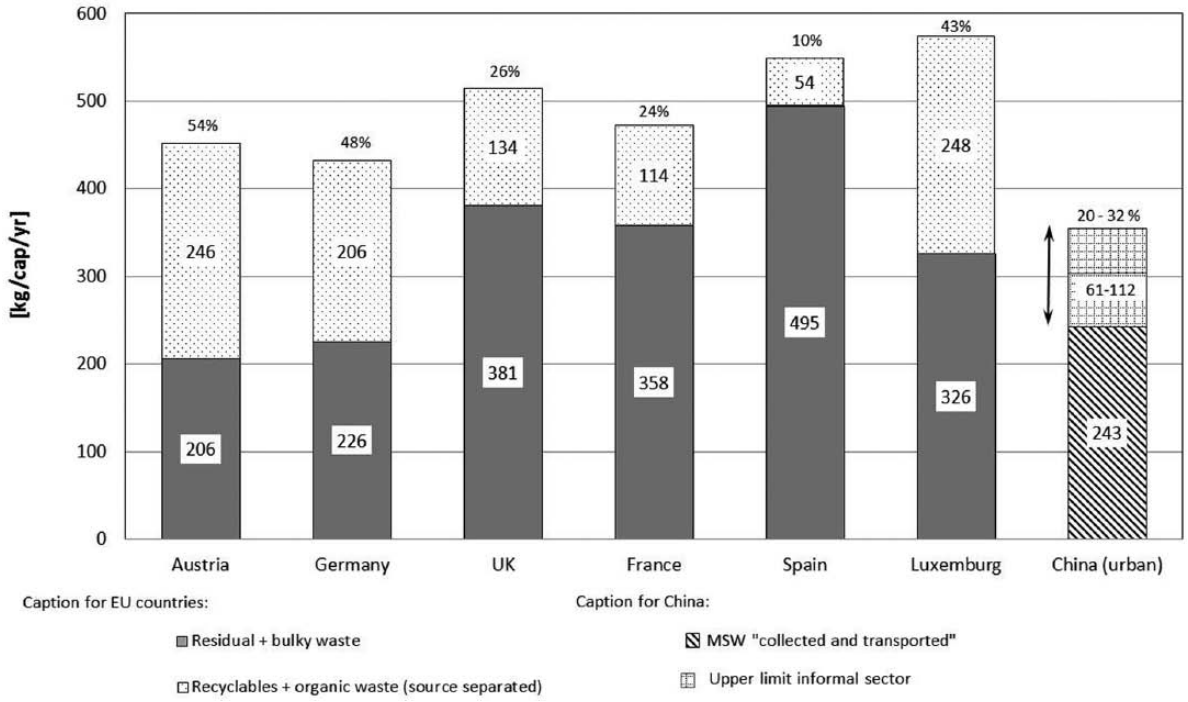

Figure 4. MSW generation in selected EU countries and urban China.
MSW: municipal solid waste.

ever increasing amounts of waste. The informal sector is extremely active in the collection, processing (mainly sorting and cleaning) and trading of recyclables in urban China, providing secondary raw materials for the burgeoning demands of industry. Source separation at household level is still in its infancy; only several pilot projects have been implemented.

Essentially, two main conclusions can be drawn.

1. Literature data on the size of informal waste workers show a range of approximaately 0.2%–2.5% of the urban population is involved in informal waste collection and recycling activities. Based on an urban population of approximately 600 million, this comparably large interval is equivalent to 1.2–15 million people. Many studies and investigations exist on the topic of migrant workers in China. It was revealed that the estimate of roughly 3% of the migrant workers in urban areas being involved in waste management activities fits with other sources on informal waste workers and can used as an additional indicator to estimate the size of the informal sector. This would narrow down the interval to approximately 0.56%–0.93% of the urban population or 3.3–5.6 million people involved in informal waste collection and recycling activities.

Estimates based on triangulation show that informal recycling rates of approximately 17–38 w/w% of MSW generated are achieved in urban China. On the one hand the informal diversion of recyclables influences waste characteristics and composition of the MSW reaching the formal waste management system, and on the other hand it will be a challenging task for the formal waste management system to increase revenues as the marketable recyclables are already informally collected. The estimates on informal-sector recycling provided are naturally rather indicative values and should be considered as upper limits, as other practices, such as indiscriminate dumping or burning of wastes, also do not appear in official MSW statistics.

The modernisation of the Chinese MSW management system, which is assumed to be more resource oriented, might also attract other stakeholders, for example the public or private sector may be interested in setting up a value chain to procure recyclables. In this case, datasets on informal activities should be extended to include more information about the reliability of the informal systems, viability and quantities amassed over time, quality of materials collected, prices and so on. This may be different from conventional solid waste management planning data.

2. A basic prerequisite for waste management planning is reliable data on waste amounts at the point of generation. The Chinese data provided in literature is usually based on data available in Statistical Yearbooks, but there is growing evidence, from both literature as well as practitioners on location, that such data is obtained after informal sector access. In addition, the interfaces between formal and informal systems in terms of recycling are not well documented – the extent of formal recycling rates remains elusive.

China will face important decisions on how to deal with MSW. The questions are whether to support informal structures and professionalise/formalise activities, but this should take into account who gets the revenues from recyclables, as well as how to treat the non-recyclable parts. Another possibility would be to completely eradicate informal recycling and set up a formal recycling

system that is cost-intensive in terms of collection, requires the additional raising of public awareness and would lead to millions of informal waste workers being without an income. The traditional system of informal collection is also supported by the waste generators as this is a possibility of generating additional incomes from selling recyclables to itinerant waste buyers. Therefore, the formal establishment of a source separation system of recyclables may be even more difficult.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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4.3 Research article 3 - Modelling informally collected quantities of bulky waste and reusable items in Austria

Disparities in earnings between Western and Eastern European countries are the reason for a well-established informal sector actively involved in collection and transboundary shipment activities from Austria to Hungary. The preferred objects are reusable items and wastes within the categories bulky waste, WEEE and metals, intended to be sold on flea markets.

Despite leading to a loss of recyclable resources for Austrian waste management, these informal activities may contribute to the extension of the lifetime of certain goods when they are reused in Hungary; nevertheless, they are discussed rather controversially. The aim of this paper is to provide objective data on the quantities informally collected and transhipped.

The unique activities of informal collectors required the development and implementation of a new set of methodologies. The concept of triangulation was used to verify results obtained by field visits, interviews and a traffic counting campaign. Both approaches lead to an estimation of approx. 100,000 t per year of reusable items informally collected in Austria. This means that in addition to the approx. 72 kg / cap / yr. formally collected bulky waste, bulky waste wood, household scrap (excluding packaging) and WEEE, up to a further 12 kg / cap / yr. might, in the case that informal collection is abandoned, end up as waste or in the second-hand sector.

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Modelling informally collected quantities of bulky waste and reusable items in Austria

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ABSTRACT

Disparities in earnings between Western and Eastern European countries are the reason for a well-established informal sector actively involved in collection and transboundary shipment activities from Austria to Hungary. The preferred objects are reusable items and wastes within the categories bulky waste, WEEE and metals, intended to be sold on flea markets. Despite leading to a loss of recyclable resources for Austrian waste management, these informal activities may contribute to the extension of the lifetime of certain goods when they are reused in Hungary; nevertheless they are discussed rather controversially. The aim of this paper is to provide objective data on the quantities informally collected and transhipped. The unique activities of informal collectors required the development and implementation of a new set of methodologies. The concept of triangulation was used to verify results obtained by field visits, interviews and a traffic counting campaign. Both approaches lead to an estimation of approx. 100,000 t per year of reusable items informally collected in Austria. This means that in addition to the approx. 72 kg/cap/yr formally collected bulky waste, bulky waste wood, household scrap (excluding packaging) and WEEE, up to a further 12 kg/cap/yr might, in the case that informal collection is abandoned, end up as waste or in the second-hand sector.

1. Introduction

According to a resolution concerning decent work and the informal economy the General Conference of the International Labour Organisation (ILO) describes that "informal economy" refers to all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements. Their activities are not included in the law, which means that they are operating outside the formal reach of the law; or they are not covered in practice, which means that – although they are operating within the formal reach of the law, the law is not applied or not enforced; or the law discourages compliance because it is inappropriate, burdensome, or imposes excessive costs (ILO, 2002). An Organisation for Economic Co-operation and Development (OECD) study shows that the financial crisis has adversely affected the employment situation of many people and, in low-income countries with no unemployment insurance, they are forced to take informal jobs with low pay, no protection and high risk exposure. The study found that 1.8 billion people, or more than half of the global labour force, were working without a formal labour contract and social security (Jütting and de Laiglesia, 2009).

1.1. Informal waste recycling sector in low-income countries

Ezeah et al. (2013) state that individuals and family groups within the informal waste sector do not usually possess trading licences, do not pay taxes, and are not included in the government insurance, social welfare and funding schemes. Especially health insurance or at least regular access to medical services are important, as usually informal workers have low awareness on occupational health and safety (Gutberlet and Baeder, 2008; Ezeah et al., 2009). Scheinberg et al. (2010) define the informal solid waste recycling sector (IS) as referring "to individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognised, supported, organised or acknowledged by the formal solid waste authorities, or which operate in violation of or in competition with formal authorities." Wilson et al. (2006) and Kinobe et al. (2015) segregate the main categories of informal waste recycling according to where and how the material recovery takes place i.e. doorstep waste pickers, itinerant buyers who move around the streets to purchase clean reusable and recyclable materials, street waste picking and waste picking from dumps/landfills.

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People earn their livelihoods by collecting, processing, recycling and selling waste at different levels along the value chain. Beside the individual pickers at the bottom of the informal "recycling value chain" other activities are involved in this hierarchy, such as sorting, processing (e.g. cleaning, crushing, bailing, etc.). Usually the value of the recyclables increase, the higher they are traded within this hierarchy. The recycling trade hierarchy consists of individual waste pickers (or family type units) at the lowermost levels, ascending to recycling small and medium-sized enterprises (SMEs), craftsmen and middlemen, brokers, wholesalers and manufacturing industries as the final destination of informally collected recyclables. Informal, that is "non-authorised" activities may contribute significantly in extending waste management services, e.g. collection in poorer areas, the provision of cheap secondary raw materials for local economies, but also in improving hygiene, extending lifetime of dumps/landfills, reducing costs for the formal system and reducing greenhouse gas emissions (Medina, 2008; Nzeadibe; 2009; UN-Habitat; 2010).

Informal activities in waste management were formerly seen as a social problem without considering the economic activities carried out. International donors and institutions reacted with projects that were thus welfare based, focusing mainly on improvement of the working conditions and disregarding the enabling environment, meaning "the political and social forces that influence their position" (Scheinberg et al., 2006). The discourse on the informal sector has been largely framed within poverty reduction and livelihoods perspectives (Nzeadibe and Anyadike, 2012; Adama, 2011). In addition, more development oriented approaches gave rise to "social and economic interventions such as education, credit and income generation to enable pickers to exit to other occupations", ignoring significant issues related to the importance of waste picking as a means of generating income. Other approaches were more rights-based, including "supporting pickers to form organisations and lobby for rights and social status, but still without acknowledging the economic importance of picking" (Scheinberg et al., 2006). Early approaches were driven mainly from a social point of view, but are more changing towards recognising the informal waste sector and the involved individuals as an integral part of waste management systems (Velis et al., 2012; Ezeah et al., 2013).

The informal waste recycling sector also increasingly attracted interest for research expressed by the number of publications listed in the scientific search engine Scopus using the terms "informal" and "waste management". In the mid of the 2000s the number of scientific papers on the topic increased from around five papers per year to more than twenty in the years 2012–2014. Ezeah et al. (2013) state that more research is needed on estimating the economic importance of informal activities on a local, national and regional scale and if successful, this would highlight the benefits the sector brings and, through this recognition, would drive greater integration within the formal municipal collection system. Linzner and Lange (2013) perform an extensive literature research with the goal to gather a large amount of research in this area, and to compile research outcomes, mainly from the last decade, with the aim of providing key performance indicators for waste management planning or monitoring. Accordingly, the results presented stem from more than 100 international published journal papers, reports and case studies, rather than original research based on primary data. Based on 42 datasets the authors present calculated percentages of informal waste workers of the urban population in different regions of the world. The average value of informal waste workers accounts for approximately 0.6% of the urban population. Other literature sources report figures between 0.5% (UN-Habitat, 2010) and 2% (Bartone, 1988; Medina, 2000). This is equivalent to approx. 12.5–56 million people worldwide working in the informal sector in waste management.

The amounts of recyclables that can be collected informally by time unit are dependent on several factors such as the location of activity and accessibility of materials (e.g. dump picking as opposed to itinerant waste buyers); the means of transport (by foot, pushcarts, animal-driven or motorised vehicles); the physical condition, age and sex of collectors; the type of materials (bulk densities) and the geographical conditions (length of trips to be made to collect materials, flat or hilly areas). Data presented in literature show the daily amounts collected by informal workers with respect to the means of transport in use. The data have to be considered as approximate values as it is not described what type of materials were collected. It is not clear from the literature whether the figures display mixed recyclables or certain types of recyclables. It is described that collectors on foot may collect a minimum of 9–17 kg/d (study for Delhi, whereas children collect 9 kg) or maximum 40 kg (Chintan, 2003). Cyclists can collect 14–60 kg/d, rickshaw and pushcart use leads to increased collection rates from 40 to 200 kg/d, and by using pick-up trucks the collection rate can increase up to 2–3 t/d (Agarwal et al., 2005; Ezeah et al., 2013). A compilation of different sources asserting daily amounts of material collected is provided in Linzner and Lange (2013), ranging from 15 to 82 kg/d and with an average value of 49 kg/d. Kinobe et al. (2015) illustrate the recycling potential at a landfill in Kampala (Uganda).

The ratio of waste picker income related to minimum wage is displayed in Chintan (2005), Medina (2007), Crivellari et al. (2008), Nzeadibe (2009) and Scheinberg et al. (2010) typically ranging from 0.7 to 5. Ruiz Rios et al. (2009) calculate the profit margins for each step in the informal recycling value chain in Peru. The price for 1 kg of material increases along the value chain. Certain paper and cardboard products increase by a factor of 1.3–3.0, polyethylene terephthalate (PET) plastics by 2.0 and for some metals by a factor of between 1.4 and 2.5. Nzeadibe and Ajaero (2011) refer to waste pickers in Nigeria earning approx. three times the minimum wage, whereas scrap dealers in the next level of the informal recycling value chain realise monthly incomes that are fifteen times higher than the minimum wage. Informal waste reclaiming activities can be considered as important revenue factor in low-income countries; the incomes may even reach a multiple of the minimum wage.

1.2. Informal activities in the European context

The existence of informal waste management activities in Europe has generally been neglected to date, but such activities are greater than an issue that affects merely the homeless. In Central and (South)-Eastern European countries (CEEC), informal practices are visible in the streets and on landfills. Informal collectors pick potentially recyclable wastes out of the municipal waste stream e.g. at household level or out of municipal bins, with the goal of earning an (additional) income by selling them.

Scheinberg and Nesic (2014) present the results of a consultation process on the informal waste recycling sector in Europe. The authors point out that most European waste pickers are men, between 20 and 60 years old and that waste picking and recycling is an individual entrepreneurial activity, not (primarily) a family activity. It is also expressed that informal work is carried out seasonally or part time. The authors also estimate the numbers of informal recyclers in Europe of more than 60,000 second-hand and reuse operators in Italy; 20,000 in Greece; approx. 5,000 in the Western Hungarian city of Devecser, and thousands of informal recyclers documented in virtually all Balkan countries. Hence the estimate of one million persons supported by informal recycling within or at the gates of the European Union does not seem far-fetched. Moreover the authors stress that most waste pickers in the European Union belong to one, or in some cases to two

extremely vulnerable groups: (1) persons of Roma ethnicity, who have very low educational levels and are the targets of a range of social exclusion measures; and (2) pensioners, elderly persons without family, and older women heads of household, who are excluded from the labour market for a number of other reasons.

A specific variety of informal activities, namely the "waste-brigades", have evolved in recent years, becoming more and more visible in Central Europe by performing informal collection activities at household level or at civic amenity sites/recycling centres/waste collection centres (WCCs) in Western European countries. Common target countries for these informal collectors are Austria and Germany, but may include Switzerland and The Netherlands. The members of the "waste-brigades" originate in Slovakia, Hungary, Poland and other CEEC countries; at flea markets in these countries it has been observed that informal traders buy and transport some of those items further e.g. to Serbia, Ukraine and Belarus. From a geographical point of view, this paper focuses on estimating the quantities of reusable items informally collected in Austria and the transboundary movement of these items from Austria to Hungary.

Different types of waste and reusable items such as Waste Electrical and Electronic Equipment (WEEE), household metal scrap and bulky waste (especially useable and saleable goods like furniture, household effects, textiles, sports equipment or toys) are gathered by non-authorised (informal) collectors without any statutory permit. The items are subsequently transported to countries whose waste management is in the process of being modernised – mostly to (South)-Eastern Europe. A detailed description of the sites of activities and their related implications are summarised in Obersteiner et al. (2010). The collected items are, where necessary, repaired, and sold at flea markets or in junk shops in Eastern Europe for being reused. On the one hand, this diminishes recyclable resources and secondary raw materials available for Austrian waste management, but on the other hand, these informal activities lead to the extension of the lifetime of certain goods when they are reused in Hungary.

Problems related to informal activities have often been addressed by the formal authorities in Austria (municipalities and waste management associations) – these complaints are mostly based on the observations of localised, formal stakeholders combined with assumptions, prejudices and rumours; a compilation of reported problems is displayed in Table 1.

Nevertheless, informal activities in this regional context have positive impacts by providing cheap, reusable goods or secondary raw materials for local markets, supporting waste prevention due to extended product lifetimes, and generating some income to the most vulnerable groups in CEEC, such as the ethnic Roma minority population which is heavily involved in such activities. Previously, accurate data on the quantities of informal collection and subsequent transboundary shipment did not exist. The competitive situation between formal and informal systems was the impetus for obtaining such objective data for the present study. The intention, after generating data on informal activities, is to stimulate an objective discussion on the theme, and to assess potential solutions and formalisation ideas.

The informal collection and subsequent transboundary shipment from Western to South East European countries is difficult to assess as the scale of activities and the composition of the collected items has been scarcely investigated up to now. Piecemeal investigations into IS at case study level exist for Serbia, Romania, Bosnia and Bulgaria (Vaccari et al., 2013; Scheinberg et al., 2010; Soos et al., 2008). Compared with "typical" IS activities in low-income countries, the informal collection and transboundary movement of bulky waste and reusable items as described in this paper features considerable differences (see Table 2). In particular, European transboundary IS activities cover larger geographical areas, operate over higher transport distances and utilise a range of vehicle types. In addition, the items collected in Central Europe are not comparable to the typical recyclables in low-income countries (e.g. waste paper and cardboard, glass,

Table 1
Problems and complaints reported by formal and informal stakeholders.

Problem area	Description/complaints reported by formal and informal stakeholders
Economic problems	Waste management associations (WMAs) report the loss of money as informal waste collectors remove precious materials (loss of revenues on the commodities market) and therefore it is difficult for the formal stakeholders to maintain their (costly) infrastructure WMAs report increased expenses due to cleaning activities after waste littering due to informal activities Informal actors may lose income possibilities due to the reorganisation of waste management systems in CEEC Financial issues also occur in the case of transhipment, e.g. when a household waste fee is charged in Western Europe but the final disposal (and the related costs) takes place in Eastern Europe
Social problems	Under pressure to comply with EU directives, a modernisation of the solid waste sector is in progress in CEEC (Scheinberg, 2008). Informal activities in waste collection and waste recycling run the risk of being excluded and replaced without considering those affected – for whom waste picking represents a livelihood
Environmental problems	Problems arise if parts of non-saleable items are recycled, treated or disposed of in inadequate places in the target countries. This may cause major environmental harm, especially regarding WEEE. Moreover, waste is transported from regions with higher developed waste management systems to regions with lower standards. The nature of informal activities means the waste can neither be tracked nor adequate waste processing be guaranteed. Both improper waste handling and disposal (especially littering both in Western and in Eastern countries) may contribute to greenhouse gas emissions or other pollutants
Legal issues	Informal activities are somewhat in conflict with existing laws and regulations at EU national levels. Legal topics include, amongst others, collection permits (waste vs. product and the legal issues of end-of-waste), regulations on transboundary shipment, treatment permits, trade laws, tax laws etcetera

Table 2
A comparison of IS activities in low-income countries and those researched in this paper.

Informal sector in low-income countries	Informal sector with transboundary movement (Europe)
0.5–2% of urban population involved	0.05–0.16% of population involved
Locally rooted	Transboundary shipment
Low transport radius depending on means of transport (<25 km)	High mobility (trips of 300+ km)
Means of transport: on foot/pushcart/horse-carts/bi- and tricycles/motor rickshaws	Means of transport: passenger car plus trailer, vans
Collection/processing of all kinds of recyclables	Bulky waste/reusable item collection: e.g. WEEE, metal scrap, useable and saleable goods like furniture, household effects, textiles, sports equipment or toys.
Amounts per day collected: 15–700 kg depending on means of transport	Amounts per trip up to 1000 kg
Income (revenue): 0.3–15 USD/day	Income: 50–300 EUR/month
Low legal background and lacking law enforcement	Legal issues a high priority (end of waste (product vs. waste) and the related legal issues such as collection permits and transboundary shipment issues)
Source: Linzner and Lange (2013)	Source: Pertl et al. (2010a)

metals, certain plastics (e.g. PET bottles), etc.). A further difference is created by competitive issues that arise as informal European systems compete with formal systems within a comparably well-established legal framework. Formal system representatives argue that there is a lack of legal compliance – that IS workers should require waste collection, treatment and transboundary shipment permits. Finally, the high mobility of the "waste brigades" and the large geographical area of activity makes it more difficult to track the IS involved in transboundary shipment.

2. Materials and methods

In the assessment of informal activities, it is difficult to carry out measurements and surveys as the people concerned are highly mobile. In the current paper, the quantity of informally collected items was estimated using the triangulation concept. Triangulation is used in social sciences to double-check results with two or more independent methods; it intends to facilitate the validation of data through cross-verification from two or more sources (Bogdan and Biklen, 2006). Triangulation in this case means that an iterative estimate has been calculated using several methodological approaches or entry points of assessing the informal activities in use. A prior example of the use of this concept in estimating informal activities in China was presented by Linzner and Salhofer (2014). Other methods of validation cannot be applied in this specific case, as no comparable literature data are available. In addition it was tried to use official, electronically obtained traffic counting data, but these were only available partly and not covering all border crossings. Furthermore it turned out to be impossible to derive information on the number of vehicles involved in informal collection based on a total number of vehicles counted electronically.

In the first part of this article two methodologies developed to assess the quantities of informally collected reusable items are described. This is followed by a description how variables of two equations to be used in assessing informal quantities were determined through field visits, interviews and a traffic counting campaign. In the last sections the results are presented and discussed.

2.1. Preliminary survey

At first, a selection of municipalities, WMAs and provincial governments in Austria were contacted by email and telephone to ask for information on informal waste collection activities to obtain a quick overview of the situation in Austria. The authors started this pre-survey in the Austrian regions bordering Hungary and Slovakia as it was assumed that informal collection activities are concentrated in the outermost areas. In a second step, WMAs and municipalities throughout Austria were contacted in order to obtain information as to whether or not informal activities occur. This was paving the ground for determining the regions where field visits were carried out.

2.2. Field visits

Based on the results of the preliminary survey, field visits were planned by the research team. Field visits were considered the most suitable method for obtaining useful information on amounts collected informally. Face-to-face interviews and direct observation appeared to be more fruitful than telephone interviews. For this reason, questionnaires were developed and translated into Hungarian – the field visits took place in municipalities affected by informal collection activities in 2009.

Careful planning of field visits was necessary to obtain information most efficiently, as large distances had to be travelled throughout Austria, and it was planned to visit as many municipalities as possible each trip. Informal collectors, WCC staff and local, affected residents needed to be interviewed; interviews at locations with kerbside collection were also carried out. The results of the interviews were inputted to a database. One important issue was to approach the informal collectors in such a way so as not to frighten them, as they were considered valuable resource of information. The interviews were therefore always conducted by the same interviewer, and in Hungarian. This was of major significance, as it emerged that the same collectors were encountered at different locations. This led to a strengthening of trust – after some time the interviewer and respondent became familiar and it was easier to obtain useful answers. It emerged that the WCC staff could not give precise information regarding which items are preferentially collected, or their quantities. The interviews were very important in gathering insights on the day-to-day problems of the staff, and also for approaching the informal collectors to obtain useful information regarding their practices, e.g. how long they have been collecting, which items they prefer, what happens to the items, their motivation(s), how often they visit a site, how much they earn with these activities etc. In total 63 representatives of WMAs, 18 representatives at municipal level, 4 representatives of provincial governments, 76 employees at WCCs and 83 informal collector groups (representing 167 individual collectors) were interviewed.

2.3. Traffic counting

In order to verify the results from the field visits, a traffic-counting campaign was undertaken in the Austrian border regions with Hungary and Slovakia. The goal was to count the number of cars used by informal collectors that cross the border to Hungary or Slovakia in order to extrapolate the quantity of informally collected and transhipped items per year. The main focus was placed on vehicles registered in Hungary. The traffic counting required many issues to be tackled in the planning phase. Some important questions included: where to carry out the traffic counting (all border crossings or only on the main routes?), when to carry out the counting (season, weekday, time of day?) in order to identify potential variations (see Section 2.3.1). In addition, it was necessary to develop a plan where and when to carry out traffic counting in order to optimise the staff input.

2.3.1. Traffic counting dates

In total five "full-day" traffic counting days were chosen and were complemented by eleven "spot-checks" in order to obtain data for an estimate of the seasonal variations. On a "full-day", seven to nine border crossings were observed from 12 noon to 8 pm in the evening, as the most important time of day was the afternoon to "catch" the collectors on their way back home. Based on the results of the first two full counting days, the spot-checks were carried out for two hours in the afternoon (3–5 pm) on the most frequented weekday (Friday) once a month on the most frequented border crossing. The overall counting period was from 1 August 2009 to 20 August 2010. The data obtained at the third and fourth full counting day at the border crossing Klingenbach (AT) to Sopron (HU) in the period of 3–5 pm was used also for estimating the seasonal variation.

Table 3 summarises the dates of the traffic counting campaign. On some counting days, cars were also stopped with support of police/customs, in order to ascertain the contents. This also made it possible to estimate the degree of filling of the cars, in percent, and to take pictures for assessing the composition of the load.

Table 3
Dates of full-day counting campaigns and spot-checks of the traffic counting.

Five "full" counting days	Eleven spot-checks at the border crossing Klingenbach (AT)–Sopron (HU)	
1st counting Saturday, 01.08.2009	1st spot check: Friday, 02.10.2009	6th spot check: Friday, 12.03.2010
		7th spot check: Friday, 16.04.2010
2nd counting Wednesday, 30.09.2009	2nd spot check: Friday, 13.11.2009	8th spot check: Friday, 21.05.2010 (within the daily counting)
3rd counting Friday, 02.10.2009[a] (reference counting)[b]	3rd spot check: Friday, 18.12.2009	9th spot check: Friday, 18.06.2010
4th counting Friday, 21.05.2010[a]	4th spot check: Friday, 15.01.2010	10th spot check: Friday, 23.07.2010
5th counting Saturday, 31.07.2010	5th spot check: Friday, 19.02.2010	11th spot check: Friday, 20.08.2010

[a] Data from these full counting days were used for the 1st and 8th spot check.
[b] The full counting day with the highest cross-border traffic of informal collectors' vehicles.

2.3.2. Vehicle types and implementation in practice

Another important issue to be tackled prior to practical implementation was how to identify the vehicles used by informal collectors during the counting campaign. In order to standardise the procedure and to obtain comparable results, a traffic counting data sheet and instructions for the researchers carrying out the counting were developed. Fig. 1 shows the traffic counting data sheet used in the field, and examples of vehicle types used by informal collectors and thus to be counted. The data sheet includes the following vehicle types: passenger cars (PC), normal vans (V_N), large vans (V_L), flatbed/platform trucks (Tr), small trailers (t_S) and large trailers (t_L).

As expected, it was sometimes difficult to assess whether a vehicle was in use for an informal collection service or not, especially in the case of closed vans. For this reason the following probability levels were introduced: "Collector" (>90%), "Unknown" (10–90%) and "Definitely no collector" (<10%). During the traffic counting, researchers counted a number of vehicles (N_{veh}) belonging to a certain vehicle category (type) and allocated them to a certain probability level of being involved in informal waste collection and transhipment. A contention was how to deal with the numbers of vehicles that were allocated to the probability level "10–90%" (P_{10-90}). To assist, some counting periods were carried out with police support in order to stop vehicles randomly and to verify the allocation to the categories. A supplementary benefit was the ability to inspect the load and take pictures for estimating filling percentage and composition of the transhipped items. Using this information, maximum ($N_{veh\text{-}max}$), medium ($N_{veh\text{-}med}$) and minimum ($N_{veh\text{-}min}$) scenarios were developed with different probability factors (P) for each probability level. The factors applied to the three scenarios are shown in Table 4. It shows, for example, that in the medium scenario, 45% of the allocated vehicles to P_{10-90} are considered as being involved in informal activities.

3. Results

In the following, the yearly informally collected volume and quantities of bulky waste and reusable items are estimated by developing two equations and by applying the results of the field visits in Eq. (1) and the traffic counting results in Eq. (2).

3.1. Yearly informally collected quantities based on field visits

An approximate quantity of informally collected items per year was estimated using several parameters obtained from interviews, such as the type of vehicles that informal collectors use, the loading capacity and the regularity (frequency) of carrying out waste collection activities in Austria. Additional information derived from the interviews was the number of municipalities affected by informal activities, and the average number of collector groups per municipality. Eq. (1) represents a formula on the estimation of the yearly informally collected quantities based on field visits.

Yearly amount of informally collected items (t/yr):

$$Q_{informally} = M_{informally} * CG_{av} * F * AV * \rho/1000 \quad (1)$$

where $Q_{informally}$ is the yearly amount of informally collected items (t/yr); $M_{informally}$ is the number of municipalities in Austria affected by informal waste collection activities; CG_{av} is the average number of collector groups per municipality (results from interviews); F is the frequency of collection activities per year (results from interviews); AV is the average transhipped volume per collector group (m^3 per trip); ρ is the bulk density of the transhipped items (kg/m^3); 1000 is the correction factor (kg/t).

The most sensitive parameter is the number of municipalities which are affected by informal waste collection activities in Austria ($M_{informally}$). In total 158 municipalities were visited (out of 2357 municipalities in Austria) during the field visit; the extrapolated results also include a peer-reviewed distribution of informal activities within the provinces. For example, in districts in Burgenland it is estimated that 90% of municipalities are affected by informal waste collection activities, whereas in Tyrol only 20% of municipalities are likely to be affected (see Table 5). These estimates are based on experiences obtained during the field visits and interviews with stakeholders. The estimated values were presented to stakeholders in order to ask them for verification of the estimate and adjustment, respectively.

According to the interviews, it can be stated that informal activities take place in 76% of Austrian districts, of which 50 districts (51%) experience periodical, informal collections (e.g. in front of WCCs), and 25 districts (25%) in the form of collector-induced collections (e.g. with flyers distributed to households). 17 districts (17%) have no informal collector activities. From the total number of 99 districts (including cities) in Austria, it was not possible to obtain information from 7 districts (7%). Districts characterised as affected by informal collection activities were combined with the values of municipalities affected in each district (see Table 5). Extrapolation indicates that 29.3% of municipalities encounter periodic, informal collections (690 municipalities) and in 21.0%, collector-induced, informal collections occur (496 municipalities), all over Austria. Thus, in total, 1,186 municipalities (or 50.3% out of 2,357 municipalities) are affected by informal collectors ($M_{informally}$). Fig. 2 shows the Austrian administrative classification and the occurrence of informal collection activities based on field visits and interviews. It can be seen, that the most affected areas are located in the north-eastern and eastern regions bordering to Slovakia and Hungary.

The average number of collector groups per municipality (CG_{av}) was calculated from the results of the field visits and amounts to 2.0 per municipality. For the frequency of collection activities per year (F), results from interviews were taken as a basis. The number of yearly collection activities per collector group collecting at WCCs amounts to 84 (or 1.6 trips per week), whereas kerbside collection usually is carried out two times a year in the municipalities, leading to a frequency of 2.0 for collector induced collections. In addition to these figures, the average transhipped volume per collector group and trip (AV) had to be determined and averaged – resulting in approx. 6.0 m^3 per ride and vehicle, in accordance with the interviews. Finally, the bulk density (ρ) of transported items had to be estimated. For estimating the quantities based

Data sheet traffic counting **Sheet No.:**

date: .....

border crossing: .....

name: .....

		Number of vehicles					
counting period (full hours)							
vehicle type	likelihood	car only	vehicle with small trailer	vehicle with large trailer	car only	vehicle with small trailer	vehicle with large trailer
passenger car (only waste pickers) 	> 90%						
normal size van 	> 90%						
	10 - 90%						
	< 10%						
large van 	> 90%						
	10 - 90%						
	< 10%						
flatbed truck (covered or uncovered) 	> 90%						
	10 - 90%						
	< 10%						

Fig. 1. Traffic counting data sheet (above) and examples of vehicle types used by informal collectors (below).

Table 4
Probability levels and the linked probability factors and associated scenarios.

Scenarios	Probability factors (P)		
	>90%	10–90%	<10%
$N_{veh\text{-}min}$	0.95	0.40	0.00
$N_{veh\text{-}med}$	0.98	0.45	0.01
$N_{veh\text{-}max}$	1.00	0.50	0.02

on volumes collected, three scenarios were used for different bulk densities.

Table 5
Percentage of Austrian municipalities affected by informal collection activities.

Province	Percentage of municipalities where informal activities occur (%)
Burgenland	90
Lower Austria	70
Upper Austria	30
Styria	70
Salzburg	50
Carinthia	20
Tyrol	20
Vorarlberg	10

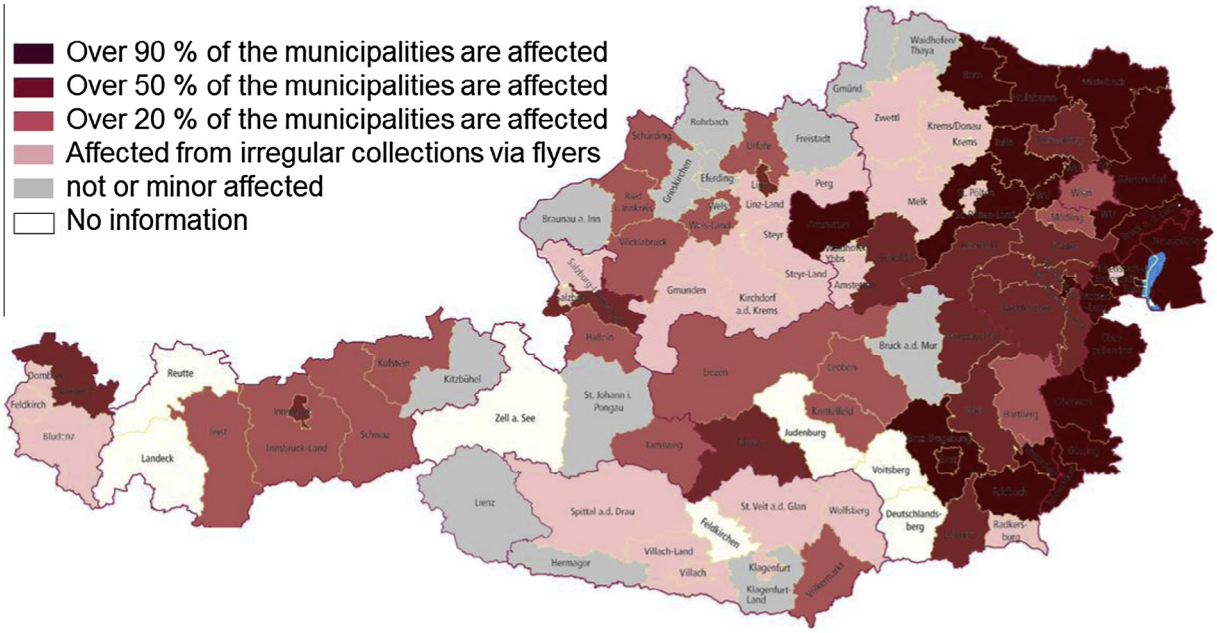

Fig. 2. Districts in Austria and occurrence of informal collection activities.

Table 6
Estimates on yearly informally collected amounts for three bulk densities based on field visits and interviews.

	Periodical informal collections			Collector induced collections		
	Min scenario	Med scenario	Max scenario	Min scenario	Med scenario	Max scenario
Share of municipalities affected by informal collectors (%)	29.3%	29.3%	29.3%	21.0%	21.0%	21.0%
Share of municipalities affected by informal collectors ($M_{informally}$)	690	690	690	496	496	496
Average number of collector groups per municipality (CG_{AV})	2	2	2	1	1	1
Frequency of collection activities per year (F)	83.9	83.9	83.9	2.0	2.0	2.0
Average transhipped volume per collector group (m^3 per trip)	5.49	5.49	5.49	14.00	14.00	14.00
Bulk density of the transhipped items (kg/m^3)	125	150	175	125	150	175
Conversion factor (kg/t)	1000	1000	1000	1000	1000	1000
Yearly informally collected amount (t/yr)	79,455	95,347	111,238	1736	2083	2430

Table 6 shows the result of Eq. (1) for three scenarios regarding the bulk density of collected items (min, med and max scenario) both for collector groups active in front of WCCs (periodical informal collections) and for groups actively approaching households via flyers (collector induced campaigns).

By adding the estimate for periodical and collector induced collection activities, the result of the yearly informally collected items in Austria, based on field visits and interviews, amounts to 81,191 t (min scenario), 97,430 t (med scenario) and 113,668 t (max scenario).

3.2. Yearly informally collected volume in Austria based on traffic counting

In the following, an extrapolation formula is presented that allows for estimating the yearly transhipped volume based on the traffic counting campaign.

3.2.1. Extrapolation formula of yearly transhipped volume

The results of the traffic counting (five full-day counting campaigns and eleven spot-checks) led to the development of an extrapolation formula for the yearly transhipped volume (TV) by informal collectors (Eq. (2)). This allows the calculation of a projection to one whole year (starting from a reference day in October, which was the counting day with the highest cross-border traffic of informal collectors' vehicles).

$$\begin{aligned}\text{Yearly informally collected and transhipped volume (TV) } (m^3) &= (N_{>90} * P_{>90} * AV_{>90} * BC_{vol>90} + N_{10-90} * P_{10-90} * AV_{10-90} \\ &* BC_{vol10-90} + N_{<10} * P_{<10} * AV_{<10} * BC_{vol<10}) * 52 * WC \\ &* SC * LC \end{aligned} \quad (2)$$

where N is the number of vehicles counted on Friday 2 October 2009 (reference day) between 12 noon and 8 p.m.; indices represent the allocation to the probability categories; P is the proportion of waste pickers for each probability category – probability factor is based on the three scenarios in Table 4; AV is the average transported volume per vehicle for the particular probability categories; BC_{vol} is the correction factor for additional volume from other border crossings for the particular probability categories; 52 is the weeks of a year; WC is the correction factor resulting from weekly variations; SC is the correction factor for seasonal variation; LC is the correction factor concerning length of counting period.

The variable AV represents the average transported volume (m^3) per vehicle in a particular probability category and is calculated from average potential loading volumes derived from car manufacturers and levels of filling observed during the five full-day counting campaigns. Based on internet research and information material from car manufacturers, the average potential loading volumes for the different vehicle categories were estimated (see Table 7).

Table 7
Vehicle types, average potential loading volumes (m^3) and observed filling degree (%).

Vehicle type	Average potential loading volume (m^3)	Average filling degree per vehicle type based on police stop-checks (%)
PC	1.2	92
V_N	6	71
V_L	12	68
Tr	9	63
t_S	2.5	88
t_L	7	71

Table 8
Calculated average transported volume per vehicle (AV) for the three probability categories.

Based on five full-day counting campaigns	Probability categories		
	>90%	10–90%	<10%
Number of vehicles counted	986	857	926
Calculated transhipped volume (m^3)	5413	5636	5490
Calculated AV (m^3/vehicle)	5.49	6.58	5.93

Table 9
Correction factor for additional border crossings (BC_{vol}).

First full-day observation (01.08.2009)	Probability categories		
	>90%	10–90%	<10%
Transhipped volume for 8 border crossings (m^3)	2791	1696	960
Transhipped volume for 5 border crossings (m^3)	2486	1350	777
BC_{vol}	1.12	1.26	1.24

Table 10
Weekly distribution of informal collectors' work based on interviews and counting results.

Weekday	Preferred working days		Used for calculating the weekly variation WC (%)
	Interview results Austria (%) (n = 98)	Interview results Hungary (%) (n = 100)	
Monday	10	10	10
Tuesday	16	10	13
Wednesday	48	40	63
Thursday	10	10	10
Friday	100	100	100
Saturday	132	90	100
Sunday	0	0	0

Another factor of influence is the percentage of filling (filling degree) of the vehicles. This percentage was calculated from records and photos taken during police stop-checks and by responses from the collector interviews. Following the five full-day counting campaigns, the variable AV was calculated for each probability category (see Table 8). The vehicle numbers per vehicle type counted were multiplied with potential loading volumes and observed filling degrees, leading to a calculated volume transhipped during the five days, allowing the calculation of the variable AV for each probability category.

3.2.2. Correction factors

The extrapolation of volumes collected from a reference counting day (02.10.2009) to a yearly transhipped amount requires several correction factors that are presented in the following.

3.2.2.1. Additional border crossings. The first correction factor of Eq. (2) (BC_{vol}) deals with smaller border crossings that were observed only on the first day of the observation (01.08.2009). It transpired that the smaller border crossings would require too many staff resources to allow observation on the four remaining full-day counting campaigns. Therefore the ratio between the transhipped volume of eight border crossings (including the smaller ones) and five border crossings was calculated for this first observation day. Again, this was done by multiplying the vehicle numbers per vehicle type counted with potential loading volumes and observed filling degrees, leading to a transhipped volume for eight and five border crossings. Table 9 shows the calculated ratio BC_{vol} used for extrapolation.

3.2.2.2. Weekly correction. The correction factor of weekly variations is based on the results of the traffic counting and interviews with informal collectors. The results of the five full-day observations show that Friday is the day with the highest collector activity and therefore is allocated 100% collector activity. Real counting results are available for Wednesdays, Fridays and Saturdays (see Table 3 in Section 2.3.1); the remaining weekdays' collector activity was estimated with information derived from interviews with informal collectors. Based on the traffic counting, Friday and Saturday were set at 100% and Wednesday calculated at 63%. During the field visits, the collectors were asked to name the weekdays that are most preferred for their activities, with Friday as reference day at 100%. The results of the interviews in Austria and Hungary are displayed in Table 10. The remaining weekdays – Mondays, Tuesdays and Thursdays were calculated as the average value from the interview results. The last column in Table 10 shows the weekly distribution of work used for calculating a correction factor. This weekly correction factor amounts to 2.96 related to a Friday counting (on 02.10.2009 as reference day). This means that based on a Friday counting, the number of

Table 11
Vehicles counted at monthly spot-checks and calculation of seasonal correction factor (SC).

Klingenbach spot-checks Fridays, 3–5 pm	Number of vehicles				$N_{veh\text{-}med}$	Percentage related to reference day
	Sum >90%	Sum 10–90%	Sum <10%	Total		
02.10.2009	36	34	34	104	50.92	100.0%
13.11.2009	40	25	35	100	50.45	99.1%
18.12.2009	18	32	18	68	32.04	62.9%
15.01.2010	31	20	30	81	39.38	77.3%
19.02.2010	36	27	23	86	47.43	93.1%
12.03.2010	36	15	25	76	42.03	82.5%
16.04.2010	29	18	56	103	36.52	71.7%
21.05.2010	27	8	50	85	30.06	59.0%
18.06.2010	32	22	36	90	41.26	81.0%
23.07.2010	33	19	36	88	40.89	80.3%
20.08.2010	38	12	36	86	42.64	83.7%
					SC = 0.8257	

vehicles counted is multiplied by approx. three to get the weekly numbers of vehicles crossing the border.

3.2.2.3. Seasonal correction. The field visits established that informal collectors are well-informed about the opening hours of Austrian WCCs and also when and where kerbside bulky waste collection campaigns take place. The "waste brigades" do not react to seasonal variations in bulky waste generation; this can be explained by the fact that informal collectors must work regularly to ensure as regular an income as possible. In addition, even in months with higher bulky waste generation, the routes and frequencies do not change considerably.

In order to investigate seasonal variations in the informal activities, spot-checks were carried out for two hours in the afternoon (3–5 pm) on the most frequented weekday (Friday) once a month at the most frequented border crossing at Klingenbach. Table 11 displays the dates of the spot-checks and the number of vehicles counted and allocated to the respective probability categories. The vehicles per category counted are converted to $N_{veh\text{-}med}$ by multiplying the number of vehicles with the conversion factors outlined in Table 4 (Section 2.3.2). The reference day (Friday, 02.10.2009) is set as 100% and the calculated $N_{veh\text{-}med}$ results are compared with this day. The results show a yearly variation of informal activities based on traffic counting. The correction factor for seasonal variation can be calculated by adding up the percentages and dividing the result by twelve. SC amounts to 0.8257.

3.2.2.4. Correction factor for length of counting period. The full counting day observations were carried out in an eight 8 h time span from 12 noon to 8 pm on the respective days. To involve the period outside this time span, a correction factor also has to be applied. For the counting days of 21 May 2010 and 31 July 2010, the counting activities started at 11 am and ended at 9 pm, providing a basis for the estimation of additional collectors crossing the border. The analysis of these two additional hours counted led to 12–17% higher amounts compared to the counting period from 12 noon to 8 pm for the sum of the probability categories >90% and 10–90%. Vehicles allocated to probability categories <10% are neglected as their influence on the entire result is negligible.

Conversations with police and customs revealed that during the night hours and before noon, the quantity of informal collector vehicles crossing the border decreases considerably. The extrapolation factor concerning the length of counting period (LC) is calculated based on the sum of the overnight factor (+15%) and the factor of the two additional counting hours (approx. +15%) to an overall +30%. The factor (LC = 1.30) represents a rough estimate, but nevertheless includes information observed and adjusted with police and customs officers.

3.2.2.5. Correction factor for nationalities. As described in Section 2.3, the counting campaigns focused on Hungarian collector groups, identified by their vehicle number plates. As the methodologies used in the traffic counting and during field visits (interviews with collectors) diverge regarding the consideration of different nationalities, a reconciliation is necessary for comparison. Interviews were conducted with 69% Hungarian collectors and 31% collectors from other nationalities. For a proper triangulation of the different methods (interviews and traffic counting), the traffic counting results of Hungarian collectors must be extrapolated to encompass the total informal collection in Austria i.e. correction of the traffic counting results have to consider other nationalities. This correction factor amounts to 1.45.

3.2.3. Volume estimation

In the following, the results of Eq. (2) are displayed step by step. Table 12 displays the total number of vehicles counted and the allocation to probability levels for the reference counting day (Friday, 02.10.2009). In total, 858.5 vehicles were counted on this day.

In a next step, the total number of vehicles counted in the respective probability category were recalculated by applying the maximum ($N_{veh\text{-}max}$), medium ($N_{veh\text{-}med}$) and minimum ($N_{veh\text{-}min}$) scenario as displayed in Table 4 (Section 2.3.2). In the following, the recalculated vehicle numbers are multiplied by the average transported volume per vehicle (AV) calculated for the three probability categories, as outlined in Table 7 (Section 3.2.1) and with the correction factor for additional border crossings (BC_{vol}) as depicted in (Section 3.2.1). Finally, the correction factors for weekly variation, seasonal variation, length of counting period and other nationalities are applied, leading to the yearly transhipped volume. In Table 13, the results of the yearly informally collected volumes in Austria are presented, ranging from approx. 615,000 m^3 in the minimum scenario to approx. 706,000 m^3 in the maximum scenario.

3.3. Yearly informally collected quantities in Austria based on traffic counting

In order to calculate the yearly quantities collected in Austria, the results of Table 13 have to be extended with bulk densities

Table 13
Yearly collected volume (m^3) in Austria for the three scenarios based on traffic counting.

Yearly collected volume (m^3/yr) based on...		
Scenario $N_{veh\text{-}min}$	Scenario $N_{veh\text{-}med}$	Scenario $N_{veh\text{-}max}$
TV_{min} = 614,986	TV_{med} = 662,625	TV_{max} = 706,410

Table 12
Total number of vehicles counted and probability levels at the reference counting day.

		Numbers of vehicles counted at 5 borders on reference day (Friday, 02.10.2009)					
Vehicle type	Probability category (%)	Vehicle	t_S	t_L	Sum >90%	Sum 10–90%	Sum <10%
PC	>90	19.0	67.0	16.0	102.0	–	–
V_N	>90	41.0	13.5	10.0	64.5	–	–
V_N	10–90	102.0	5.0	0.0	–	107.0	–
V_N	<10	133.5	4.0	1.0	–	–	138.5
V_L	>90	53.0	14.0	14.5	81.5	–	–
V_L	10–90	152.5	2.0	3.5	–	158.0	–
V_L	<10	64.0	4.0	1.0	–	–	69.0
Tr	>90	12.0	0.0	1.0	13.0	–	–
Tr	10–90	48.5	0.0	1.0	–	49.5	–
Tr	<10	70.5	3.0	2.0	–	–	75.5
Total		696.0	112.5	50.0	261.0	314.5	283.0

Table 14
Estimates of yearly informally collected amounts (t/yr) in Austria for three bulk densities based on traffic.

	Three bulk density scenarios for items collected in Austria		
Inputs	ρ-min (125 kg/m^3)	ρ-med (150 kg/m^3)	ρ-max (175 kg/m^3)
TV_{min}	76.873 = Q_{min}	–	–
TV_{med}	–	99,394 = Q_{med}	–
TV_{max}	–	–	123.622 = Q_{max}

Table 15
Triangulation results of yearly quantities collected based on traffic counting and interviews.

Triangulation	Q_{min} (t/yr)	Q_{med} (t/yr)	Q_{max} (t/yr)
Results of the yearly quantity collected by all nationalities based on traffic counting	76,873	99,394	123,622
Results of the yearly quantity collected based on field visits and interviews	81,191	97,430	113,668

of the collected items. Within the police stop-checks during traffic counting it was possible to have a short look into the collectors' vehicles but at the place of counting there was no possibility to weigh the vehicles. One attempt to verify the bulk density was by weighing and measuring typical items that are collected by informal collectors. The results of this weighing campaign were evaluated and an average bulk density of 148 kg/m^3 was calculated. Subsequently an informal Hungarian collector was invited in order to take the preferred goods with him. These goods had been numbered during weighing before for an identification whilst the loading process. Thus weight and volume of the really collected goods were calculated with approx. 1600 kg and 13 m^3. The average bulk density of this exemplary collection was 124 kg/m^3. In addition literature data from Austrian bulky waste densities was assessed resulting in an average density of 125 kg/m^3 (BMLFUW, 2006). In order to consider different compositions of the loads three scenarios were developed. The first (low-density) scenario is based on the results of the literature data for bulky waste. The result of the weighing campaign is used for the second scenario (150 kg/m^3). In a third scenario it was assumed that the influence of a higher metal content raises the bulk density of the transhipped items to 175 kg/m^3.

Table 14 displays the quantities of the yearly informally collected items for the three bulk density scenarios calculated with the volumes of Table 13 (Section 3.2). It can be seen that the quantity for the minimum scenarios amounts to approx. 77,000 t/yr. ranging to approx. 124,000 t/yr. in the maximum scenarios. The medium scenarios result in a yearly informally-collected quantity in Austria of approx. 99,000 t/yr.

3.4. Comparison of field visit results and traffic counting

The results of the yearly quantity collected from the field visits (Table 11, Section 3.1) and the results from the traffic counting (Table 14, Section 3.3) are compared in Table 15.

It can be seen that for the medium scenario, both methodologies result in approx. 100,000 t per year collected informally in Austria.

4. Conclusions

The specific research question of assessing informal reusable item collection in Austria required a new set of methodologies. The high mobility of foreign, informal collectors, coming mainly from Hungary, made it difficult to estimate quantities linked with these activities. Two methodologies were applied in order to compare and cross-check the results.

Firstly, informal collector groups were interviewed in order to obtain information on places of activities, collection frequencies, locations, vehicles used and filling grades. In addition, representatives of WMAs from municipalities and provinces and employees of WCCs were interviewed in order to assess the municipalities affected by informal reusable item collection. Secondly, traffic counting campaigns were conducted, aimed at counting vehicles involved in informal collection activities at important border crossings from Austria to Hungary. Both methodologies show, that a similar range of approx. 100,000 t per year of reusable items are likely to be informally collected (see Table 15).

When compared with data for the same waste streams formally (officially) collected from households in Austria in 2009 (BMLFUW, 2010), i.e. bulky waste, bulky waste wood, household scrap metal (excluding packaging) and WEEE, it can be seen that informally collected reusable items represent additionally approx. 16.5% of the total 601,700 t per year (see Fig. 3).

This means that in addition to the approx. 72 kg/cap/yr formally collected, up to a further 12 kg/cap/yr might, in the case that informal collection is abandoned, end up as waste or in the second-hand sector. The collection of reusable items by third sector organisations (not to be confused with the informal sector, the term relates more to social enterprises) may move waste management up the waste hierarchy from disposal to recovery and reuse (Williams et al., 2012). On the one hand this contributes to lower waste collection costs for formal systems, saves resources and on the other hand these organisations perform important service functions in society, i.e. "filling gaps" by providing services when public and private sectors fail to provide them (Sharp and Luckin, 2006).

A study from England suggested potential reuse rates for household bulky waste depending on the collection system. Curran et al. (2007) report that in case bulky waste is collected via kerbside systems, then the reuse potential is ranging from 36% for electrical appliances to 51% for furniture. Disposal via bring system to waste collection centres (civic amenity sites) leads to a reuse potential of 59%. Williams et al. (2012) note that furniture and electrical appliance reuse organisations reuse three times the number of bulky items that local authorities do overall, despite handling only a tenth of the number of items. Curran and Williams (2010) describe that 85% of the household bulky wastes in England that is collected by third sector organisations (representing 7% of the total items discarded) are reused, whereas local authorities (formal collection systems) only provide 2–3% reuse but collect 71% of the totally discarded items. Alexander et al. (2009) address that the current recorded reuse is 15% of the total bulky waste in England. The authors also estimate an additional potential for reuse with 12.3%, leading to almost 30% of the bulky waste in England that could be reused.

The informal collection of reusable items and transboundary shipment to Hungary is somewhat different compared to social enterprises providing similar services, e.g. the provision of affordable goods for socially deprived. Some Austrian stakeholders argue that informal collectors act beyond the law. In low-income countries where waste legislation is patchy or weakly enforced, and where formal authorities lack the capacity to establish recycling activities, a parallel informal system flourishes in the collection and sale of potential recyclables. In changing systems, where material recovery and the associated revenues are starting to become of interest to the formal systems, both formal and informal systems compete for recyclables. In the case of Austria, where laws are in place and enforced, solutions to these issues are discussed primarily from a legal point of view: about the demarcation of waste and

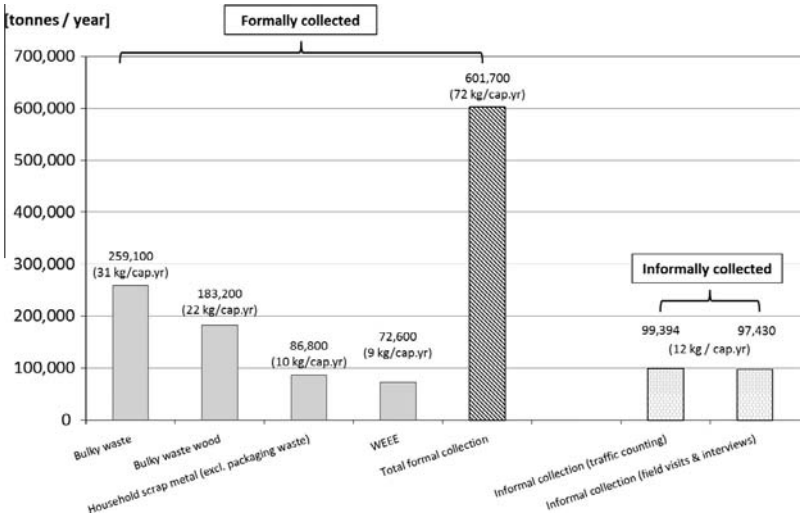

Fig. 3. Formally and informally collected quantities in Austria.

products. Some formal representatives consider informal collection illegal, as according to them, informal stakeholders do not have the necessary permits to collect, tranship and trade waste. Other stakeholders argue that when functioning items are donated to informal collectors, then those items are products and therefore should not to be considered as waste. It has been argued, that the second-hand goods market (also including internet platforms and charity collections) shows similarities to the activities of Hungarian collectors. It seems that discussions around informal activities in the reusable items sector are centred on an ambivalence regarding waste vs. product. It also has to be stated that discussions around these informal activities sometimes include prejudices against certain person groups and the fact that "someone is coming from outside and picks the cherries out of the waste stream". More important is to provide facts and figures and to objectify discussion.

From an environmental point of view, the Hungarian reuse of certain items that were informally collected in Austria makes sense. Life Cycle Assessments were carried out for a "typical set" of items preferred by Hungarian collectors: furniture, a refrigerator, a washing machine and a personal computer with cathode ray tube (CRT) monitor. When comparing the formal scenario, where reusable items are collected and treated by the Austrian formal systems, with informal reuse scenarios in Hungary, the results show the following: furniture reuse in Hungary leads to environmental benefits not only resulting from waste prevention in general but in particular by saving the environmental burdens accompanying the new production of this furniture, but also by saving the environmental burdens caused by "conventional" recycling activities (Obersteiner et al., 2011). Pertl et al. (2010b) describes that for the refrigerator, an improper handling of cooling agents by informal collectors may cause higher environmental burdens compared to a formal treatment in Austria, whereas the reuse of a washing machine shows better results in a reuse scenario (depending on the age and energy consumption in the use phase). Scherhaufer et al. (2011) show that reuse for a PC including CRT monitor shows best results. Generally it can be concluded, that if products are not reused, new goods must be produced which causes high environmental effects. If goods are reused, then the production of new items (providing the same function) can be avoided, which results in a major reduction of environmental effects. The authors also found out, that the transport processes due to transboundary shipment to Hungary play a minor role in the overall life cycle of the products.

Other recent examples in Eastern Europe show that in modernising waste management systems, competition occurs: extended producer responsibility (EPR) schemes were set-up in order to provide a separate collection scheme for selected recyclable streams. It is reported that informal collectors, in some cases, use the expensive EPR infrastructure to directly pick out of designated collection bins. This decreases the quantities of incoming valuable materials, increases the operating costs, damages the established collection infrastructure and demotivates the inhabitants to separate waste (EXPRA, 2014). In many cases the reaction was to adapt collection infrastructure to prevent direct access. The participants at a workshop in Bucharest dealing with informal collection activities in Eastern Europe agreed that the rapid development of informal collection in the region has been caused by the increased value of some recyclable materials, social problems and poverty, a lack of legal provisions regarding the ownership of waste, a lack of effective enforcement of existing legislation, and no clear definition of the responsibilities and scope of action for different stakeholders. The lack of official data was cited as one of the major problems in the sector. The informal sector usually keeps no records of its activities, and therefore it is difficult to estimate its potential contribution to waste collection, processing and recycling services. In order to better understand informal waste management systems, their participants and the values attached to the waste, methodologies assessing their contribution to recycling and reuse are required. Due to the specific characteristics of the informal sector and its varying framework in different regions (see Table 2), different methodologies to conduct assessments are needed. On the one hand key performance indicators on the size of the informal sector and collected quantities per time unit may be used for rapid appraisals (Linzner and Lange, 2013; Linzner and Salhofer, 2014). On the other hand, applying methods to estimate size and contribution of the informal sector it is important to consider different methods simultaneously, e.g. by using interviews and traffic counting. Different methods shall allow narrowing down the magnitude of informally collected quantities, in other words: one cannot expect to receive very accurate results. Estimates on the quantities of informally collected waste are just the beginning in planning new or adapting existing waste management systems. It is of paramount importance that changing (modernising) waste management systems require holistic approaches: a focus shall be put on inclusive systems, where formal and informal systems may interact rather than to eradicate informal recycling.

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5 Main findings

In the following the main findings of this doctoral thesis are presented. As described in Chapter 2.2 informal activities are per definition difficult to assess as this sector has no inherent reason, obligations or simply not the capabilities to keep records on its activities, e.g. on the quantities of recyclables collected. The motivation to obtain information regarding its activities is different (see Table 2).

Several methods for estimating the magnitude of informal work were developed based on direct and indirect estimations and calculations, but mainly aim at determining the percentage of GDP that is informally produced. In terms of informal work in waste management, mainly the official performance data provided by formal stakeholders usually do not cover informal systems; official waste statistics do not reflect the big picture in low- and middle-income countries. Therefore, for waste management planning or monitoring purposes it is of paramount importance to obtain data on informal systems.

This doctoral thesis provides different methodological approaches on measuring informal waste recycling sector performance. Basically the presented options relate to an (informal) recycling value chain approach with the goal to map out waste flows within a geographical region and to consider mass balances in order to calculate different waste streams (see Figure 3 and Figure 4).

Methodological approaches to estimate quantities of recyclables that are informally collected within a waste management system depend on the availability and quality of waste-related data. Generally speaking, sources of information that can be used are available at the level of waste generators, or are related to information provided by the formal waste management stakeholders. Options to estimate data regarding the informal share of diverted recyclables are to use Key Performance Indicators or surveys.

The concept of triangulation to cross-check results from KPI or survey estimates proves to be a promising approach to narrow down the quantities informally collected. Below the main challenges of assessing informal waste management systems are discussed.

5.1 Challenges of assessing informal waste management systems

As starting point, it proves to be advantageous to map the waste management system in terms of a value chain and material flow approach from the point of waste generation until the point of final disposal and final destination of recyclables. Sometimes it might be challenging to find out what stakeholders are involved to what extent and where in the (informal) recycling value chain, but it is important to “understand” the material flows.

When carrying out surveys it is possible to obtain information on the quantities collected per time unit, but often the number of involved pickers in a system is the great unknown. From a statistical point of view, it is therefore recommended to obtain valid data on quantities collected to reduce overall insecurities in extrapolating survey results to larger geographical regions. In addition, survey results can consider informal realities in terms of quantities collected for example as “specialist” for a certain recyclable stream or as “generalist”. Thus surveys may include data focussing on qualitative information on the living and working conditions, values, attitudes, beliefs, motivations and problems related to informal work. One

option to examine the size of the IRS is related to counting campaigns (see Chapter 3.3.2.3.2). Difficulties arise due to the mobility of informal waste pickers; double counting have to be avoided.

There is still need for additional research on KPIs: for example, extended information is needed on quantities collected per time unit for different recyclables, but also for different locations, e.g. difference in quantities between street waste picking and landfill picking. Estimations based on KPIs are only indicative values and therefore have to be seen as rough estimates. Informal waste recycling sector realities vary from region to region therefore estimates based on KPIs have to be cross-checked. Different methodologies can be used for the estimation of informal sector collection and recycling rates, but the results of these estimations have to be verified via triangulation. The more triangulation points are available in a system the better is the verification of data leading to more plausible results.

KPI estimates can be considered as contact-free option to make estimates on IRS contribution to recycling, nevertheless on-the-ground research is indispensable in order to obtain “real life” data and information - it is not reasonable to evaluate informal activities from the distance only.

Special challenges and difficulties of researching informal waste management systems are largely the same in different cities of the world:

- The IRS itself has often not the capacities / needs / interest to keep records on its activities.
- Sometimes there is a high level of discrimination against ethnic minorities involved and waste pickers in general.
- It might occur that IRS escapes all data collection efforts of the authorities. This can be related to mistrust, negative experiences made in the past or similar. In such an environment special care has to be taken when approaching informal sector individuals.
- Waste pickers work informally, follow no schedules and sometimes they follow no collection route. They often cannot explain what they do in terms of the conventional units of measurement researchers know, i.e. kilograms or kilometre (inability of pickers to determine the exact quantities of materials they collect).
- Waste pickers may be either ashamed of sharing information about their work or fear that they may be persecuted for the information they provide. When they are willing to talk they are on the run to collect more and don’t always have the time to answer too many questions.
- Waste pickers work informally and may not be registered. It can happen that a significant fraction of informal waste workers consists of illegal immigrants, possessing no papers, no permit to live in a country and often have a very poor command of the local language.
- Language barriers between interviewers and interviewees; this occasionally caused some difficulty in understanding the questions of the questionnaire.
- Employees and owners of “higher levels” in the informal recycling value chain, e.g. scrap yards are often reluctant to provide information on quantities of materials received and sold, fearing fiscal or legal audits.
- Data collection on the informal recycling sector is only possible at local level but there are no “formal” data at local level as most of the official data is reported at national level.
- Also for interviewers cases of threats may occur: either from people that may be involved in illegal activities near the street pickers’ area of work, or from some street pickers themselves who may have felt threatened.

5.2 Modernisation of waste management: inclusive or competing systems?

When new system parts to improve solid waste management are introduced and investment decisions have to be made, a key question often asked is where and how to make those investments to maximise the intended outcomes. This is of crucial importance in the case where formal and informal systems enter competitive situations: this usually happens, when formal systems recognise that the collection, processing and selling of recyclables may lead to revenues. Especially in the low-income countries the only options to "earn something" as where poverty is prevalent, it is difficult to collect waste fees.

The main question is whether to use the knowledge and experience of existing systems where informal actors play a key role and built up informal recycling value chains or to strive for modernisation, excluding this knowledge, and to focus more on large-scale technologies (which unfortunately often stand for modernisation in low-income countries, ignoring socio-cultural and economic feasibility).

Formal and informal systems have different values, attitudes, drivers, motivations, capabilities and beliefs towards waste, inclusion in this case means that existing informal systems are given an equal or preferred opportunity to deliver the goals of improved collection and recycling rates.

For future developments and decisions to be taken on how to introduce modernisation processes that are sustainable, the following issues have to be considered (see also Linzner and Ali (2013)):

- At the planning and policy level it is important to establish that inclusivity means that both the informal and official systems are equally important and could exist side by side, rather than one needing to be a sub-set of the other. Care needs to be taken on how to design the interface between these two systems, especially when the systems interact with each other. Both will need support for data, information and planning, but the nature of that support will be very different. Demarcation of the operating space in terms of waste stages and geographical area needs to be done at the stage of strategic planning and policy development. Informal systems will need protection. Planning and policies are the stages when different perspectives about waste need to be understood and incorporated.
- For good planning, data and information are needed. At this stage conventional waste-related data and use of planning methods could inevitably push out the informal systems, as these data/information sets are designed for conventional planning of waste systems, with the ultimate conclusion of more investment. For example, in the case of informal systems, business and marketing support may be more important, whereas in the case of modern systems, technical, policy and legislative support may be the centre of attention. Inclusive planning activities should consider extended data sets on informal activities, such as the reliability of the systems, viability and quantities captured over time, quality of the materials collected, achievable prices, necessary provision of sorting space and so on. Analytical methods such as value chains could be more useful for the existing systems, while the methods for the environmental analysis, such as environmental impact assessment could be more relevant for the modern and official systems. Imposing all

the tools on all the actors, without understanding their perspectives, could lead to confusion and collapse of less powerful actors.

- In some cases, it will be necessary to shut down some existing informal systems to create space for the modern systems and vice versa. Such closures may have a negative impact on the livelihoods of certain groups. This needs to be carefully handled, with safeguards put in place through rehabilitation and substitution of livelihoods programmes. Potential losses of livelihoods of affected groups need to be understood and analysed carefully.
- When both the systems are operational side by side, monitoring of both the systems is required to ensure that both are contributing to the same goals, although possibly through different pathways and approaches. Monitoring indicators need to be developed and a supportive environment needs to be maintained for both systems.
- Finally, it is expected that further research into and publications about informal systems will enable more influence and impact for the informal sector. This means it is necessary to draw a more inclusive and broader picture at the beginning. With this research there should then be a framework containing financing, institutions, values, actors, motivations and other factors, with a clearer indication on what needs to change and how.

In the European context, the EU is currently facing several difficulties related to its foundations: on the one hand, economic crisis led to problems including increased unemployment rates. In addition, the recent refugee migration into the EU may also result in a situation where more and more people are forced into informal work. Experience shows that banning and eradicating informal activities (e.g. by preventing access to waste materials and bins) is often not easy as informal activities pop up frequently at different (other) places.

In order to change IRS activities motivation and added value is needed, otherwise informal stakeholders won´t change their habits, especially when the revenues made are good compared to other (informal) businesses. Added value could be related to school enrolment for pickers´ kids or programmes supporting that kids are not at landfills / dumps anymore, regular and probably higher revenues, improved working conditions, access to health services, registrations and issuance of IDs (some European pickers are refugees from the Yugoslavian wars still without registration) etc. When thinking on inclusive issues one has to consider trade-offs between revenues and the other added values.

When formal and informal systems shall work together careful collaboration is needed: on the one hand two complete different worlds are involved, sharing one common thing: the interest in collecting valuable recyclables. The IRS has a non-governmental, non-industrial perspective and therefore different values attached to their activities / waste. It has to be considered that street pickers with their type of occupation respond to a market demand for raw materials (recyclables) and not to environmental issues.

Forming associations and interest groups could be an option to support informal systems: it might build up trust and support, helps to understand realities, opens communication paths and also probably increases achievable per kg prices in case it is directly bargained with middle-men, scrap yards, dealers or directly with the industry. This also strengthens their voice and therefore their bargaining power as frequently inequalities are reported related to the next levels of the informal value chain (e.g. scrap dealers refuse to pay “good” prices).

Often it is difficult to approach informal recyclers directly, e.g. due to language issues or bad experiences made in the past. Intermediaries are therefore needed; this part could be taken

by research institutions with linked projects or NGOs having experience in advocating IRS. Experience shows that it might happen that advocates are defending the IRS but do not understand the perspective of the counterparts (i.e. formal waste management system, EPR schemes etc.). Nevertheless, the discourse has to be planned and carried out carefully, it is necessary that both “worlds” understand each other’s motivations and drivers – solutions have to be developed jointly.

Owing to the economic recession, the continuing growth of urban agglomerations and increasing market prices for secondary raw materials it can be expected that the number of people involved in informal waste collection, recycling and trading activities will further increase. It is therefore time to rethink potential future developments in waste management in the context of low-income countries. It seems that the globalised waste business keeps an eye on the huge market potential of the developing world and fears that informal actors already occupy strategic places for future materials and potential revenues and profits, even in regions where no primary collection service exists. Inclusive approaches have the goal of ‘killing two birds with one stone’: on the one hand to improve the overall system performance and the related environmental, social and economic goals, and on the other hand to build on the existing strengths and experience of an army of informal actors.

Of course issues of reliability and efficiency of the informal sector have to be discussed, but what matters is a step-by-step process where, for example, the technology-based waste industry takes over certain parts of the system or enters at certain stages of the recycling process. One thing is important: changes in behaviour and in practices need an added value, especially for informal actors, and this cannot always be expressed in terms of profits.

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7 Annex 1

Photo 1: Informal sector in urban China (upper left: informal street picker, upper right: tricycle, lower left: truck used for informally collected waste paper, lower right: procedures at an informal recycling market in Beijing. All pictures © ABF-BOKU

Photo 2: Informal UBC collection activities in Europe (upper row: Athens (Greece), middle row: Sofia (Bulgaria), lower row: Vienna (Austria))

Photo 3: Landfill picking activities in Addis Ababa (Ethiopia)

8 Curriculum Vitae

1	**Family name**	RAMUSCH (né Linzner)	
2	**First name**	Roland	
3	**Date of birth**	19.08.1973	
4	**Nationality**	Austrian	
4a	**Contact** Address(es): Phone: Fax: E-Mail: Link:	Home: Kutschkergasse 1/28, 1180 Vienna, Austria Work: Institute of Waste Management, Muthgasse 107, 1190 Vienna, Austria 0043 / 1 / 318 99 00 -336 0043 / 1 / 318 99 00 -350 roland.ramusch@boku.ac.at http://www.wau.boku.ac.at/abf/personen/roland-ramusch LinkedIn: Roland Ramusch	
5	**Education / Professional studies**		
	Dates (from-to)	Institution	Degree / diploma
	10/1994 - 07/2003	University of Natural Resources and Applied Life Sciences, Vienna (BOKU-University)	M.Sc. in Environmental Management

6	**Language skills -** Common European Framework of Reference for Languages (* = mother tongue)			
	Language	Understanding	Speaking	Writing
		Listening / Reading	Spoken Interaction / Spoken production	
	German	*	*	*
	English	C2 / C2	C2 / C2	C1
	June 2002: passed Test of English as a foreign language (TOEFL)™			
7	**Skills**			
	Social skills and competences: good ability to adapt to multicultural environments, gained through work experience abroad; good communication skills gained through experience in associations; good presentation skills. Organisational skills and competences: sound experience in project acquisition and calculation, project and team management of small and large-scale research and implementation projects; experience in training activities and workshop organisation in multicultural environments.			

	Computer skills and competences: good command of Microsoft Office™ tools (Word™, Excel™ and PowerPoint™); good knowledge of e-learning implementation and tools. Lecturing and training: Courses "Global Waste Management II" and "Waste management planning and assessment" both at the BOKU-University, Vienna. Preparation and conduction of several training courses on waste management for IFC, organic waste management courses in different African countries, training on waste and environmental management in South America and Asia. Internal training courses at BOKU University: teaching in an international class room, solution-driven conflict management, project management training.		
8	**Membership of professional bodies and journals**		
	• Since 2005: Board member of the Centre for Development Research (CDR) at the BOKU-University, Vienna. More information: http://www.boku.ac.at/cdr/personen/our-partners/ • Member of the International Waste Working Group (IWWG) Task Group on Developing Countries (http://www.tuhh.de/iue/iwwg/task-groups/developing-countries.html); and Task Group on Informal Recycling. • Member of the Editorial Advisory Panel of the Journal "Waste and Resource Management" (http://www.icevirtuallibrary.com/content/related/panel?pubId=warm) • Member of the Scientific Advisory Panel CO2-compensation at the University of Natural Resources and Life Sciences, Vienna Reviewer and referee in several Scientific Journals: Waste Management and Research; Waste Management; Proceedings of the ICE - Waste and Resource Management; Resources, Conservation and Recycling; Habitat International; Environment, Development and Sustainability; Österreichische Wasserwirtschaft; Politische Ökologie		
9	**Name of organisation currently working for** **Present position in the organisation**	University of Natural Resources and Life Sciences, Vienna (BOKU); **Institute of Waste Management**. Research associate, lecturer	
10	**Awards**	BOKU Teaching Award 2014: 3rd place with the lecture "Planning and assessment of waste management systems"	
12	**Professional experience record**		
12a	Location	Date	Organisation
	Vienna, Austria	Since 2003	University of Natural Resources and Life Sciences, Vienna (BOKU); Institute of Waste Management
	Position	Research associate and lecturer	
	Responsibilities	Development, acquisition, implementation and management of various small and large-scale research projects dealing with waste logistics, composting, waste management and its impact on climate, waste management in developing and newly industrialising countries and capacity development (training courses and development of master courses).	
12b	Location	Date	Organisation

	Belgrade (Serbia)	07/2002 to 09/2002	University of Belgrade
	Position	Research internship in Belgrade	
	Responsibilities	Master thesis "*Municipal Solid Waste Management in the City of Belgrade – Current Situation and Perspectives*"	
12c	Location	Date	Organisation
	Linz, Austria	1992-1994	Mayreder Bau GmbH: Technical construction of Bridges
13	**Selected publications** (see: https://forschung.boku.ac.at/fis/suchen.person_uebersicht?sprache_in=de&menue_id_in=101&id_in=5547)		