Waste Free Cities: Pathways to Future Smart Cities in India

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A thesis submitted in partial fulfilment of the requirements of the University of Greenwich for the Degree of Doctor of Philosophy

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DECLARATION

I certify that the work contained in this thesis, or any part of it, has not been accepted in substance for any previous degree awarded to me, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations, except where otherwise identified by references and that the contents are not the outcome of any form of research misconduct.

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ABSTRACT

Rapid urbanisation worldwide has led to unplanned increases in the population of some cities. This has resulted in a number of social and environmental problems such as space, traffic congestion, housing, and increased waste volumes. Various concepts of sustainable and smart cities have been developing as platforms of solutions to these issues, including urban waste management problems. The 'green and sustainable' cities concept focuses on environmental perspectives and the 'smart' cities concept focuses towards technological solutions. For a variety of reasons, application of these solutions to developing countries is very restricted. Moreover, issues such as waste management have so far been given less consideration although they can significantly contribute towards smart urban objectives.

As a response, this research project engaged in further developing the concept of waste free cities as an integrated framework that links waste management with smart cities' objectives. The research utilised the case study method by considering three cities in India. The key stakeholders in the cities' waste management operations were identified and primary data were collected through citizen surveys as well as structured interviews with the local authorities, NGOs, private entrepreneurs, and the wider informal sector.

The waste free cities concept was developed by following a holistic approach and considered various aspects such as environmental protection, healthy living, governance, stakeholders, awareness, among other criteria. The research identified the contribution of waste management towards the smart and sustainable resource utilisation. During the transformation of waste to a resource, the value adding activities associated with it are identified by mapping the waste value chains.

The major finding shows that the city having highest level of stakeholder interaction and greater degree of collaborations resulted in higher value addition to waste and showed a positive effect towards the smart transformation when waste free cities framework was applied. The findings also pointed towards the significant contribution of the informal sector in helping these three cities meet smart objectives besides contributing in effectively managing waste volumes. The research contributes to the theories for waste free cities and provides strategic, operational and tactical recommendations that can have an impact in the formation of smarter and cleaner cities in developing countries.

Keywords: Waste management, sustainability, smart cities, stakeholders, developing countries

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ABBREVIATIONS

AMO	Assistant Medical Officer
CBO	Community Based Organisation
CCC	Clean City Championship
CDP	City Development Plan
CMOH	Chief Medical Officer of Health
CPHEEO	Central Public Health & Environmental Organisation
CSO	Central Statistics Organisation
DRCC	Dry Recyclables Collection Centres
EPR	Extended Producer Responsibility
GDP	Gross Domestic Product
GO	Government Order
GoI	Government of India
GPS	Global Positioning System
GVMC	Greater Visakhapatnam Municipal Corporation
GWMC	Greater Warangal Municipal Corporation
ICT	Information and Communication Technology
IMF	International Monetary Fund
IoT	Internet of Things
ISWM	Integrated Solid Waste Management
IT	Information Technology
KMC	Kakinada Municipal Corporation
LA	Local Authority
MoEF	Ministry of Environmental and Forest
MoHUA	Ministry of Housing and Urban Affairs
MoU	Memorandum of Understanding
MoUD	Ministry of Urban Development
MRF	Material recovery facility
MSW	Municipal Solid Waste
NGO	Non-Governmental Organisation
PAYT	Pay As You Throw
PH	Public Health

PPP	Public Private Partnership
RFID	Radio Frequency Identification
RWA	Resident Welfare Association
SME	Small and Medium Enterprises
SWaCH	Solid Waste Collection and Handling
SWM	Solid Waste Management
TPD	Tons Per Day
ULB	Urban Local Body
WtE (W2E)	Waste to Energy
WtF (W2F)	Waste to Fuel
WOW	Well-being Out of Waste

Chapter 1: Introduction

1.1 Introduction

Cities are engines of economic growth offering opportunities which attract people. Rapid urbanisation and the associated influx of people to cities have resulted in drastic population growth which is beyond the capacity of cities. This resulted in various problems such as resource depletion, infrastructure, mobility, social segregation, housing space, water, energy, waste management, etc.

This population growth and life style in cities have resulted in high volumes of waste generation (Filho *et al.,* 2016) which has become a global problem. It is expected that waste generation would reach 2.2 billion tonnes by 2023 and 97% of it would be produced by developing countries in Asia and Africa (Navigant Research, 2014). According to Shekdar (2009), Asian continent alone has six highly populated countries in the world (namely, China, India, Indonesia, Pakistan, Bangladesh and Japan) with 3.7 billion people of which 1.38 billion live in the urban areas. According to Bandara *et al.,* (2007) waste generation is proportional to population and living standards of people. Hence, it is expected that the Asian cities would contribute to higher waste generation.

Waste is perceived differently from person to person. Waste generated by one person may be treated as a resource by the other person (Zaman and Lehmann, 2011) and this results in circular flow of materials (Ilic and Nikolic, 2016b). This approach in waste management not only helps in gaining value but also minimises its effect on environment due to the reduction of waste sent to landfills (Matete and Trois, 2008), providing raw material for manufacturing industries, energy generation, etc. (Cheng and Hu, 2010).

The solid waste generated in cities of developing countries is comparatively lower than developed countries, but its management is inadequate (Prokic and Mihajlov, 2012). As the waste management sector is infrastructure intensive, the developing countries are unable to afford it (Annepu, 2012). In addition to lack of financial resources (Kumar *et al.*, 2009), lack of citizen participation, their unwillingness to pay user charges (Sujauddin *et al.,* 2008), lack of suitable machinery (Kumar *et al.*, 2009), inadequate education and knowledge of stakeholders, scarce trained staff, low service quality are also some of the reasons for its poor management (Ilic and Nikolic, 2016a).

Developed countries prioritise recovery from waste due to the concern for environmental protection, recycling rate targets, need for resources and high landfill taxes which drive an

efficient waste management system. In developing countries, the concern is public health for which waste is collected and transported away from the city to avoid residents' exposure to accumulated waste (Wilson, 2007). It is estimated that around 30-70% of waste generated is collected and most often disposed into open dumps generally in the city's outskirts (Ezeah *et al.,* 2013).

The composition of waste in developing countries is predominantly biodegradable, out of which food, paper and cardboard have major share of waste and can be reused (Ilic and Nicolic, 2016b). Though waste minimisation is emphasised, most proportion of waste in developing countries is considered unavoidable due to the differences in life styles (Wilson *et al.,* 2015b). This draws more attention on source segregation, recycling and resource recovery from waste. Source segregation requires participation of citizens and it is seen as a challenge in developing countries (Srivastava *et al.,* 2015). The recycling process is greatly contributed by the informal sector and waste dealers. It is estimated that 15-20% of the waste is collected by the informal sector in most developing countries (Gupta, 2012). Their presence has a significant role in recycling activities in countries like Egypt, India, China and South Africa (Jaligot *et al.,* 2016; Srivastava *et al.,* 2015; Ezeah *et al.,* 2013 and Gupta, 2012). They are often given low social status and are considered as a social stigma without considering the benefit they bring to the society and local authorities (Praveena *et al.,* 2015). There is a need to integrate them into the formal waste management chain to support as well as promote the recycling performances. There are several stakeholders whose participation determines the value generated from it. The complexity and multi-dimensionality of the system affects the entire process from waste collection to recovery and disposal. These also resulted in poor waste management in developing countries and local authorities continue to face the challenge of managing the waste and recovering value from it.

The concept of smart cities was developed in 1990's as a strategic innovation to respond to changes caused by urbanisation and make the cities liveable and fuel sustainable development (DBIS, 2013). There is no single definition accepted for smart cities and is often seen as use of modern infrastructure and digital technology to tackle the urban problems. Smart cities are considered as the "future reality of all municipalities around the world" (Zaman, 2015, p3). The smart cities constitute two domains namely the hard and soft. The hard domain refers to the areas where infrastructure and technology have a decisive role to play. The soft domains refer to the areas such as governance, policy, stakeholder collaboration, education, etc. where technology does not have a decisive role

to play in most cases. Waste management in smart cities is viewed as a hard domain (Albino *et al.,* 2015). Hence, in the process of making cities smarter, waste management sector has seen technological advancements and infrastructural upgrade to manage the growing waste volumes and is often referred as smart waste management. It is applied throughout the waste value chain including collection, processing, recovery and disposal. There are many cities in developed countries that started to commercialise these technologies but developing countries have not actively adopted them due to financial constraints. Solid waste management sector consumes greater proportion of cities' budget to provide the service, and technological adaptation is an added investment. The payback period for such investments is long. Therefore, it is a challenge to strike the balance between cost effectiveness and quality of service offered while upgrading the infrastructure particularly for developing countries due to the pace of urbanisation and limited resources (Ahmed and Ali, 2004).

The concept of sustainability development has emerged as a response to the growing imbalances between human activity and environment. It emphasises on urban sustainable development by drawing a balance between social, economic and environmental dimensions (Hiremath *et al.,* 2013). But according to Ahvenniemi *et al.,* (2017), waste is only studied with environmental priority but does not study the benefit it's management could bring to social and economic dimensions. These differences in priorities and approaches in managing urban waste, restrict the concepts of sustainability and smart cities in developed countries.

There are cities in developing countries that are aiming to transform to smart cities. But viewing smart cities only as a technological adaptation decelerates the process due to financial constraints particularly in waste services. The literature on waste management in developing countries confirms that, policy, stakeholders and governance are important factors to achieve integrated sustainable waste management (Wilson *et al.,* 2013; Shekdar, 2009). Hence, from developing countries' perspective, waste management should be seen as a soft domain of smart city rather than hard domain. The soft domains such as governance, multi-stakeholder participation and collaboration are important in smart cities. Mapping the role and participation of stakeholders result in understanding the relationship and interactions between them. These interactions between multiple stakeholders help in value creation (Mayangsaria and Novani, 2015; Polese, 2009). It is also evident from literature that stakeholder collaboration and interactions are important for value addition to

waste and resource recovery. Hence, interactions are drivers of value creation in managing waste services of developing countries in smart cities.

The integration of stakeholders and their collaboration can provide a solution to the waste management system in transforming smart cities of developing countries. Therefore, waste management in a smart city should not only be considered as the use of smart waste management and should consider improving soft domains. The benefits offered by effective waste management of the city and its contribution for the transformation process is not identified and waste management is seen as one of the sectors that need improvement for the city to transform into sustainable and smart city. This is identified as a gap from a circular economy point of view. The research relates the transition process to a smart city and integrates the mutual benefit with waste management sector by considering the factors that affect it, including the use of technology in developing countries. This gap is filled with the development of waste free cities concept and the overview of the research is shown in figure 1.1. It identifies the relationship between sustainability, smart cities and waste management using real world scenarios while considering both soft and hard domains. Due to the importance of stakeholders and value creation through collaboration, their interactions and activities are mapped. To justify the study of soft domains, the research draws its relevance to stakeholder theory proposed by Donaldson and Preston (1995). The theory has three approaches. Descriptive approach which observes reality and corelates to embedded theory by studying the behaviours. Instrumental approach connects the stakeholder management and their performance. The third approach is normative which explains the ideal behaviour of stakeholders and organisations. The research takes the stance of descriptive approach and extends it to the instrumental approach as it first identifies the practices in the real world and relates them to the existing concepts of smart cities and waste management. It extends to the instrumental approach as it includes the factors that help in improving stakeholder collaboration and the effect on value addition to waste.

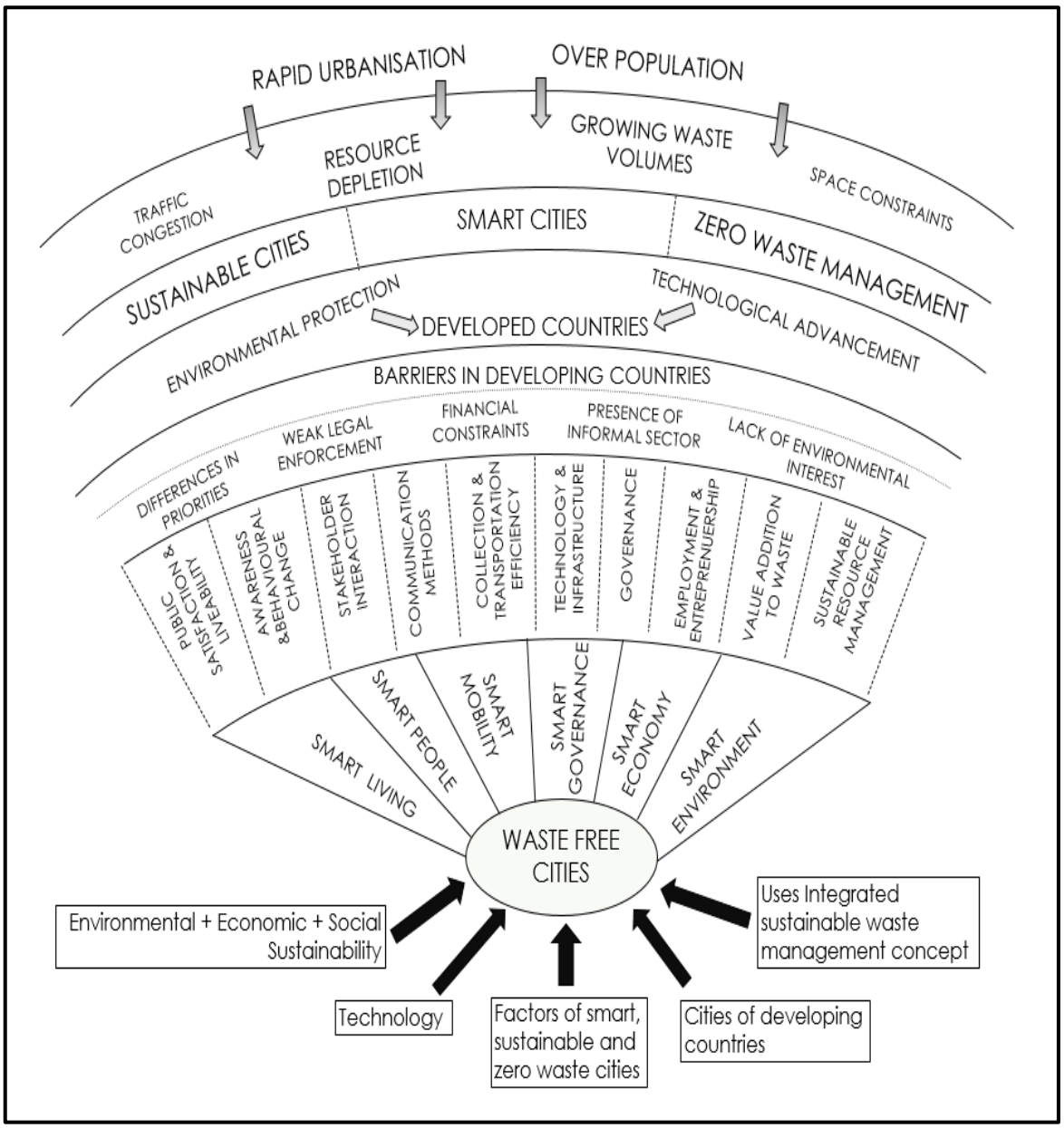


Figure 1.1: Overview of the research (Source: Author)

1.2 Significance of research

There is a gap in research as it fails to show the relationship between waste management, sustainability and smart cities. There are several works on waste management and the significant works in the recent time that are applicable for developed and developing countries are by Wilson *et al.,* (2015a) and UN-Habitat (2010). The research on waste from circular economy point of view is conducted by Zaman and Lehman (2013) which developed the concept of zero waste but is restricted to developed countries and do not relate to smart cities and sustainability concepts. The works of Ahvenniemi *et al.,* (2017) and Bibri and Krogstei (2017) relate sustainability and smart cities but do not consider waste management sector. Similarly, there are several studies on smart cities and consider

many characteristics of it (Eremia *et al.*, 2017; Chourabi *et al.*, 2012; Giffinger, *et al.*, 2007).

Chowdhury and Chowdhury (2007), Abdoli (2009) and Iriarte *et al*., (2009) have related waste management to smart cities but restricted their study to developed countries by limiting to application of smart waste technologies. Their studies did not consider the soft domain aspects such as stakeholder collaboration, policies, incentives, etc. that affect the process. Work of Peltola *et al.*, (2016) identifies the need for mapping and roles of stakeholders in waste management to understand its effect on value creation. This study does not relate to its benefit to smart cities and the types of possible stakeholder interactions are not identified. Hence, there is a need for research to study the relationship between the three concepts. This research develops the concept of waste free cities that shows such relationship and is also applicable for the cities in developing countries.

The research has practical significance as it provides a theoretical framework. The framework comprises of factors that affect the waste management and are divided into sustainability and smart city categories according to their relevance. Each factor is measured using one or more indicators. Hence, it can be used to relate how each waste management factor is affecting the smart transformation and identify the problems that hinder the performance by applying the framework. The research applies this framework in three Indian cities as empirical setting and limits the study to household waste. The research identifies the problems for smart transformation, value addition to waste and provides best practices to solve the problems.

1.3 Research Aims and objectives

Research Aim: The aim of the research is to contribute to existing knowledge by developing a theoretical framework that integrates urban concepts with waste management to achieve waste free cities in developing countries context.

Research Objectives: To meet the research aim, the following research objectives are formulated.

RO1. To *map* the value generating process of waste and identify the stakeholders

RO2. To *investigate* the role of stakeholder collaboration in value adding activities

RO3. To *identify* the indicators and factors that influence the transforming smart cities to become waste free cities

RO4. To *enrich* the theories by drawing relationship between waste management, smart and sustainable cities

RO5. To *provide* best practices as practical recommendations for achieving a waste free city

Research Questions:

RQ1. How does stakeholder interaction promote value addition to waste?

RQ1a. Who are the stakeholders in waste free cities?

RQ1b. How does the role of stakeholders' effect value addition to waste?

RQ2. How can a waste free city contribute towards the smart transformation of a city and achieve sustainability?

RQ2a. What is the relationship between waste free cities and smart cities?

RQ2b. What are the best practices that can be applied to achieve waste free cities in developing countries?

1.4 Structure of thesis

The thesis is broadly divided into four parts and structured as seven chapters. The first part is introduction which is presented in chapter 1. The second part is based on the existing research and is presented in chapters 2, 3 and 4 that are literature review, theoretical framework and research methodology respectively. The third part of the thesis is based on the primary research. This includes chapter 5 that provides the background of the case studies that are chosen for the research and chapter 6 which presents the results and discussions of the research. The fourth part is the conclusion of the thesis presented in chapter 7. The overview of the thesis, the details of chapters and the process to meet the research objectives are mapped and shown in figure 1.2.

Chapter one introduces the context of study. It explains the focus of the research, its significance and how the gap in knowledge is filled. It outlines the aim and objectives of the research and explains the structure of the thesis.

Chapter two presents the literature review. This chapter reviews the literature available for sustainability, smart cities and waste management. It provides the definitions and frameworks for urban sustainability. Similarly, it provides the working definitions and frameworks for smart cities, reviews them and focuses on the soft domains of smart cities.

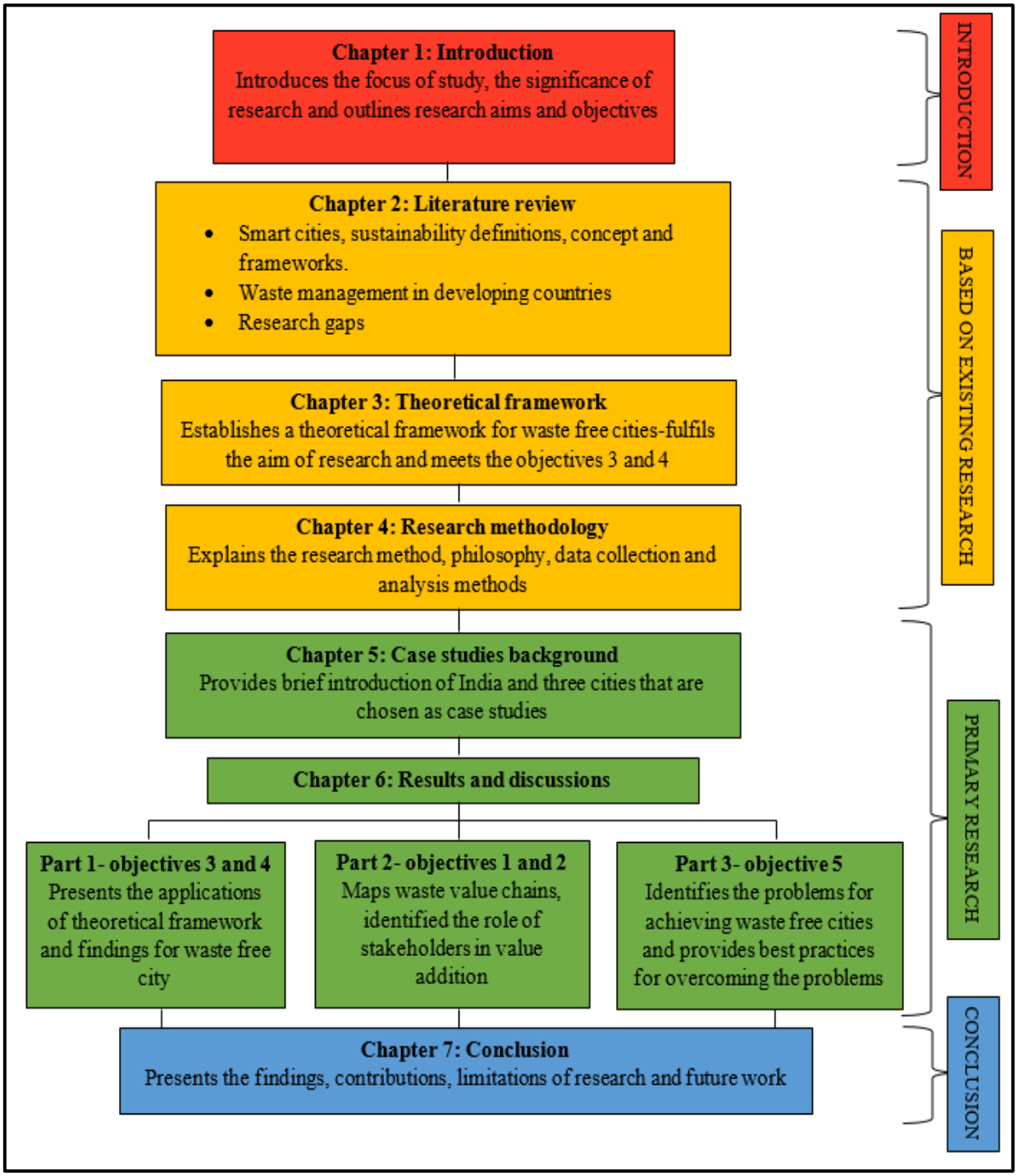


Figure 1.2: Structure of thesis (Source: Author)

The relevance of smart cities and sustainability with waste management is reviewed. The commonality between the topics is identified and highlights the gaps in research which did not integrate the waste management sector for smart city transformation particularly through soft domains.

Chapter three develops the concepts of waste free cities that fills the gap in knowledge. The concept is introduced and a definition for waste free cities is provided. A theoretical framework is developed that shows a relationship between the smart cities, sustainability and waste management. It facilitates in measuring the performance of cities in developing countries to show a transformation process through effective waste management and helps in comparing the performances of cities to learn from each other.

Chapter four describes the methodology followed for this research. It explains the research paradigm and research process. The data collection methods, analysis procedures, reliability and validity of the research are explained.

Chapter five provides background of the empirical setting of the research. An introduction to India, waste management status, its policies and governing structures are described. The India's smart cities mission and *Swachh Bharat* programmes are explained and the details on the three cities that are chosen as case studies are provided.

Chapter six present results and discussions of the research. They are divided into three parts. The first part of the chapter presents findings of the application of waste free cities framework and discusses them. The second part of the chapter extends towards the soft domains and maps the value chains for waste in three Indian cities, identifies the role of stakeholders and their contribution towards the value addition to waste. It identifies different levels of interactions among them. The third part identifies the problems for achieving waste free cities. It reviews the best practices in other cities and provides

applicable or transferable solutions to overcome the problem and achieve waste free smart cities.

Chapter seven provides a conclusion to the thesis. It presents the findings of the research and contributions from academic and practical aspects. It provides strategic, tactical and operational implications of the research. It identifies the limitations of the research and indicates the future work.

Chapter 2: Literature Review

2.1 Introduction

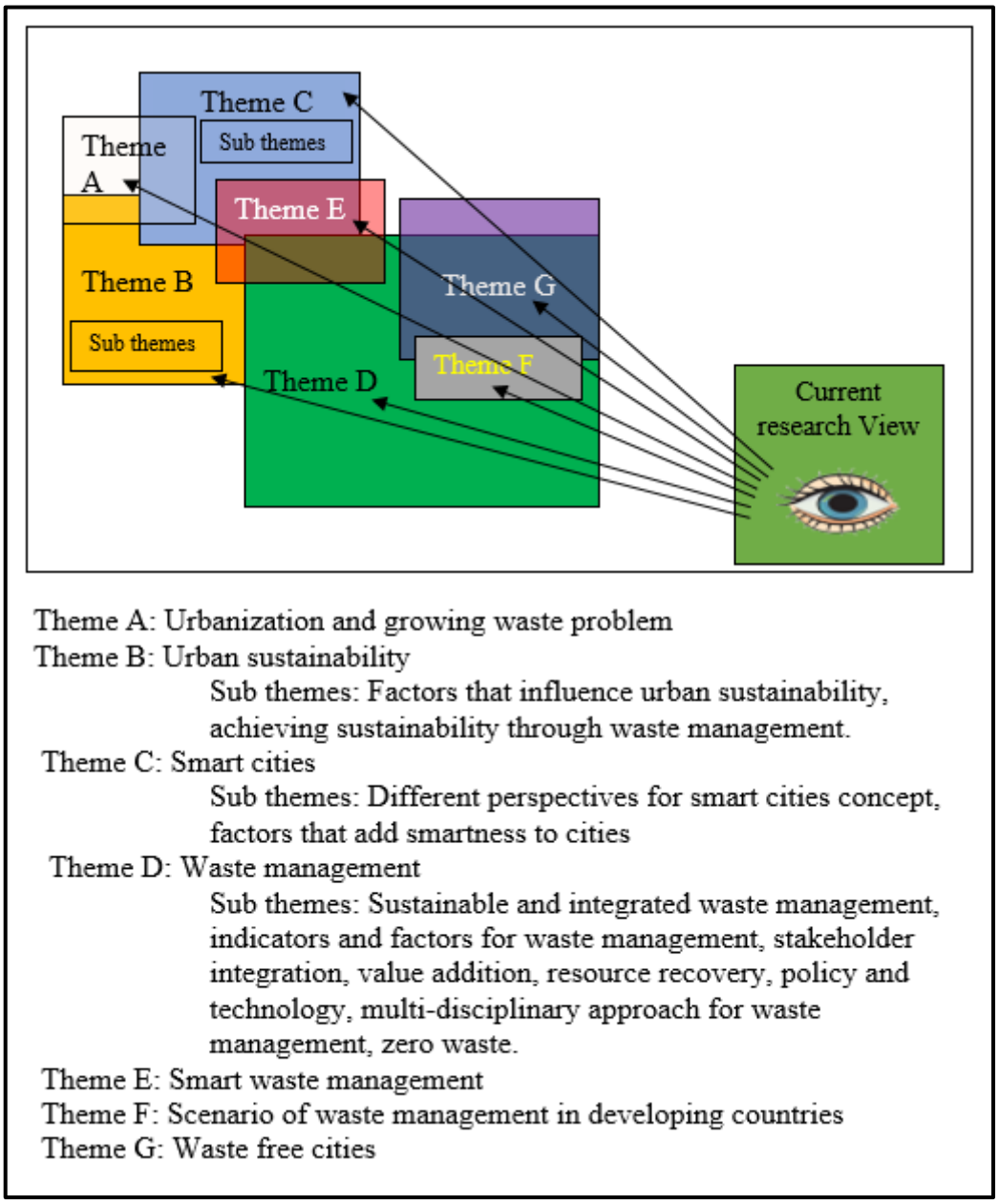
Conducting a literature review is important to know what has already been done in the field of study and identify what the current study can add to the wealth of knowledge (Kotzab *et al.*, 2005). Hence, the objective of this chapter is to critically review the existing literature in related fields to this research and identify the gaps.

The concept of waste free cities is new and consequently existing literature in this area is limited. So, the related areas of research are reviewed and are categorised into themes as presented in the figure 2.1 to show a relevance to the current research. They include, population growth and urbanisation which set the context to urban problem and the need for sustainable and smart cities. Hence, the concepts of urban sustainability and smart cities are reviewed along with their definitions and frameworks. Since, growing waste volumes is a major urban challenge and is the context for the current research, literature related to sustainability, waste management, similarly smart waste management are reviewed as their sub themes to know how these urban concepts provide a solution to this problem. It is also presented how these solutions can benefit economy, society and environment to achieve sustainability. Following this, literature pertaining to waste management, particularly from urban context is reviewed. The review provided insights on the indicators and factors that must be considered for sustainable waste management. The differences in scenarios for managing waste in developed and developing countries are reviewed. From these reviewed topics, the gap in the literature is identified and a need to develop the concept of waste free cities is justified.

2.2 Method of review

The review of literature focuses on waste management as the important area of study due to its need in urban environment. The literature on sustainability and smart cities is reviewed to understand their need, their function and their use in manging waste effectively as these concepts gain importance to improve the urban environment. The research emphasises from developing countries point of view due to the differences in waste generation, composition, stakeholders, ability to invest in waste treatment or infrastructure and legal enforcement when compared to the developed countries. The sources used for the information include articles from peer-reviewed journals, white papers, academic and grey literature. Some of the journals reviewed are Cities; Cleaner Production; Ecological Indicators; Habitat International; Journal of Industrial Ecology;

Journal of Urban Technology; Resources, Conservation and Recycling; Sustainable Cities and Society; Waste Management and Waste Management and Research.



Theme A: Urbanization and growing waste problem
Theme B: Urban sustainability
Sub themes: Factors that influence urban sustainability, achieving sustainability through waste management.
Theme C: Smart cities
Sub themes: Different perspectives for smart cities concept, factors that add smartness to cities
Theme D: Waste management
Sub themes: Sustainable and integrated waste management, indicators and factors for waste management, stakeholder integration, value addition, resource recovery, policy and technology, multi-disciplinary approach for waste management, zero waste.
Theme E: Smart waste management
Theme F: Scenario of waste management in developing countries
Theme G: Waste free cities

Figure 2.1: Various themes in literature review and their relation to the context of current research (Source: Author)

The search was performed using online databases and after a preliminary research, the research streamlined to more specific topics including smart waste management, indicators for urban waste and particularly for developing countries. From the sources selected initially, further relevant articles were scanned and used for the review. The literature reviewed is confined to solid waste and particularly household waste, while the other types

of urban wastes such as commercial and hazardous waste, waste water are not reviewed as it is out of the scope of research. The structure of literature review is shown in figure 2.2.

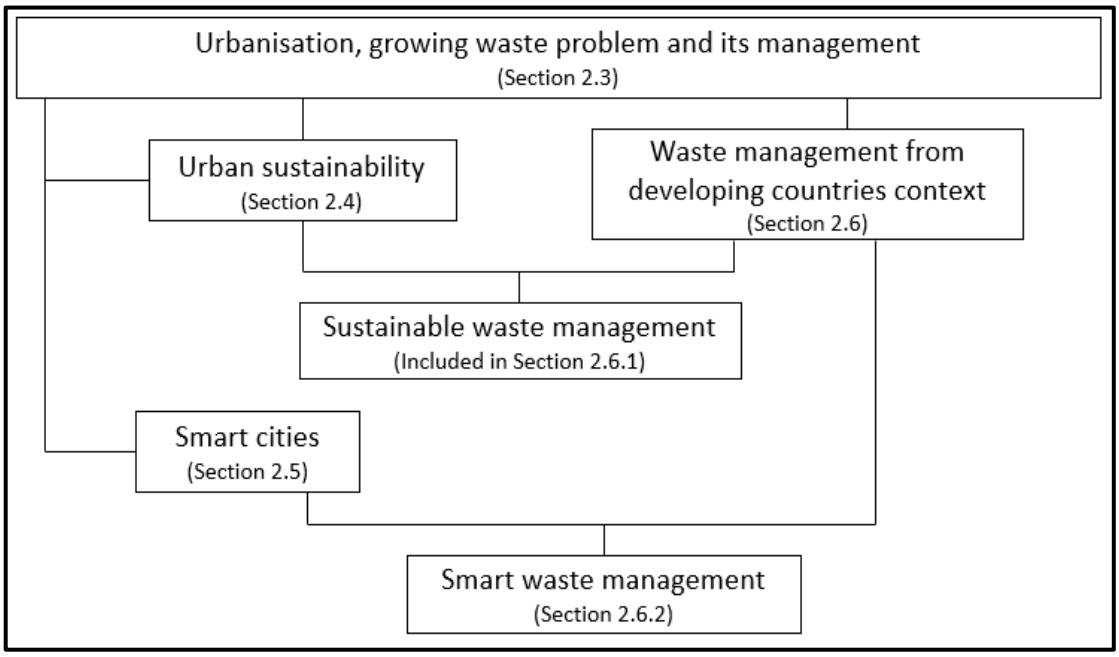


Figure 2.2: Structure of literature review (Source: Author)

2.3 Urbanisation and waste management

Urbanisation is at a fast pace around the world due to the economic benefits cities offer (United Nations, 2015). In developed or industrialised countries, the urbanisation is at a faster rate. Due to their high consumption behaviour, there is also high waste generation (Zaman and Lehmann, 2011). In developing countries, there is increased waste generation due to large population and a transition from low consumption to high consumption life styles coupled with urbanisation (Sharholy *et al.,* 2007). Hence, growing waste volumes and its management has become a global problem as introduced in Chapter 1. Waste management is often given less importance in city administration unlike other utilities such as water and electricity which also adds up to the problem (Filho *et al.*, 2016). To overcome the problems caused by urbanisation and to provide long term city plans by alleviating social inequalities and improve the life in cities, the concept of urban sustainability has gained importance. Though managing growing waste volumes is a pressure to the local authorities, managing it in a sustainable way is adding new challenges (Zaman and Lehmann, 2011). Sustainable urban waste management is gaining importance and local authorities are looking for solutions that can improve the current processes. Innovation and technological advancements appear to provide solutions for urban problems and to maintain urban sustainability that leads to the development of the urban concept

called smart city. The smart cities have developed models that use technology to manage many urban problems like water and energy management, traffic control, as well as waste management (Falconer and Mitchell, 2012). Since, waste generation and its management are affected by numerous factors such as behaviour, governance, policies, income levels, development status of countries or regions etc., no single model is proven to be successful in providing a solution for it. Hence, a more holistic approach and a need for integration of the concepts of smart cities, sustainability and sustainable waste management should be practiced. So, the following sections review each of them individually and draw relevance to waste management.

2.4 Urban sustainability

Sustainability is a concept that focuses on the natural system's importance and states that the societal actions should not lead to depletion of resources while satisfying their needs. The concept of sustainable development established as a response to environmental effects caused due to the human activities with its origin from the Brundtland Report. Sustainable development is "the development that meets the needs of the present without compromising the ability of future generation to meet their own needs" (WCED, 1987, p43). Since, economic growth and development are occurring at fast pace, they also bring many environmental and social challenges. Similarly, with increasing attention to environmental issues associated with failure of growth-based models that prioritise economic growth over environmental issues, there arises a need to develop new concepts or alternative models. Sustainable development does not inhibit the development but emphasises on to what extent it should be brought without affecting the other systems. It is a process to achieve long term sustainability by bringing a balance between ecological and social systems through a strategic approach (Bibri, 2013, 2015 in Bibri and Krogstie, 2017). Since, sustainable development provides a meeting point for environmentalists and developers (Dresner, 2002) it has gained wide attention.

Cities foster economic growth, swift development process and rapid urbanisation resulting in higher associated problems as explained in section 2.3 and urban sustainable development has gained importance. According to Hiremath *et al.*, (2013), developments of urban areas and environmental protection have to be balanced while maintaining equity in providing the urban services to achieve urban sustainable development. The author also includes transportation, infrastructure, shelter, employment, and income in addition to economic development and environment in urban setting. Hence, the author addresses social, environmental, economic and developmental aspects that are required in a city. In

similar lines, but with a more holistic view, Bibri and Krogstie (2017), states that urban sustainability is the balance between social equality, economic development and environmental protection with long term goals and strategies but can be achieved when the urban society strives for this. This view provides insights on the need to integrate stakeholders in urban environment for collective actions. This can help in minimising demand and use of resources and reduce the overall associated environmental impact. The author's view also reiterates on the reduced material use and waste generation as the result of urban sustainable development besides providing healthy living conditions. Such an integrated development in cities make them sustainable cities as they can maintain a balance between their production and reproduction capacities over time, as stated by Castells (2000).

The Brundtland report also provides such views as it categorises sustainability into social, environmental and economic sustainability. They are later called the three dimensions of "triple bottom line", a concept developed by Elkington (1998 in Gimenez *et al.*, 2012) which is most widely used for sustainability. It prioritises a bottom up approach in achieving them by showing the importance of citizen centric approaches. Moreover, it identifies resource management as not just environment related issue, but also needed for economic growth and human wellbeing (Sharpley, 2009). Sustainability though has an origin to counteract environmental issues, it also integrates other aspects that are required for a smooth functioning of cities and provide solutions for its problems. Hence, maintaining urban sustainability through an integrated approach is vital for the future of cities and their inhabitants. This could help in mitigating the urban challenges such as waste volumes and resource management through a holistic approach rather than seeing it as an environmental problem alone.

Though sustainability addresses the functioning aspects of cities and their challenges, according to Giddens (2006), the concept appears to be applicable to western countries or developed countries whose consumption patterns and resource dependence are high and does not take into account the needs of developing countries. There are many definitions proposed for this concept as shown in table 2.1. The concepts of sustainability and sustainable development do not have universally accepted definitions (Bibri and Krogstie, 2017) and is eyed from several perspectives like economist, environmentalists, techno-centrists, etc. Though Brundtland Report's definition for sustainability is most widely accepted, it is criticised as it does not define what the true needs of the present generation are (Blackburn, 2007). It can also be understood that the concept is dynamic in nature due

to the advancements and diversified activities in cities. This resulted in several frameworks, assessments and indicators that are proposed to measure or assess sustainability from different perspectives which are discussed in the following sections.

Table 2.1: Definitions for sustainability, sustainable development and urban sustainable development (Source: Author, compiled from literature)

Concept	Definition	Author
Sustainability and Sustainable development	Sustainability is "the capacity for the continuance into the long-term future and that sustainable development is the process by which we move towards sustainability".	Porrit (2007)
Sustainable development	Sustainable development is defined as "the planned and strategic development processes of working towards a balance of economic, environmental, and social values and goals, i.e. a balance of the need for economic development and prosperity with environmental protection and integrity and social equity and justice".	Bibri (2015 in Bibri and Krogstie, 2017)
Sustainable development	Sustainable development can be thought of as maintaining development (however defined) over time	Elliot (2006)
Sustainable development	"The development that meets the needs of the present without compromising the ability of future generation to meet their own needs"	Brundtland Report (WCED, 1987)
Sustainable urban development	Urban sustainable development is "achieving a balance between the development of the urban areas and protection of the environment with an eye to equity in income, employment, shelter, basic services, social infrastructure and transportation in the urban areas".	Hiremath *et al.,* (2013)
Sustainable urban development	Sustainable urban development is a process of change in the built environment which foster economic development while conserving resources and promoting the health of the individual, the community and the ecosystem'.	Richardson (1989)

2.4.1 Frameworks for sustainability and urban sustainability

There are a number of frameworks proposed to understand and measure sustainability. The frameworks chosen for this study are primarily based on the triple bottom line as it is the most widely used theory for sustainability (Gimenez *et al.,* 2012). The frameworks chosen include indicators and assessments of sustainability for cities (urban sustainability), provides insights on technology led and integrated approaches. The details of key frameworks are given in table 2.2. The study considers these aspects for selecting the frameworks but does not limit to them. It includes other frameworks that are widely used or well known for this topic to understand the importance given to waste management in cities either from environmental view or from a holistic view due to its ability for resource management.

Table 2.2: Details on sustainability frameworks considered for the study (Source: Author, compiled from literature)

Author	Details
Yigitcanlar *et al.,* (2015)	The author gives importance to urban sustainability through integration of social, environmental and economic goals and objectives and proposes a multi-scalar urban sustainability model to provide a scaling system that can be applied in micro and meso levels. The model is studied using a case study approach by applying it in Gold Coast city in Australia.
Turcu (2013)	The author studies sustainability concept from stakeholders' point of view and develops an indicator set to measure urban sustainability by integrating expert led and citizen led approaches and considers the local conditions for sustainability than proposing a global solution. The indicators are used to study three cities in United Kingdom.
Shen *et al.,* (2011)	The authors reviewed various indicators for sustainability and proposed International Urban Sustainability Indicators List (IUSIL). The indicators were applied on 9 practices and studied for comparison and includes governance category as an extension to the triple bottom line.

Hiremath *et al.,* (2013)	The authors study a range of indicators for sustainability and develop benchmarking indicator-based approach for urban sustainability by considering long term benefits. The indicators are reviewed based on the local conditions and therefore be used for urban planning and decision-making process.
Block *et al.,* (2013)	The authors consider the complexity in the city components and formulate sustainable development indicators that integrate multiple actors. The study identifies complexity of the 'City Monitor' that is followed in Belgium for sustainable development. Hence, it simplifies the indicators for decision making purpose by using communication as an instrument to integrate the actors in city.
Adinyira *et al.,* (2007)	The authors review the current assessment methodology and identify the lack of connection between the theory and practice. The author suggests that interaction between all the city elements and actors is a solution to achieve urban sustainability.
Ahvenniemi *et al.,* (2017)	The authors review sustainability assessment tools and smart city assessment tools and draw a relationship between the two. A framework is proposed where the indicators for both sustainability and smartness are chosen and categorised into sector categories and impact categories enabling each indicator to represent smartness as well as sustainability element.
Bibri and Krogstie (2017)	The authors review the emerging concept of smart sustainable cities. The literature for smart cities and urban sustainability, their assessments and indicators are reviewed and the need to integrate them is explained. Numerous views and paradoxes are explained and the use of technology for achieving sustainable development is briefed.

Shen *et al.,* (2011), conducted a detailed review of the sustainability indicators that were applied in cities of different parts of the world and created a consolidated International Urban Sustainability Indicators List (IUSL). It comprises of four sustainability dimensions namely environmental, social, economic and governance. Waste management is seen as one of the categories in environmental dimensions and is measured based on the waste collection service provision and waste management process by the author. Though material

consumption patterns are included in the economic dimension, recycling rates and resource management through waste re-utilisation are not identified. This indicates that waste management and material utilisation are seen differently. The indicator list proposed by Turcu (2013) includes resource utilisation under the environmental sustainability dimension. This draws a relationship between the waste use and recycling under resource category showing the importance of resource re-utilisation (from waste) contributing to environmental sustainability. Hence, indicators proposed by Turcu (2013) draw a relevance to the study of Shen *et al.,* (2011), where resources and material consumption patterns are placed under economic dimensions. This indicates the role of waste and its efficient utilisation can help in achieving both economic as well as environmental sustainability.

A more recent work conducted by Ahvenniemi *et al.,* (2017), reviewed various assessment indicators used to measure sustainability. It is reported that only 12% of all the urban sustainability indicators reviewed were identified for water and waste management together. This shows that the indicators for waste management alone are even lesser in number. Additionally, Ahvenniemi *et al.,* (2017) has categorised the indicators under three impact categories such as social sustainability, economic sustainability and environmental sustainability. It was found that water and waste management indicators account to 10% and 1% of environmental and social sustainability respectively. The study does not show relevance in obtaining the economic sustainability. Waste is seen as an economic activity in many cities, and public private partnerships exist in waste managing activities (Scheinberg, 2011), indicating waste should be given importance in economic sustainability dimension. So, there is a need to re-develop or improve the current sustainability indicators.

In addition, Turcu (2013) included local authorities, communities and partnerships leading to institutional aspects of sustainability. This indicates the need for social interaction and participation in achieving urban sustainability. Turcu (2013), also showed that sustainability indicators development differs when using citizen led and expert led approaches and gives importance to citizen-led approach. More interestingly, the research dated back to 1998, by Huang *et al.,* (2009) has included waste treatment, resource recycling and public participation and NGOs involvement on environmental protection as indicators in measuring urban sustainability. The review provided by Ahvenniemi *et al.,* (2017), indicates the role of governance and citizen engagement contribute to 8% of the sustainability indicators. Shen *et al.,* (2011) has included citizen participation and sustainable management of the authorities and businesses in the indicator set under the

governance aspects and Huang *et al.,* (2009) included NGOs involvement in policy making indicators for urban sustainability. This reiterates on the importance of soft domains in solving urban problems as explained in chapter 1.

Yigitcanlar *et al.,* (2015) conducted a study to assess sustainability of cities where two different sustainability assessment tools were compiled. It indicated that a sustainable design of cities should include participation of stakeholders by empowering them through communication and awareness. However, the author failed to include waste management or its related indicators in the assessment tool though several themes related to natural environment, pollution, ecology, water and material consumption, etc. are identified for the assessment. This shows utilities and their management are given importance to achieve environmental sustainability but fails to view waste as a utility and resource recovery from waste as one of the means to achieve sustainability.

There are some views that put forward the use of technology as a solution for attaining urban sustainability (Sharpley, 2000). There are opposing views that using technology can lead to unsustainability as it affects the social and environmental aspects negatively (Bibri, 2015). According to Bibri & Krogstie (2017), urban sustainability should be achieved through an all-inclusive approach, integrating several actors and infrastructures. Hence, it should also include technology and innovation but by performing a scenario analysis to know how it can help to achieve urban sustainability. Yet, the role of technology or its impact on urban sustainability (positively or negatively) is not considered by the authors while proposing frameworks or assessment indicators.

Alberti (1996) states the indicator sets are not helpful in achieving urban sustainability, unless there is a relation between the natural resources or built environment with the urban patterns. This relation is seen as interaction by Adinyira *et al.,* (2007) who advocates that sustainability can be achieved through the feedback mechanism caused because of interaction between infrastructural, environmental, social and economic systems. Multi-level and multi actor governance as well as actor related approaches are suggested as requirements for the development of sustainability indicators for policy making process (Block *et al.,* 2013). Hiremath *et al.,* (2013) reviewed indicator sets proposed by various authors and concluded that role of stakeholders and communication show a greater contribution towards the development of urban sustainability indicators due to their effectiveness in providing solutions.

The above studies reinstate on the role of stakeholder participation through citizen engagement and education, private and public partnerships, and importance of local governance. This suggests that these are important to achieve urban sustainability but none of these studies indicate a relation to stakeholder participation in achieving each of the economic, social and environmental dimensions of sustainability. Though sustainability is critiqued to be a concept for environmental protection and limits the other dimensions, waste management is seen to be given less importance even in the environmental dimension. Even when considered, waste management and resource utilisation are seen independently and only from environmental view and there is a lack of research on waste and its management from multidimensional view in achieving sustainability. Therefore, this draws the need to develop indicators for achieving multidimensional sustainability through effective waste management which is a growing urban problem and impacts the liveability of a city.

From the literature related to urban sustainability, it is clear that waste is an important aspect that needs to be treated with equal importance like other resources in order to maintain urban sustainability. From the review of frameworks, in addition to the three dimensions of triple bottom line, it is observed that stakeholder inclusion, partnerships, communication and technology have gained attention to maintain urban sustainability. This has also laid road to the development of new concepts such as smart cities. There are several indicators in the frameworks for sustainability which are extensions to the triple bottom line. Previous research emphasises on the need for sustainable urban waste management due to its ability to improve quality of life and resource substitution. Waste is not given significant place in the indicators or frameworks of sustainability in spite of resource management being one of the main objectives of sustainability. Hence, there is a need to identify relevant indicators and integrate the frameworks along with the advancements such as use of technology that can assure sustainability through waste management. In addition, it is also important to identify how each of the indicators can help in achieving sustainability.

2.5 Smart Cities

Cities provide opportunities and face abnormal increase in population resulting in several problems like resource utilisation, traffic, etc. as mentioned in section 2.1. Hence, cities around the world are looking for long term solutions to improve urban services while maintaining sustainability. One of the approaches is through the use of technology which has given rise to the concept of smart cities. The term smart city was used for the first time

in 1990s where attention was given to the use of Information and Communication Technology (ICT) and modern infrastructure in cities (Albino *et al.,* 2015). Smart cities are seen as a solution to improve urban services for citizens and maintaining sustainable development (Girardi and Temporelli, 2017). The concept has gained momentum and many cities around the world are making attempts to transform into smart cities by employing technology to create more sustainable and liveable places while reducing costs and increasing efficiencies (Falconer and Mitchell, 2012).

A City is composed of multiple actors such as government, businesses and citizens. Their interactions are required to enhance political and governing efficiency which can improve economic, social and urban developments (Falconer and Mitchell, 2012). This can be achieved by smart cities due to integration of technology that drives such interactions through e-participation (Eremia *et al.,* 2017) and networked infrastructure (Kummitha and Crutzen, 2017). Therefore, ICT is seen as the core of smart cities and vehicle for the transformation process. Henceforth, use of ICT in managing utilities and infrastructure is seen widely as part of smart initiatives like smart water meters, smart waste management, energy grids, smart mobility, etc. to improve resource management and liveability (Eremia *et al.,* 2017).

There are other views for smart city which advocate that technology alone cannot improve the quality of life and it requires human capital (Kummitha and Crutzen, 2017), multi-actor collaboration (Marsal-Llacuna *et al.,* 2015), entrepreneurial and infrastructural capitals (Kourtit and Nijkamp, 2012). Though the concept is gaining attention, it also faces criticism. Hancke *et al.,* (2013) advocates that technology and automation may cause a disconnect between city and people besides inviting cyber threats. In addition, automation may result in replacing man power in long term leading to higher unemployment (Sujata *et al.,* 2016) and use of technology may result in digital divide resulting in social divisions and larger inequalities in the city (Graham, 2002). Though one of the objectives of smart cities is to decrease inequalities and unemployment, contrastingly, use of technology in smart cities may bring back the same problems leaving a question on how smart cities would help in sustainable development. The concept and definition of smart cities are unclear, but many cities are transforming into smart cities by embedding advanced infrastructure or employing technology-based developments. This is not just inviting new problems, but also neglecting the sectors like waste management and resource conservation for future thereby leaving the urban problems unsolved. Hence, there is a need to clearly define smart cities to solve the current problems and avoid new problems that may arise due to this undefined transformation process. There is also a need to demarcate between

the extent and need of technology and the role of humans in smart city before the cities transform to smart cities. This means a balance between hard and soft domains of smart cities is needed.

2.5.1 Definitions for smart cities

Each actor in the city views a smart city from their own perspective. The private sectors view a smart city as technology integrated city, while the governing bodies view from economic and infrastructural growth, citizens view from utilities provision and city services and non-governmental organisations see the environmental and social benefits brought by the city (Letaifa, 2015). The concept of smart city remains unclear and there is no single definition given to it (Lombardi *et al.,* 2012). There are many definitions for smart city as shown in table 2.3 given by academicians and practitioners with the perspective of their field of study.

Table 2.3: Definition of smart cities given by various authors (Source: Author, compiled from literature)

Main area addressed	Definition	Author
• Information and Communication Technology	"Smart City implies a high-tech intensive and an advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce and a recuperating life quality with a straightforward administration and a good maintenance system (for Barcelona)"	Bakici *et al.,* (2012)
• Information and Communication Technology	"Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centres that are at once integrated, habitable and sustainable."	Barrionuevo *et al.,* (2012)
• Information and Communication Technology	"Safe, secure, environmental and efficient urban centre of the future with advanced infrastructures such as sensors, electronic devices and networks to stimulate sustainable economic growth and a high quality of life."	Caragliu *et al.,* (2009)
• Multifaceted	"A city is smart when investments in	Caragliu *et al.,*

approach • Information and Communication Technology • Stakeholder management	human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."	(2009)
• Information and Communication Technology	"Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone."	Chen (2010)
• Multifaceted approach	"A city well performing in a forward-looking way in economy, people, governance, mobility, environment and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens."	Giffinger *et al.*, (2007)
• Infrastructure and services	"City that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximising services to its citizens."	Hall (2000)
• People and communities (Citizen centric)	"Any adequate model for the smart city must therefore also focus on the smartness of its citizens and communities and on their well-being and quality of life, as well as encourage the processes that make cities important to people and which might well sustain very different – sometimes conflicting – activities."	Haque (2012)
• Information and Communication Technology	"A smart city denotes an instrumented, interconnected and intelligent city."	Harrison *et al.*, (2010)
• Infrastructure	"A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective	Harrison *et al.*, (2010)

	intelligence of the city."	
• Information and Communication Technology • Stakeholder management	"It is the implementation and deployment of information and communication technology infrastructures to support social and urban growth through improving the economy, citizens' involvement and governmental efficiency."	Hollands (2008)
• Information and Communication Technology • Stakeholder management	"*Smart Cities* initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors."	Marsal-Llacuna *et al.*, (2015)
• Information and Communication Technology	"Cities should be seen as systems of systems, and that there are emerging opportunities to introduce digital nervous systems, intelligent responsiveness, and optimization at every level of system integration."	MIT (2013)
• Stakeholder management • Institutional	"Smart Cities are about leveraging interoperability within and across policy domains of the city (e.g. transportation, public safety, energy, education, healthcare, and development). Smart City strategies require innovative ways of interacting with stakeholders, managing resources, and providing services."	Nam and Pardo (2011)
• Information and Communication Technology	"A [smart] city is where the ICT strengthens freedom of speech and the accessibility to public information and services."	Partridge (2004)
• Education and knowledge	"A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish their own lives."	Rios (2008)
• Multifaceted approach	"Smart cities combine diverse technologies to reduce their environmental impact and offer citizens better lives. This is not, however, simply a technical challenge. Organisational change in governments – and indeed society at large – is just as essential. Making a city smart is therefore	Smart Cities and Communities (2013)

	a very multi-disciplinary challenge, bringing together city officials, innovative suppliers, national and EU policymakers, academics and civil society."	
• Information and Communication Technology • Institutional aspects	"A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and liveability."	Toppeta (2010)
• Information and Communication Technology • Infrastructure	"The use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare, public safety, real estate, transportation, and utilities- more intelligent, interconnected, and efficient."	Washburn *et al.*, (2010)
• Education and knowledge	"A smart city is a centre of higher education, better-educated individuals, and skilled workforces. Smart cities act as magnets for creative people and workers, and this allows the creation of a virtuous circle making them smarter and smarter."	Winters (2010)

It is evident from the table that most of the definitions focussed on the integration of technology and infrastructure in developing smart city. Some authors address the use of technology to improve administration, safety, utility services (Washburn *et al.,* 2010), infrastructure (Caragliu *et al.,* 2009) and information access to public (Patridge, 2004) in city. There are definitions (Bakici *et al.,* 2012; Barrionuevo *et al.,* 2012) which emphasise on use of technology but do not indicate how they can improve the quality of life or achieve sustainability. In contrast Chen (2010), indicates that the use of sensors and kiosks integrated to urban infrastructure will improve services such as transportation, logistics, etc. and enhance quality of life. Infrastructure plays a prominent role as connectivity and maintenance of resources are the pillars for cities to grow. Harrison *et al.,* (2010) affirms that connecting different infrastructures on a common platform or a connected multi-platform will make a city smart.

According to Hall's (2000) definition, smart cities should maximise services to citizens and for a place to be smarter, it not only needs to be advanced but also serve the purpose

for its citizens. There are other views on smart city that include role of humans such as stakeholder collaboration (Marsal-Llacuna *et al.,* 2015; Hollands, 2008), governance and economic actors with appropriate innovation in addition to technology and infrastructure (Marsal Llacuna *et al.,* 2015). These different views indicate that every factor described above has significant benefit to a city, but there is also a need to develop holistic approach by combining them effectively.

Giffinger *et al.,* (2007) indicates there should be a smart combination of various factors with aware citizens for developing smart cities. Similarly, Haque (2012) claimed quality of life of residents in a city defines the smartness. Citizens being the centre for smart city development and creativity being key driver (Thuzar, 2011), the smartness can be added through education, skill and creativity of citizens (Winters, 2010) as this would improve workforce and opportunities in cities. Rios (2008) also indicates that knowledge and sharing cultures are important in city for the development of life. Likewise, Holland (2008) advocates that self-decisive and aware citizens with the combination of other infrastructural development leads to smart city and participation of community can promote smart growth (Albino *et al.,* 2015). These different views emphasise that citizens play a critical role in smart cities. Educating them through constant communication can encourage them to participate and interact with other stakeholders of the city (Nam and Pardo, 2011). For this, innovative technology can modernise communication for interaction, enable participatory governance (Caragliu *et al.,* 2009) and mobilise the economic actors (Marsal-Llacuna *et al.,* 2015) that can bring smart combination. However, policy re-design is an important facilitator for this smart combination as existing legal frameworks may limit the use of technology in various services of the city (Giffinger *et al.,* 2007). Though there are many factors in smart cities definitions provided, a need for smart combination is identified. It is important to apply this smart combination in all the sectors that contribute to city's functioning such as transportation, utilities provision including waste management. Therefore, a multi-disciplinary approach, in multiple sectors is needed to achieve this smart combination for smart city. The current research emphasises the need for smart combination that is proposed by Giffinger *et al.,* (2007) and focuses in the waste management sector. The research also incorporates other factors proposed by various authors that are discussed in sections 2.5.1 and 2.5.2 as they are important for the development and functioning of smart cities.

2.5.2 Frameworks for smart cities

There are a number of frameworks proposed for smart cities. These include various factors and indicators such as technology, infrastructure, governance, etc. that help in adding smartness to urban environment. These frameworks are also used to compare, and rank cities based on their ability to meet such factors and indicators. Out of the many frameworks, Giffinger *et al.*,'s (2007) framework (shown in figure 2.3) is the most widely accepted (Bibri and Krogstie, 2017) and the other frameworks appear to be an addition or extension to it. This section reviews the frameworks and models proposed for smart city. The frameworks considered for this study includes city aspects such as management, economy, stakeholder collaboration, etc. in addition to technology. The frameworks that are based only on the integration of technology alone are excluded as it will not bring a holistic approach. Hence, the studied frameworks are discussed according to domains, factors or indicators addressed by various authors while drawing relevance to Giffinger *et al.*,'s (2007) framework. The details of topics addressed by each author are compiled in table 2.4.

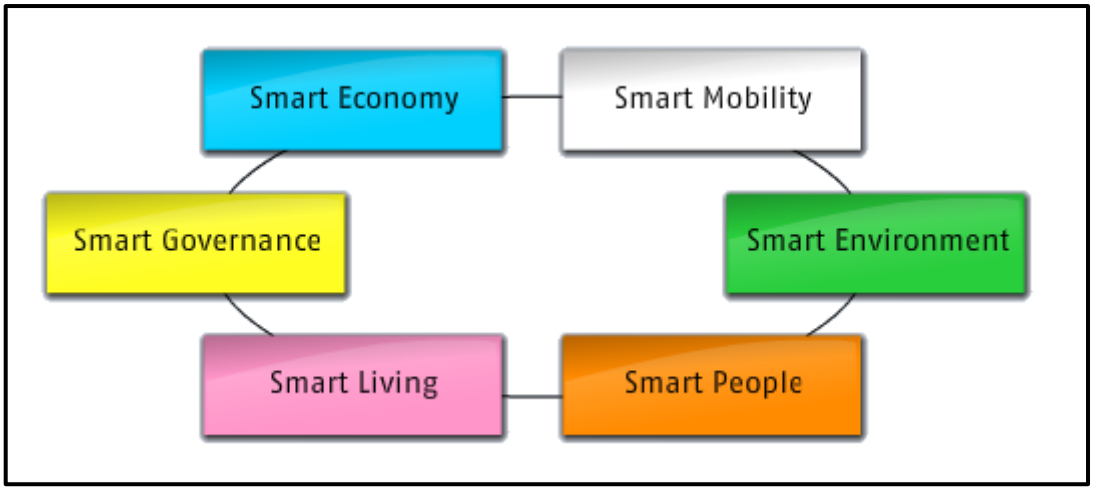


Figure 2.3: Smart city Model (Source: Giffinger et al., 2007)

2.5.2.1 Governance

Governance is identified as an important factor in smart cities by many authors. Giffinger *et al.*, (2007) identifies smart governance as one of the characteristics of a smart city which does not refer to the use of technology alone. It refers to the city administration, participation of citizens, service provisions, public private partnerships and embeds the use of technology to improve their efficiency like e-participation and e-governance. Letaifa (2015) proposed a SMART model for smart cities and found governance is crux to smart city projects as it needs long term planning and implementation. The model was used to compare three smart cities in the world and found that political stability, clear public

authority and inclusive governance are important in successful implementation of the smart city initiatives as they solve the local challenges effectively. Similarly, the frameworks proposed by Lee *et al.*, (2014) and Chourabi *et al.*, (2012) consider ICT enabled governance as part of smart governance, but also include other strategies such as identifying stakeholders, ensuring good communication and training, and reviewing best practices (Gil- Garcia and Pardo, 2005) which are important for success of governance in smart city including e-governance.

From the different views and frameworks, smart governance is believed to be based on collaboration (Chourabi *et al.*, 2012), citizen participation and public private partnerships (Giffinger and Gudrun, 2010), stakeholder inclusion, communication and use of technology for facilitating them through effective strategy.

2.5.2.2 Policy context and Legal framework

The political and legal frameworks are important for the successful development of smart cities and policies should be laid to help such developments (Sujata *et al.*, 2016). During the transformation process of cities to smart cities, there is a need to embed technology to these frameworks and there is a need to re-design policies which enable the use of technology in appropriate way to implement the smart city initiatives (Gil- Garcia and Pardo, 2005). The policies and legal frameworks should be followed, and it is also important to monitor the extent and appropriateness of the use of technology. Moreover, according to Chourabi *et al.*, (2012), the policies development should address the required changes for smart cities such as collaboration, private public partnerships and drive in encouraging new governing and business models.

2.5.2.3 Stakeholder Collaboration

Most frameworks suggest that smart city development is a multi-actor and co-creation process. According to Letaifa's (2015) SMART model, smart cities should mobilise stakeholders from varied backgrounds including private and public sectors. The city should work in multi stakeholder perspective and integrate all its actors as they should work together and become contributors to the smart city. Similarly, Chourabi *et al.*, (2012), emphasises on identifying relevant stakeholders and maintaining a healthy relationship between them as a managerial strategy for the success of smart city initiatives.

Giffinger *et al.*,'s (2007) framework emphasises on participating citizens who constitute an important characteristic of smart city which is smart people. The smart cities are built to provide better quality of life to the citizens and therefore, participating citizens are

important stakeholders. As smart cities work with a circular flow of information, their participation and interaction play an important role in the transformation process of the city (Falconer and Mitchell, 2012). Sujata *et al.,* (2016), included stakeholders and their communication as social aspects in the proposed framework and social media is seen as an important communication channel in smart city. Communication through social media can reach larger audience, disseminate information and collect data making the citizens users as well as producers in smart city through effective two-way communication. This interaction can also result in user enabled innovation for smart city (Lee *et al.,* 2014). With this flow and generation of information, smart people play a vital role in meeting the objectives of smart city.

Similarly, partnerships between public and private sectors are also a form of stakeholder collaboration. The NGOs, public and private sectors work towards a common goal. Hence, a collaboration between them can help in value creation while meeting the objectives of smart city (Letaifa, 2015) and helps in creating an ecosystem with open innovation by all its actors. In a study conducted by Letaifa (2015), collaboration between private and public sectors are observed to the success factors in smart cities initiatives in Montreal, Stockholm and London as it helped in identifying and overcoming cities' specific challenges. Similar findings are seen in a study conducted by Lee *et al.,* (2014) where different forms of partnerships are studied in Seoul Metropolitan city and San Francisco. It was found that partnerships between the two sectors was pivotal and the extent of partnership and control over the agreement also had a role in achieving sustainable eco systems. Moreover, the partnerships gave room to the development of human capital and entrepreneurship which further helps in building a smart economy. So, partnerships and collaborations between stakeholders are important for smart cities.

2.5.2.4 Economy

Economy is an important component in cities and one of the reasons for urbanisation process and a driver for a smart city. Giffinger *et al.,* (2007) addresses economy in smart city as smart economy and should include entrepreneurship, innovation, productivity to labour market and integrate national market with the global markets. The economic initiatives should create businesses and according to Chourabi *et al.,* (2012), smart cities should enable industrial development, create jobs and develop workforce. For a better and stable economic growth, smart cities should integrate the local small markets with the global markets and maximise profits to all its players and improve the entrepreneurship opportunities in the city. According to a study by Letaifa (2015), one of the reasons for

Stockholm's success in smart city initiatives is the active entrepreneurship and innovations. Hence, policies and initiatives for smart cities should drive entrepreneurships and innovation along with employment opportunities. According to Falconer and Mitchell (2012), building a strong economy through job creation is one of the objectives of smart cities. It should be linked to the cities' components such as transportation, education, healthcare, power, water and waste services through which the job creation or economic growth can be developed.

2.5.2.5 Infrastructure

Smart cities focus on infrastructure development and particularly on ICT embedded infrastructures such as Wi-Fi networks, wireless infrastructures and service-oriented information systems (Anthopoulos and Fitsilis, 2010). Interactive infrastructure, sensors, kiosks, mobile applications are seen in sectors like parking, traffic, water and waste management service provision, etc. According to Giffinger's *et al.,* (2007) framework, ICT enabled infrastructure is the key for smart mobility. Lee *et al.,* (2014), affirms that information availability through soft infrastructure like mobile applications is seen to be a successful initiative due to the ease of access coupled with increased mobile phone users. Besides this, physical infrastructure such as bridges, electric lines are also seen to have priority in the development of smart city (Eremia *et al.,* 2017) to improve connectivity. Local, national and international accessibility are essential factors for smart mobility and helps to promote smart economy (Giffinger and Gudrun, 2010) which can be achieved by improving the infrastructure of the city. It is found that the development of technology embedded infrastructure would result in high operational costs and may have a threat to security and privacy which leaves the use of such systems to be questionable. Hence, controlled use with effective monitoring can help in infrastructure development in smart cities.

2.5.2.6 Environment

Environment is one of the key factors for smart cities and a smart environment category should protect the environment, reduce pollution and ensure sustainable use of resources. Use of technology to enhance resource management is seen as a driver for the concept of smart cities (Giffinger *et al.,* 2007). There are energy grids and smart water meters installed to monitor and reduce the use of energy and water (Eremia *et al.,* 2017). This technology led monitoring of energy usage and waste management are considered as urban proactiveness of a smart city (Lee *et al.,* 2014). The use of electric vehicles is an innovation that uses renewable energy sources and can be a solution for fossil fuel

substitution and reduction in air pollution giving rise to healthy living conditions (Eremia *et al.*, 2017). Added to it, switching to non-motorised vehicles constitutes to green mobility as it does not contribute to the greenhouse gas emissions, air pollution and does not exploit resources. Hence, this can also be a contributor for a smart environment besides smart mobility (Giffinger *et al.*, 2007). This makes it evident that smart environment, can be achieved through judicious utilisation of resources as well as use of technology but this cannot be through the use of technology alone. Humans and their behaviours play a significant role in protecting the environment and transforming to smart cities.

2.5.2.7 Living

One of the reasons for origin of smart cities concepts is to improve urban liveability. Smart living is one of the six characteristics of smart city but is also found to have an overlap with other characteristics (Giffinger *et al.*, 2007). This characteristic focuses on the change in behaviour, life style and consumption patterns while improving quality of living standards of the city dwellers through ICT embedded approaches. It also focuses on the education, knowledge and social cohesion which are also important for smart combination in smart cities.

2.5.2.8 Technology

Technology is considered as an important driver for smart cities as it can help in improving the functioning and management of the city and quality of life for citizens. Giffinger's *et al.*, (2007), framework though covers many aspects of human capital and social behaviours, it also emphasises on the use of technology to make each of its characteristics smart. According to Eremia *et al.*, (2017) built environment, transportation, energy management, water and waste management are some of the areas of the city that need development using technology such as smart water meters, smart parking, smart waste management through real time monitoring of solid waste. The SMELTS framework proposed by Sujata *et al.*, (2016) considers that the transformation of a city to smart city is led by technology but the sole use of technology for smart cities, may result in digital divide (Graham, 2002). Similarly, Kummita and Crutzen (2017), argues that technology led development can hinder the inclusion of citizens and it can only benefit elite classes of the society. It also indicates that the extensive use of technology can cause a threat to replace the human investments. According to SMART model (Letaifa, 2015), technology should be an enabler to achieve the objectives effectively and governance and strategy play an overarching role in regulating the role of technology. The framework of Falconer and Mitchell (2012), indicates that there is a need to identify where and how the ICT can

provide a solution for the cities problems and be used accordingly. This suggests that ICT can only provide a solution when used appropriately with suitable strategies and objectives rather than the number of ICT embedded services.

According to Albino *et al.,* (2015), smart cities constitute of two domains, namely hard and soft domains as already explained in chapter 1. The hard domain includes resources, energy grids, water and waste management, transport, etc and the soft domain includes governance, policy re-design, education and social inclusion. Integration of ICT for the functioning of the hard domains is crucial, but not for the soft domains. To develop a holistic approach for smart city and achieve smart combination, there is a need to integrate soft and hard domains to improve the functioning of both. This can be achieved either by integration or non-integration of technology. Technology was given high priority than human centric approaches when the smart city concept was in naïve state. Human centric approaches are now considered equally important as technology cannot solve all the challenges and brings new challenges if used without limits. Hence, technology should only be an enabler (Kummitha and Crutzen, 2017) with definite boundaries to the extent of its use.

To summarise, smart cities battle to provide solutions to the fast-growing urban problems to achieve sustainable and liveable places. This is achieved through wise management of resources and reduced environmental impact. As cities are the hub for economic growth, smart cities aim to foster employment opportunities, and development of new business models. This can be achieved through the collaboration of stakeholders, creativity, education, communication, knowledge sharing, social inclusion and reducing social inequalities. Therefore, to develop a smart city in a holistic way, there is a need to maintain the balance between technology and human centric approaches. Besides technology, emphasis is given to governance, stakeholder collaboration and communication as they would result in new business models. The goal of smart cities is to improve quality of life and enhance services such as transportation, housing and utilities while maintaining sustainability. However, the frameworks and definitions do not address what areas need the smart adaptations. There are few authors (Eremia *et al.,* 2017; Falconer and Mitchell, 2012; Lazaroiu and Roscia, 2012) who also emphasise on utilities, waste and energy consumptions in city's objectives and need to deploy smart methods to enhance these services.

From the review of literature pertaining to smart cities and the context of current research which is waste management, it is evident that waste is seen as an important sector for

improving city services and for achieving sustainability. However, it is seen only as a hard domain of the city as its improvement is studied through technological and infrastructural advancements as shown in section 2.5.2 and discussed in detailed in the later section 2.6.2. The review also shows there are soft domains of a city which are required to improve the city's functioning and did not consider the city services like waste management. Considering only the technological advancements in waste services would not result in equal access to the services and smart transformation would be restricted to developed countries that can upgrade their infrastructure. Due to financial constraints, the developing countries would not be able to adopt such changes leading to greater inequalities and digital divide not only between the people in cities but also between various countries. Hence, the role of soft domains in smart cities particularly in waste management should be identified to drive the smart transformation. The following sections of this chapter reviews the relevant literature on waste management to identify such aspects that have a role in smart transformation.

Table 2.4: Topic addressed by various authors in frameworks for smart cities and the addressed topics are denoted by a tick (Source: Adopted by author from multiple sources)

Author	Technology and ICT	Infrastructure	Innovation	Governance	Policy context	Strategy	Management and organisation	People and communities	Economy	Environment	Stakeholders' collaboration and communication	Legal	Sustainability	Education	Living
Giffinger *et al.*, (2007)	✓	✓	✓	✓	✓	-	-	✓	✓	✓	✓	-	✓	-	✓
Chourabi *et al.*, (2012)	✓	✓	-	✓	✓	-	✓	✓	✓	✓	-	-	-	-	-
Letaifa (2015)	✓	-	-	✓	-	✓	✓	-	-	-	✓	-	-	-	-
Sujata *et al.*, (2016)	✓	-	-	✓	-	-	✓	✓	✓	-	✓	✓	✓	-	-
Lee *et al.*, (2014)	✓	-	✓	✓	-	-	-	-	-	-	✓	-	✓	-	-
Lombardi *et al.*, (2012)	-	✓	-	✓	-	-	-	✓	✓	✓	✓	-	-	✓	✓
Lazaroiu and Roscia, (2012)	✓	✓	✓	✓	✓	✓	-	-	✓	✓	-	-	✓	✓	✓
Falconer and Mitchell (2012)	✓	✓	-	✓	✓	✓	-	-	✓	✓	✓	-	-	-	-
Eremia *et al.*, (2017)	✓	✓	✓	-	-	-	-	-	-	✓	✓	-	✓	✓	-
Kummita and Crutzen (2017)	✓	-	-	✓	-	-	-	✓	-	-	-	-	-	-	-

2.6 Waste Management

Waste generation is a by-product of human activities and its management is an integral part of urban services. Its improper management has many adverse effects on environment and public health (Sharholy *et al.*, 2008). Due to urbanisation and increased population density, higher amounts of waste are generated in city. According to Hoornweg and Bhada-Tata (2012), the generation of waste is faster than other types of pollutants. In developing countries, the rate of urbanisation is higher than the developed countries and suffer with limited resources posing a challenge to manage the rapidly growing waste volumes (Ahmed and Ali, 2004). The smart cities concept evolved to provide solutions to such urban problems as explained in previous section (section 2.5) and emphasises on the technological adaptation for waste services. Such technological advancements are successfully adopted by few cities in South Korea, Spain, United Kingdom and Netherland (DBIS, 2013), but there is lack of evidence on their use in developing countries. This could be attributed to the differences between developed and developing countries which are financial resources or the differences in the composition of waste. It is estimated that the proportion of organic waste is higher in developing countries (Wilson *et al.*, 2012; Kumar *et al.*, 2009), and the technology that is used by developed countries cannot be applied due to such differences (Shekdar, 2009). Developing countries operate in budget constraint conditions making it challenging for local authorities to improve the service and its infrastructure. In addition to financial and technological aspects there are other factors that affect waste management system and it requires a holistic approach.

2.6.1 Factors and frameworks for waste management

There are a number of studies that include various factors for solid waste management. The notable studies are conducted by UN-Habitat (2010), Shekdar (2009) and Klundert and Anschutz (2001), who propose an integrated sustainable waste management (ISWM) concept which also include waste recovery and recycling as shown in figure 2.4. Hence, this concept emphasises on waste hierarchy and provides a holistic approach. There are many studies that consider ISWM framework as the most important concept in waste management. Guerrero *et al.*, (2013) and Wilson *et al.*, (2013) have based on the ISWM framework and extended their study on developing countries. Wilson *et al.*, (2015a), proposed an indicator set that can measure waste management performance of cities based on the ISWM framework. Solid waste management has a close relationship to economic, social, environmental aspects and quality of life (Baud *et al.*, 2001) in urban setting.

According to it, the system can function smoothly by replacing its own resources while maintaining its operational efficiency. Srivastava *et al.*, (2015), has studied issues related to ISWM in developing countries and identified sustainability aspects are important in waste management. Similarly, studies conducted by Uyyara and Gee (2013) in Manchester city's (UK) show the role of waste management in achieving sustainability in urban setting. The study also focuses on technical and governing aspects that are crucial to achieve sustainable waste management. This emphasises the role of waste management in achieving sustainability and therefore there is a need to include waste management and their indicators or measurement as a part of measuring or assessing urban sustainability.

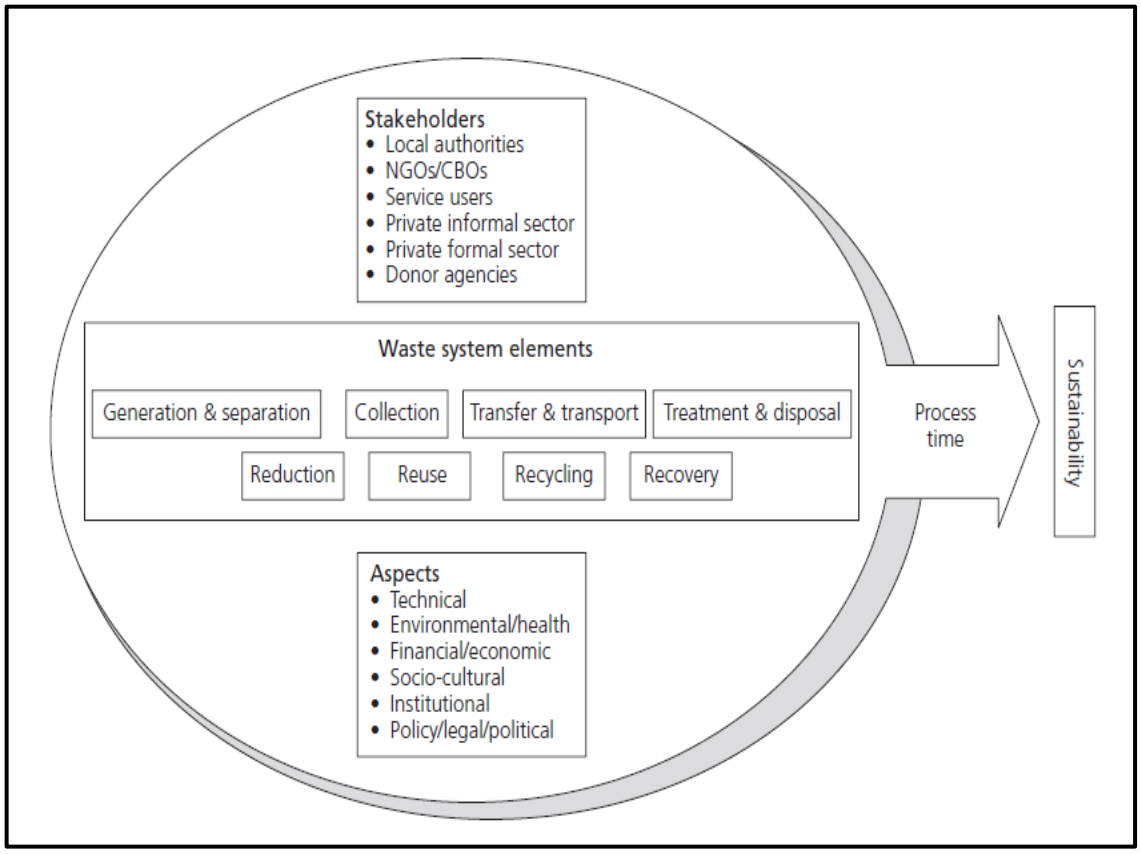


Figure 2.4: Integrated Sustainable Waste Management (ISWM) model (Source: Klundert and Anschutz, 2001)

The ISWM framework is considered for this study as it integrates the physical and governance aspects with emphasis on waste hierarchy. Hence, it comprises of soft domains and extends beyond the employment of technology. The following sections discuss the different factors and frameworks for their measurement and also consider the works beyond ISWM where relevant. In this study the literature available on various factors that

influence waste management are broadly divided into operational aspects, governing or managerial aspects and stakeholders. The operational aspects include waste generation, collection, transportation, recycling, recovery and disposal. The governing or managerial factors include financial, cultural, environmental, technical and legal aspects that affect waste management system. The third category includes stakeholders whose behaviour and participation are important to improve the overall functioning of waste managing system.

2.6.1.1 Operational Aspects

Waste generation is a result of socio-economic activities (Srivastava *et al.*, 2015) and it is affected by size of households, education, income and occupation (Sujauddin *et al.*, 2008). Waste generation is coupled with GDP. The higher the income of household, the higher is the waste generated (Shekdar, 2009). Source segregation is an important step after waste minimisation for resource recovery. It is affected by interest and awareness of citizens (Ekere *et al.*, 2009) and it is a challenge to encourage citizens to segregate their waste in most developing countries (Srivastava *et al.*, 2015). Waste collection and transportation are important steps in managing waste and for maintaining public health (Wilson *et al.*, 2013). This is generally indicated using the percentage of households covered with the waste service. It should be 100% to ensure public health, but the cities in developing countries still struggle with low collection efficiency (Srivastava *et al.*, 2015). Waste collection and littering behaviour are also affected by number and types of bins available, distance between them, type of collection, involvement of formal and informal sectors (Zaman, 2014), roads and vehicles used for transportation (Henry *et al.*, 2006). The transportation vehicles used in developed countries have standardised designs and suite their local waste characteristics. The developing countries adopt the use of similar vehicles used in developed countries, but due to the differences in operating conditions and waste characteristics such vehicles become less efficient in use in spite of high expenditure to local authorities (Shekdar, 2009). In developing countries, it is a common practice to transport waste in open vehicles for disposal and waste is disposed in open areas or low-lying areas without a scientifically managed method (Srivastava *et al.*, 2015; Shekdar, 2009). According to the studies of Wilson *et al.*, (2013), Pokhrel and Viraraghavan (2005) and Zurbrugg (2002), the governing aspects such as weak legislation, lack of adequate facilities to manage waste and limited financial resources act as barrier to safe waste disposal and result in unscientific disposal methods. They pose high environmental burden and danger to public health. There is less concern from the public about waste disposal as

people are concerned about collection as it clears the waste away and have a tendency of "out of sight-out of mind" (Zurbrugg, 2002). With the lack of available land and growing waste volumes, waste recovery is gaining importance, drawing the focus on recycling.

Many developing countries have been taking active part in recycling for long, but essentially through the informal sector (Agarwal *et al.*, 2005). There are several factors that affect recycling behaviour in developing countries. Troschinetz and Mihelcic (2009) have performed qualitative analysis on 23 case studies and found the factors that affect sustainable recycling behaviour. According to the study in 83% of the cases lack trained staff, in 79% of the cases have low waste collection and segregation efficiencies and in 77% of the cases, lack of financial resources act as barriers for recycling. The recycling activity in developing countries ranges between 0-41% which is higher than developed countries' recycling rates (Troschinetz and Mihelcic, 2009) but it is not recognised as recycling is performed by informal sector (Wilson *et al.*, 2006). In developing countries' scenario, recycling is greatly influenced by citizen participation for source segregation and informal sector for waste recovery. Education and awareness play an important role in improving citizen participation and recycling rates (Grazhdani, 2016; Starr and Nicolson, 2015). Similarly, waste collection method and social interactions also affect source segregation and recycling behaviours. It is observed that source segregation is an important value adding step in waste management. There are opposing views by Jahre (1995), that source segregation leads to high complexity in collection and higher associated costs. But according to Aphale *et al.*, (2015) when collection of source segregated waste is optimised through efficient planning, it offers an economically viable solution through post-collection processing of waste for recovering recyclables. There are other studies that identified the effect of landfill taxes and user fee collection and found they showed a positive effect on recycling (Linderhof *et al.*, 2001) and source separation (Dahlen *et al.*, 2007). Hence, governing and managerial aspects should be considered by the governing bodies (UN-Habitat, 2010) during the planning for a city's waste management and design appropriate ways to improve recycling.

2.6.1.2 Managerial/Governing Aspects

The managerial or governing aspects for ISWM include legal framework and policies, financial management, environmental and socio-cultural aspects. Legal frameworks are important for achieving integrated waste management system and have a positive effect on it (Beigl *et al.*, 2004). According to UN-Habitat (2010), the status of waste management of

the city indicates local authorities' management capability. Policies and legal frameworks play an important role as they put forward strategic objectives of the city particularly for waste management as waste services are often given less priority by local authorities (Moghadam *et al.*, 2009). There is also a challenge to cities as the local governance changes due to elections. Hence, strong policies act as a relationship between local authorities and waste management. According to Shekdar (2009), legal frameworks should be designed to link national policies with local strategies and their timelines. There is a need to integrate sustainability in policy design and include environmental quality, financial sustainability (Shekdar, 2009) and stakeholder inclusion (Wilson *et al.*, 2013), modernisation of existing system (UN-Habitat, 2010), division of roles and planning regulatory framework (Klundert and Anschutz, 2001). According to Pires *et al.*, (2011), to achieve ISWM, there is a need to look for waste management practices that are environmentally sound and economically feasible approaches. Involvement of stakeholders in decision making coupled with societal changes where producers and consumers feel responsible for their waste generation and its minimisation will be critical to achieve ISWM. Lack of adequate policies and legal frameworks or their poor enforcement has detrimental effect on the waste services (Guerrero *et al.*, 2013).

Institutional aspects are necessary for integrated sustainable waste management. The division of roles, responsibilities, organisational structures and funds allocation between national and local governments should be demarcated under the institutional arrangements for ISWM (UN-Habitat, 2010; Shekdar, 2009; Klundert and Anschutz, 2001). Since local authorities are responsible for waste management, lack of organisational and institutional capacities of local authorities lead to an ineffective waste management system. Lack of leadership and knowledge among the authorities (Guerrero *et al.*, 2013), limited training of collection staff due to low priority of waste services are referred to weak institutional aspects. Organisational structure, institutional capacity (Wilson *et al.*, 2015a) and training to waste workers (Swachh Survekshan, 2017; Zaman 2014) are important indicators in measuring the performance of cities for their waste management and have an influence on recycling (Troschinetz and Mihelcic, 2009).

Financial sustainability is also an important aspect in waste management which refers to budgeting and accounting for the service, costs involved and income generation (Klundert and Anschutz, 2001). The waste management sector consumes nearly 15 to 20% of the budget (UN-Habitat, 2010) and in developing countries the financial management is

inconsistent. In India, it is estimated that 80-90% of the budget allocated for waste management is spent only on collection and transportation but still suffers from lack of 100% collection efficiencies and scientific disposal facilities (Sharholy *et al.,* 2008). The system often struggles with limited financial support and resources (Sujauddin *et al.,* 2008). Since, waste recovery is not performed actively through the formal waste services, it does not recover value from waste and major portion of the city's budget is consumed for managing waste. Hence, the system suffers to achieve financial sustainability (Lohri *et al.,* 2015). There is also a need to upgrade the existing infrastructure and adopt advanced technology that is being used in developed countries, but according to the local conditions (Shekdar, 2009) which are additional investments. Though public also have role in waste management it is often regarded as the sole duty of local authorities and do not show willingness to pay user charges (Sujauddin *et al.,* 2008) adding to financial burden. Waste recovery and value generation through this process is important not only to protect environment and public health, but also to achieve financially viable business models. The setting up of resource recovery plants such as waste to energy or large-scale composting are capital intensive. The quality and profits of such set up depend on quality of input which is the waste composition (Kumar *et al.,* 2009). Therefore, there is a need for appropriate source segregation which is the role of waste generators and needs attention of governing aspects (Filho *et al.,* 2016).

Social aspects play a role in recovering value from waste which include awareness, education, participation (Moghadam *et al.,* 2009; Shekdar, 2009), behaviour, culture, interest of public and social conditions of waste workers (Klundert and Anschutz, 2001). Social pressure has a direct link with the community participation in recycling (Vining and Ebreo, 1992 in Aphale *et al.,* 2015) and on the degree of waste management (Barr *et al.,* 2003). Waste workers have low levels of motivation to work due to the low social status given to them (Guerrero *et al.,* 2013). Similarly, in developing countries waste or rag pickers are often ill-treated by both public and are considered as nuisance by the local authorities (Praveena *et al.,* 2015). They contribute significantly towards recycling (Agarwal *et al.,* 2005), reduce the operational costs for formal sector (local authorities) (Scheinberg *et al.,* 2010) and generate revenue from waste which is not performed by the local authorities. Though the rag pickers obtain marginal revenue that is just self-sufficient (Agarwal *et al.,* 2005), they maintain financial sustainability in the business. Overcoming such social problems of waste workers, making use of their experience (Filho *et al.,* 2016)

and promoting interest and participation (Caniato *et al.*, 2014) among the stakeholders is important to improve both operational and managerial aspects of ISWM. According to Baud *et al.*, (2001), in developing countries, the integration of policy makers to design legal frameworks that facilitate partnerships with small scale waste traders can particularly help in achieving urban sustainability. Hence, waste management should be a collaborative effort and there is need for stakeholder identification and participation.

2.6.1.3 Stakeholders

Stakeholders in waste management imply to any groups or organizations that are engaged or have interest in waste management activities. They include waste generators (citizens), service providers (local authorities), private entrepreneurs, Non-Governmental Organisations (NGOs), Community Based Organisations (CBOs), informal waste pickers, etc. (Joseph, 2006). The stakeholders in waste management and their roles have transformed over the time and play an active role in successful design and implementation of waste management and sustainable urbanization (Contreras *et al*., 2008; Srivastava *et al*., 2005). Sharholy *et al.*, (2008) have identified that local authorities are unable to implement an efficient waste management system due to the lack of stakeholder participation. According to Anand (1999), there are cases in the developing countries that have successfully managed waste with citizen (community) participation and public private partnership which emphasise on the need for stakeholder participation and collaborations.

Active participation of the public is required to maintain an efficient waste management system as this is being done by the local authorities for the public and their healthy well-being (Shekdar, 2009). The author also states that there is a direct relation between the efficiency of a system and the number of citizens participating in it. Public participation in source separation helps in higher resource recovery and maintenance of the city. Srivastava *et al.*, (2005) performed SWOT analysis on the roles of various stakeholders in waste management and found that participation of youth and implementation of their ideas, community training, awareness campaigns and environmental education play a vital role in promoting segregation of waste at household level and to encourage door to door collection. Joseph (2006) states that the waste reduction, source separation, and keeping the streets litter free through active participation of the citizens is important. This shows that stakeholder participation is influenced by the operational (section 2.6.1.1) and managerial aspects (section 2.6.1.2) as discussed earlier.

Guerrero *et al.,* (2013) studied on the challenges faced by cities in developing countries for effective solid waste management and concludes that though the local authorities are responsible for a city's waste management, but an efficient system can only be achieved through proper participation of the different stakeholders. Citizens and local authorities working together contribute to the best cases of waste management. However, communication between the stakeholders plays an important role in the cities of developing countries for effective waste management. Similar findings were seen in a study conducted by Rathi (2006) in Mumbai, an Indian city. The study shows that the cost of managing waste is the least with community participation and the next cost-effective option is the public private partnership when compared to waste management by local authorities alone. The author states that the poor participation of citizens is a barrier to its successful implementation and NGOs and CBOs play an important role in communicating with the local residents regarding their responsibilities. Sharholy *et al.,* (2008) reviewed the current situation of municipal solid waste management in Indian cities and considered the aspects from waste generation to energy recovery. The author also concludes that the citizen participation and private sector involvement in waste management are beneficial to manage the waste effectively.

The partnerships between public and private sector is increasing in the utility services sector particularly in water and waste management. The developing nations experience a gap in the services provided by their municipalities or local authorities. Contracting out certain activities in the waste management like collection to the private enterprises can help in bridging the gap in providing services (Kassim and Ali, 2006). According to Kaseva and Mbuligwe (2005), private companies have few advantages when compared to the local authorities as they are free from bureaucratic hurdles and have better functioning as well as updated technology that are helpful in providing continuous service. This efficient maintenance results in profits for the private sector. Baud *et al.,* (2001) conducted a study by comparing three cities in developing nations and understanding partnerships between different actors involved in waste management and have concluded that the involvement of the private sector in different processes like collection, transportation and recovery stages is beneficial both economically as well as environmentally. Study made by Oteng-Ababio (2011) in Ghana shows that there is higher refuse collection with the involvement of private sector.

With the increased waste generation rates, there is always a burden on the disposal sites which is a major challenge to the municipalities. So, involving the private sector helps in recovery of the valuables from the waste, leaving reduced volumes of waste going to final disposal. The private sector benefits from the revenue generated from the recovered and recycled products from the dry waste and compost generated from the wet waste. The author advocates that though PPP appears to be a cost-effective model, its efficiency depends on its design. Involvement of private sector at collection and transport are equally important along with the recovery stages as improved collection and transportation result in reduced costs of processing. Ahmed & Ali (2004) have a similar argument that the design of the PPP plays an important role and an inappropriate design would worsen the current scenario of waste management in developing countries. Besides that, the author states that the role of the citizens is a key factor to initiate a PPP as the people should be willing to pay for the service.

Civil Society Organisations such as NGOs and CBOs can be seen as a tool to promote social intermediation (Joseph, 2006) and have gained importance in the urban sanitation and particularly waste management services (Tukahirwa *et al.,* 2010). Mobilising public participation can be achieved by NGOs. They are extremely useful in promoting awareness and conducting community programmes (Shekdar, 2009). Local authorities working with NGO can be an advantage to promote public participation in waste management activities. NGOs are helpful in making the voices of locals heard (Joseph, 2006). Colon and Fawcett (2006) conducted a study in two south Indian cities and found out that the participation of NGO and CBO in waste collection and transportation activities, recycling and composting activities, in addition to awareness campaigns for public are proven to be successful models for waste management services. Suryapet, a city in Telangana State in India, showed success in achieving source segregation and 100% door to door collection through community participation that is mobilised by CBO (Joseph, 2006). There are studies made by authors on NGO and CBO participation in urban sanitation and waste services in African countries and found that the services have reached households with varied socio-economic backgrounds through the involvement of NGO and CBO when compared to local authorities alone (Tukahirwa *et al.,* 2010).

In addition to the formal waste sector, there exists informal sector who collect recyclables from waste and sell them in secondary markets to earn their living (Praveena *et al.,* 2015). They give a second life to resources that are discarded as waste. Most recovery and

recycling of waste in developing countries is contributed by informal sector (Gupta, 2012; UN-Habitat, 2010; Wilson *et al.*, 2009) and the sector is an important stakeholder in waste management (Joseph, 2006). According to the definition of Scheinberg *et al.,* (2010), the informal waste sector is comprised of individuals or group or enterprises that are working with waste management activities by providing services and are not supported, acknowledged or recognised by the formal waste management authorities. There are many actors in the informal sector and are classified differently by various authors based on the size of recycling activities and the degree of control on waste trade and pricing (Annepu, 2012; Gupta, 2012; Zia *et al.*, 2008; Wilson *et al.*, 2006; Agarwal *et al.*, 2005; Ahmed and Ali, 2004). The informal sector plays an important role in urban waste management and has significant contribution towards recycling rates, value addition to waste, contribution to formal sector and environment. According to Gupta (2012), informal sector manages 15-20% of the waste generated in developing countries. Studies have shown that the contributor to the recycling in India is mainly the informal sector in cases like New Delhi with 17% (Sharholy *et al.*, 2008; Agarwal *et al.*, 2005) Bangalore with 15% (Sharholy *et al.*, 2008) and Pune with 22% and the formal sector contributes only between 0%-8% in developing countries (Scheinberg *et al.*, 2010).

The informal sector adds value to the waste that is regarded as no value. This is termed as valorisation to waste (Scheinberg *et al.*, 2010). The informal sector begins the waste trade at households which is the point of its generation and helps in separating the recyclables at the earliest possible point, reducing the chances and extent of contamination of waste. This leads to higher value recovery from waste. The informal sector recovers the material from households reducing the volume of waste for collection, transportation and disposal by the formal sector (which is most often the local municipal authorities). This helps in saving the associated operational costs incurred to them (Wilson *et al.*, 2009). It is estimated that the local authorities in Delhi save around Rs. 600,000 per day due to the operations of informal waste sector. Similarly, the local authorities of Pune save Rs. 9 million per year (Sharholy *et al.*, 2008). Hence, the informal sector which is not supported helps in financial sustainability by subsidising the formal waste collection authorities (Gupta, 2012; Scheinberg *et al.*, 2010; Wilson *et al.*, 2009). The sector provides the supply of secondary raw materials and reduces the demand for extraction of virgin materials and protects natural resources (Kaseva and Gupta, 1996). In Bangalore, it is also estimated that 15% of the MSW is diverted from the dump sites due to the waste picker's activities (Sharholy *et*

al., 2008). By diverting the waste that is left for disposal by households, it reduces the associated environmental damage caused by waste disposal and saves landfill space and costs (Scheinberg *et al.*, 2010). The role of informal sector in waste management and their skill in identifying and recovering valuables from waste is often unrecognized. Interaction of the local authorities with them and integrating formal and informal waste management activities helps in promoting recycling performances (Agarwal *et al.*, 2005).

From the review of existing literature on stakeholders, it is evident that collaboration between them is important to improve the operational aspects. Similarly, the managerial aspects (discussed in section 2.6.1.2) play key role in enhancing such collaborations and all the three are important to achieve a holistic approach. Though stakeholder interactions are identified important for waste management, various authors have limited to study the interaction only between two to three stakeholder groups. The only studies that considered the interactions between multiple stakeholders are by Zia *et al.*, (2008) and Baud *et al.*, (2001). The study of Zia *et al.*, (2008), considers the multiple groups of stakeholders, but it is still limited to the interactions of informal sector with other groups and is applied to a single city in India. Baud *et al.*, (2001), also focuses on the informal sector, but identifies the effect of such interactions on the sustainability dimensions and quality of life. Caniato *et al.*, (2014) and Caniato *et al.*, (2015) have studied the stakeholder interactions using social network analysis but for the hazardous waste. There are no studies that relate such stakeholder interactions in household waste management with value addition to waste or with smart city characteristics.

2.6.2 Smart cities and waste management

Waste is considered as a resource and its effective management helps in meeting the objectives of smart city. Lazaroiu and Roscia (2012), tested a smart city model by weighing indicators and found sustainability, transportation and municipal solid waste indicators influence smart cities significantly. Similarly, waste is listed as a utility in city components by Falconer and Mitchell (2012) and according to Eremia *et al.*, (2017) smart utilities include smart waste management through real time solid waste monitoring. Though waste reduction is a behavioural issue (Wilson *et al.*, 2015a), its management can be influenced by using technology (Wyld, 2010). Hence, efforts to implement innovative technology in waste systems have increased for improving its management and reduce the cost of operations (Chowdhury and Chowdhury, 2007). The use of Internet of Things (IoT) in waste management is considered as a counter measure to the environmental pollution

and is used in different steps of waste management process starting from collection to treatment (Anagnostopoulos *et al.,* 2015) and has evolved from the traditional waste management process to smart waste management as shown in table 2.5.

Table 2.5: Transition from traditional to smart waste management across the waste chain (Source: Author, complied from literature)

Process Involved	**Traditional Waste Management Process**	**Smart Waste Management**
Collection	• Source segregation • Kerbside collection • Drop off points	• RFID tagging • Pneumatic/underground waste collection system
Transportation	• Routing and scheduling	• RFID and GPS tracking
Processing	• Mechanical sorting • Recycling	• Advanced MRFs • RDF
Recovery	• Incineration	• Material recovery through RFID • Energy recovery (WtE and WtF)
Disposal	• Landfills • Dumpsites	• Sanitary landfills • Landfills and solar integration

2.6.2.1 Smart waste collection and transportation

Advanced technology for waste management particularly for waste collection and transportation have gained importance namely, mobile pneumatic waste collection system, smart bins, Global Positioning Satellite (GPS) and Radio Frequency Identification (RFID) tags. Mobile pneumatic waste collection system (underground/ vacuum collection) is the most advanced (Iriarte *et al.,* 2009) as it uses suction to collect and transport waste through underground channels and avoids manual transportation by road and keeps waste collection out of sight. Though this system aims to reduce the operating costs such as lower personnel cost, cost of fuel and vehicle, its installation capital is high with longer payback period. According to Navigant Research (2014), the average period to gain return on investment is 10-12 years. Moreover, the system is also prone to high maintenance costs which can pose greater problems than benefits if not maintained regularly.

The other advanced waste collection system is the use of smart bins. Sensors are embedded in waste collection bins to sense the type of waste being disposed and enable remote monitoring of waste collection. The sensors help in optimising collection route depending on the amount of waste collected by the bins. Though these bins are successful smart city

initiatives in Barcelona (Sanroma, 2012), their use is limited in other smart cities. Similarly, compactor bins and solar powered bins have been tested in UK cities and are found to reduce operational costs (DBIS, 2013), but are not used widely.

The use of the GPS tracking system in waste collection vehicles is being adapted by global smart cities. The use of GPS will not only allow the operators of waste collection vehicles to track their location and speed of the vehicles but will also enable them to keep track of their historical routes (Fleetmatics, 2015). From the study conducted by Aberdeen Group (a consulting company), there is a 13.4% reduction in the overtime expenses and a 13.2% reduction in the cost of fuel by using GPS tracking systems (Navigant Research, 2014). Similarly, use of electric vehicles for waste collection is gaining importance. This ensures use of renewable sources of energy and more sustainable options during the waste collection. However, this needs high capital to replace the current vehicles in use (Bingham, 2018).

2.6.2.2 Smart waste sorting

RFID is one of the most efficient technologies in the recent years which has gained attention from municipalities to deploy in waste management to improve efficiency and minimize costs. In most of the European countries, RFID acts as a driving force to develop policies for solid waste management (Thomas, 2003). It is used in waste sorting, recovery of materials, pricing of Pay As You Throw (PAYT) program, etc. (Navigant Research, 2014; Binder *et al.*, 2008; Chowdhury and Chowdhury, 2007).

Waste sorting plays a key role in value generation as waste is segregated into categories. (Dahlén *et al.*, 2007). RFID is used by attaching tags to the products and antennas to bins. The RFID tags on products, describe the nature and composition of goods (Binder *et al.*, 2008) and antennas on the bins enable an automatic record of waste that is being disposed by users making sorting of recyclables easier. Moreover, when used with PAYT, this facilitates the consumers to avail value for goods with recyclable property through cash back and enables tracking of improper disposal of waste by the households at initial stages of waste processing (Navigant Research, 2014). Hence, this model is useful in promoting source separation by citizens and effective pricing by authorities during PAYT. Though this technology has many positive attributes for efficiency of solid waste management, it is associated with sustainability issues such as social, economic and environmental aspects.

From social perspective, tagging of consumer products is necessary to implement this technology. This can enable tracking individual's routine and purchases by observing the waste which leads to privacy problems (Wager *et al.,* 2005). From economic perspective, it needs 1 to 5 times of its current maintenance costs to make new investments to install systems for waste separation (Binder *et al.,* 2008). According to Thomas (2009), the cost incurred in applying technology would be very high and is not considered a feasible investment. From an environmental perspective, though tagging metals and materials with recyclable property are advantageous, the tags can cause heavy metal contamination of recyclable materials. Tags contain micro-electronic components which are hazardous in nature. Hence, they have to be treated after separating from waste streams to avoid the long-term risks (Abdoli, 2009). According to Wager *et al.,* (2005), treating the small particles is not an economically feasible solution.

2.6.2.3 Smart waste recovery

Energy and fuel recovery from waste deploy the use of advanced technology and are regarded as smart recovery methods due to their value generating potential. However, both waste to energy (W2E) as well as waste to fuel (W2F) processes suffer from lack of market due to high costs incurred (Navigant Research, 2014). The cost incurred in W2F plants is generally 2 times higher to the projects set for commercial refining of oils (Navigant Research, 2014). Therefore, it is a challenge to obtain investments to deploy these technologies in waste recovery and treatment particularly in developing countries. Hence, this method needs a better business model and economically viable solution.

2.6.2.4 Smart waste disposal

The remaining fraction of waste after value recovery is left for disposal. Innovative practices facilitate in identifying alternative solutions to maximize value of disposed waste. Sanitary landfills are engineered sites that collect the gas released during natural degradation of waste that is filled in the site. This gas can reduce impurities during electricity generation and is widely used in developed countries. However, this requires high capital and trained human resources. The gas contains methane which is 20-30 times more destructive than CO2. Like other technologies, if not managed carefully, it can pose danger to environment and mankind. To mitigate this problem, bioreactor landfills are designed by integrating remote monitoring sensors which can regulate the decomposition of waste, extraction of gas from landfill, etc. (Navigant Research, 2014). However, this is in testing phase and therefore cannot be commercially exploited yet.

From the review of smart methods for waste management, it is evident that these methods do not create a balance between environmentally sound practices and economically viable procedures. Though these methods improve waste management, there are also problems associated with them. This indicates that technology is not the only solution for waste management and these advanced systems do not include other factors that add smartness to city, such as collaboration, policies, etc., but are driven by latest technology. There is a need for integrated approach of human centric methods with technological innovations to provide a solution to waste in smart cities. Thus, smart combination is required for managing waste by including citizen participation, stakeholder collaboration and behavioural change with inclusive governance as discussed in section 2.6.1. Appropriate technologies for engaging and educating citizens through enhanced communication and interaction can help in achieving smart waste management.

2.7 Gaps in literature

The review of literature suggests that all the three concepts sustainability, smart cities and waste management are important for cities and the three concepts can be linked towards common objectives. The urban sustainability is only viewed as an environmental issue and the smart cities are seen as technologically advanced cities although the real concept is beyond environment and technology. It incorporates several other aspects that are required for achieving sustainability and for transformation of cities to smart cities. Moreover, these concepts are seen restricted to the cities in developed countries due to differences in priorities and financial circumstances. For cities in developing countries, public health and poverty alleviation are more important than environmental health. Providing basic facilities like healthcare, education, etc are prioritised for investments than on the advanced technology and urban infrastructure. Both the sustainability and smart cities concepts view waste management as one of the urban services to improve the environmental health. The other benefits of efficient waste management in achieving sustainability and meeting the characteristics of smart cities are not studied. Waste management also depends on several aspects such as stakeholders, technology, operational and managerial aspects as discussed in the previous sections. There are common factors that can also help in achieving sustainability and towards a smart transformation. But there is absence of literature that can relate these concepts as shown in figure 2.5 and also apply them to the developing countries.

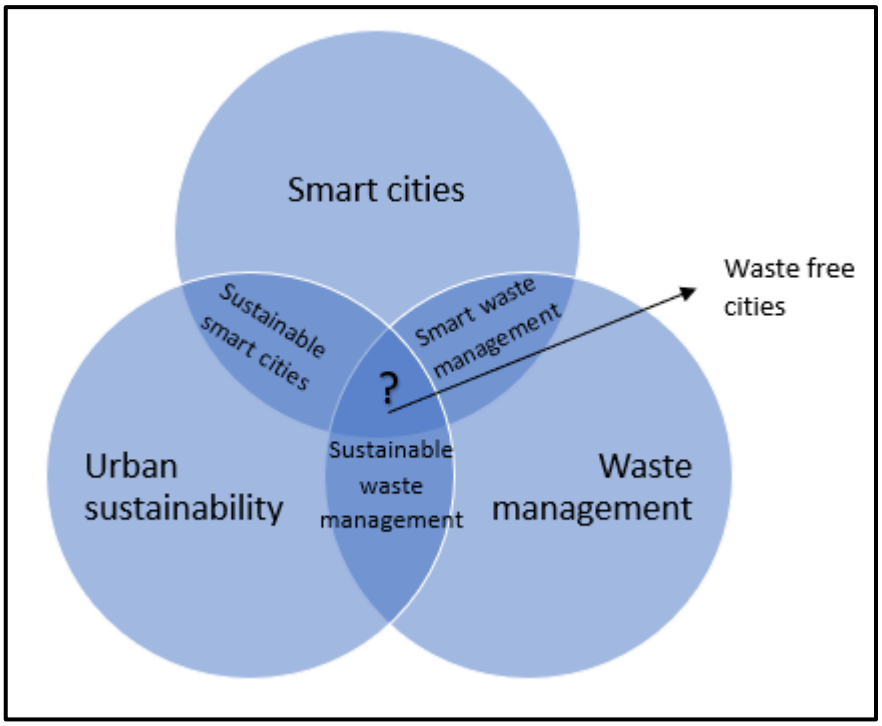


Figure 2.5: Gap in literature (Source: Author)

The research fills this gap in literature by developing a concept of waste free cities. It relates the three concepts, provides a definition for it and a framework that can be used to measure the smartness and sustainability through waste managing services. An effective waste management can not only solve the ever-growing waste problem but can also help in meeting the objectives of sustainable and smart cities. For example, by considering the soft aspects like stakeholder's role in value addition to waste, it can help in creation of new business models that can provide entrepreneurial opportunities, employment generation, and sustainable resource utilisation, improve environmental health, etc. which are smart city's objectives. Hence, a waste free city is defined as "*A city that provides an evolving solution to its waste problem by focussing on circular flow of materials through active stakeholder interaction and governance, fuelling business and employment opportunities in value recovery from waste and deploys technology as an enabler for improved waste services is called a waste free city (Source: Author)".*

Further details of the waste free cities framework that is developed as a part of the research and details on the relationship between waste management with urban concepts are provided in next chapter.

Chapter 3: Theoretical framework

3.1 Introduction

Many cities across the world are aiming to achieve urban sustainability and transform into smart cities. These cities face rapid urbanisation due to the opportunities they offer and suffer with increased waste generation rates and waste management remains a global problem. The developed countries employ efficient technology and transform their waste management into smart waste management. The developing countries face challenges and barriers to employ the use of technology as there are many other factors that influence it. Since the world started moving from liner flow of materials to circular flow of materials, the importance is given to waste hierarchy and recycling, resource recovery have been prioritised as mentioned in chapter 1.

There are several studies that identify factors and performance indicators for waste management and zero waste. The zero waste studies are limited to the cities of developed countries and there is lack of evidence on its applicability in developing countries. There are studies that identify indicators for smart cities and sustainability. Finding solutions for sustainable development was one of the many reasons for the origin of smart cities concept (Bibri and Krogstei, 2017). Consequently, the concept evolved and included several aspects that influence the city's functioning (Eremia *et al.*, 2017) and many frameworks and indicators have been developed for smart cities. However, these do not answer how the various indicators that add smartness to a city can also help in achieving sustainability. So, this waste free city framework takes into account both the frameworks of smart cities and sustainability to relate them. Both these concepts give less consideration to waste management and only list it as a sector that needs to be addressed for the development of sustainability and smart cities. They do not indicate a relationship between smart cities, urban sustainability and how each urban concept is addressing the urban waste problem. A comprehensive understanding of the complementary benefits brought by smart cities, sustainability and waste management is lacking. In addition, the smart cities and sustainability studies are treated as western concepts and are limited to the developed countries though many cities in developing countries are transforming (or trying to transform) themselves into smart cities. Identifying this gap in literature, the research provides a theoretical framework for waste free cities particularly developing countries.

The framework is developed with a combination of smart cities and waste management frameworks, their relevant factors and indicators in addition to sustainability categories.

3.2 Importance of waste free cities framework

The waste free cities framework considers an interplay between technological adaptation, stakeholders' involvement, governance aspects, operational aspects of waste management and sustainable smart cities. The framework provides a comprehensive tool to measure the waste management performance, sustainability and its relevance to smart cities. It provides the details of all the waste management indicators that are required for a smart city. It helps to draw a comparison between the cities in developing countries and compare the smartness and sustainability together. The framework facilitates the stakeholders such as policy makers, local authorities, private sectors and citizens to clearly identify how each of them is participating and where to improve for transforming to smart and sustainable cities. This allows the decision makers to particularly focus on that aspect at local level to improve the waste management service. Therefore, this framework evaluates the current situation of waste services and smart transformation by using indicators, identify the challenges and opportunities, and develop a strategic and operational plan to improve the situation as shown in figure 3.1. It also makes comparison possible between different cities for general comparison and allows comparison at smart city category and sustainability dimension levels. The use of this framework enables the other stakeholders to realise their role and areas of improvement. The application of framework uses both primary and secondary data. The primary data includes both top down and bottom up approaches, thus making it more reliable by creating balance between policy makers' and citizens' point of views. The secondary data is used where factual information such as waste generation rates, service provision, etc. are required. Since the framework emphasises on the cities of developing countries, the common aspects that are more relevant to developing countries like financial constraints, labour availability, etc. are included. Though developing countries are not deploying technology as much as the developed countries (Ilic and Nicolic, 2016b), since, smart cities consider technology as an enabler to improve city services, technology and the extent of its use is still considered where relevant to waste operations. Moreover, by considering the local conditions of developing countries, the factors and indicators do not replace workforce by the use of technology or result in problems like digital divide which are two criticisms for smart cities concept as discussed in chapter 2. The framework includes the possible factors that are currently being practised

in the developing countries and attempts to bridge it with the likely path towards modernisation of the service. Thus, the framework shows the road for transformation into smart city by bringing smartness from the often under prioritised waste services.

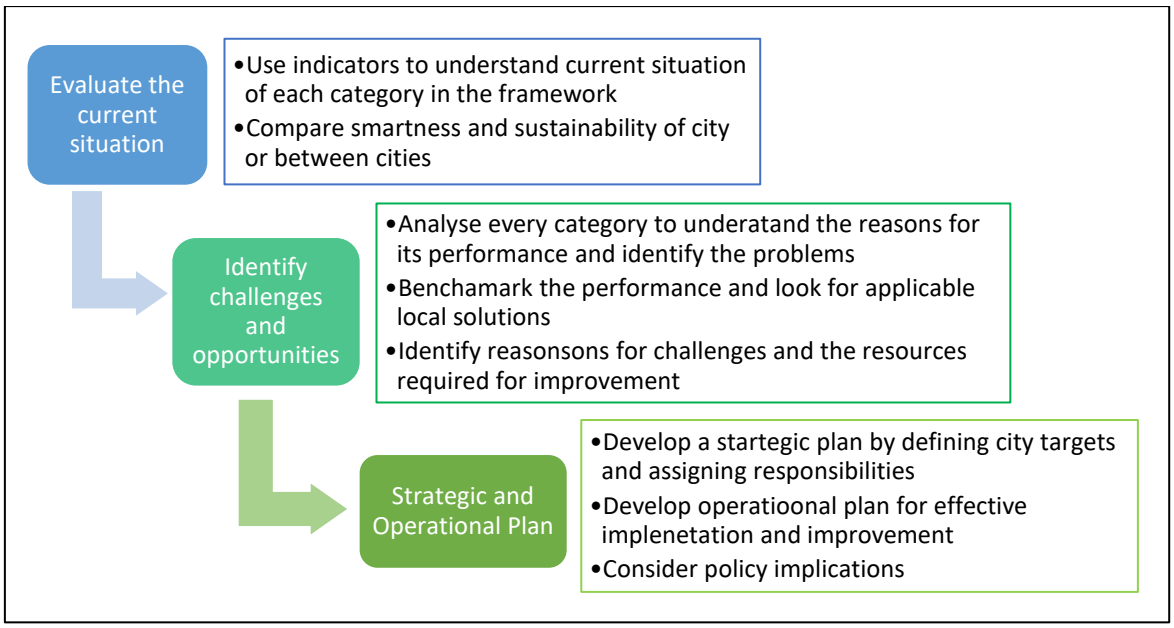


Figure 3.1: Importance of waste free city framework (Source: Author)

3.3 Development of waste free cities framework

The waste free cities framework is developed from the literature on smart cities, waste management and sustainability. It uses smart city categories from the most widely accepted smart cities framework proposed by Giffinger *et al.,* (2007). The study is not limited to it, but also includes the key indicators for smart cities proposed by other authors (Sujatha *et al.,* 2016; Tsiatsis *et al.,* 2016; Letaifa, 2015; Lee *et al.,* 2014; Chourabi *et al.,* 2012; Lombardi *et al.,* 2012). The sources for waste management include research works on frameworks, indicators, factors, drivers and challenges for effective and sustainable waste management in developing countries (Ilic and Nikolic, 2016a; Ilic and Nikolic, 2016b; Srivastava *et al.,* 2015; Wilson *et al.,* 2015a; Guerrero *et al.,* 2013; Marshall and Farahbakhsh, 2013; Shekdar, 2009; Wilson, 2007; Klundert and Anschutz, 2001) but is not confined to them and included other research works relevant to the topic. The research on waste management of developed countries is also considered where they are identified to be useful in improving the current scenario of developing counties. Since, the work of Wilson *et al.,* (2015a) has been extensively studied on several cities of developed and developing countries, the proposed indicators and their scoring methodology have been adopted. For the sustainability categories, the most widely accepted triple bottom line

proposed by Elkington (1998 in Gimenez *et al.*, 2012) is considered where environmental, economic and social dimensions of sustainability are identified. Additionally, categories with the combination of the three dimensions are used as a clear boundary between the factors from sustainability categories point of view is not clear (Troschinetz and Mihelcic, 2009) due to their interplay between more than one sustainability dimension. Therefore, the framework has six smart categories and six sustainability dimensions that are represented by factors and sub factors measured using relevant indicators.

There are two types of indicators- qualitative and quantitative. The qualitative indicators are assessed using Likert measurement by assigning scores (Likert, 1932) to each indicator. The measurement scale used for scoring maintained centrality and therefore ensured the characteristics of a good Likert scale. The quantitative indicators are represented using a range that is appropriate for each of their measurements. The upper and lower limits for such indicators are selected after reviewing the ranges in a number of popular cities in developing countries. Efforts are made to choose a range, where the upper limit overlap with the lower limits of such measurements in developed countries. This is to provide a scale to compare developing and developed countries to show the gap in the transformation. All the factors and sub factors for each category are equally weighted, the means of all factors (or sub factors) are calculated to assign the final score to each of the smart categories.

The framework is applied on three Indian cities that are listed in the smart cities mission by Ministry of Urban Development (MoUD), Government of India (Smart Cities Mission, 2016). Since the literature suggests there are a number of challenges to achieve effective waste management, the research collected primary data from all the key stakeholders of the three cities to address such challenges and provide solutions for achieving waste free cities.

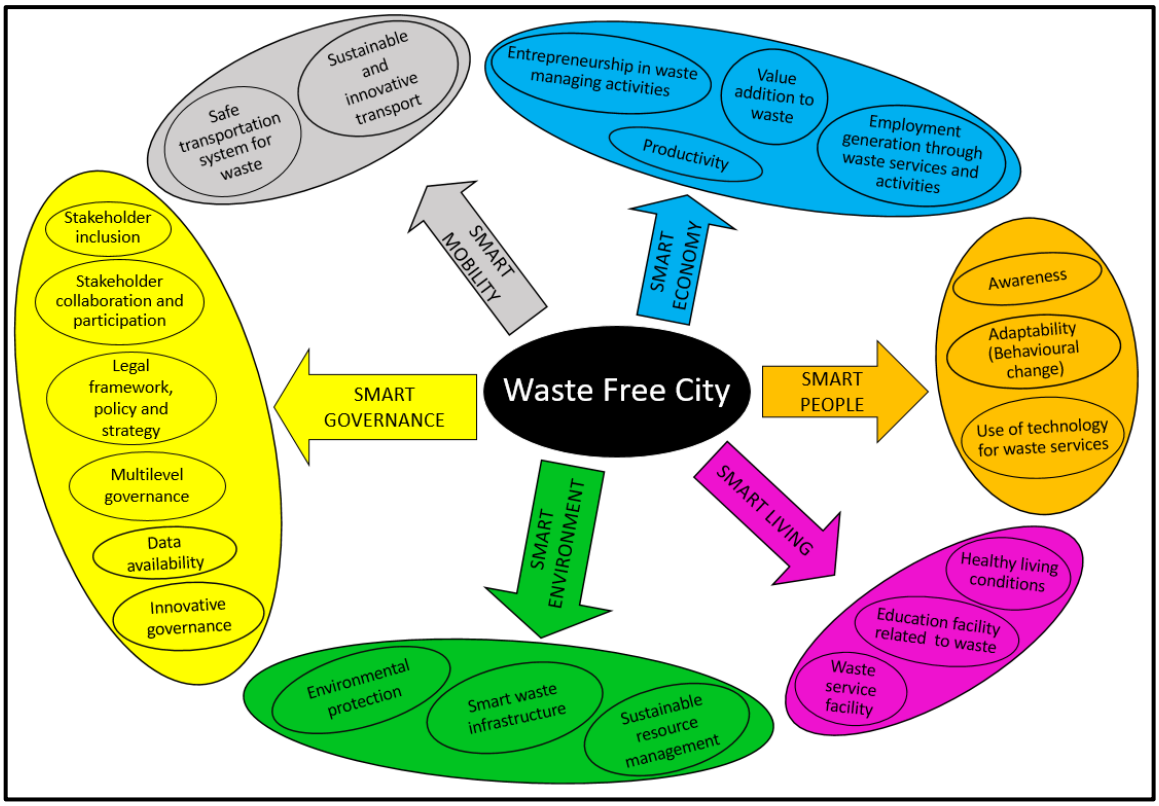


Figure 3.2: Waste free cities framework (Source: Author)

3.4 Description of the framework

The waste free cities framework has six categories namely smart economy, smart people, smart governance, smart mobility, smart environment and smart living which are derived from the Giffinger *et al.*, s' (2007) smart cities framework. Each smart city category is represented by factors that affect waste management as well as smartness to the city. Since the factors have multiple attributes, some of the factors are further divided into sub factors as shown in table 3.1. Both factors and sub factors are represented by indicators. Each indicator is further categorised into sustainability dimension. As mentioned earlier in section 3.3, due to a more integrated approach of the study, sustainability dimensions are divided into six, namely, economic, social, environmental, socio-economic, socio-environmental and economic-environmental dimensions.

Table 3.1: Factors and sub-factors used for each smart category for waste free smart cities framework (Source: Author)

Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living
Productivity	Adaptability (Behavioural change)	Stakeholder collaboration and participation • Public private partnerships • Citizen participation • Involvement of NGOs and CBOs • Inclusion of informal sector	Safe transportation system for waste	Environmental Protection • Assessment and monitoring • Environmental savings • Environmental burdens	Waste service facility
Employment generation through waste sector	Use of technology for waste	Stakeholder inclusion	Sustainable and Innovative Transport • Green transport • Technology/ICT in transport	Sustainable resource management • Efficient use of waste	Education facility related to waste
Entrepreneurship in waste sector	Awareness	Legal framework, policy and strategy		Smart waste infrastructure	Healthy living conditions
Value addition to waste		Multilevel governance Data Availability Innovative governance • e-governance • Communication methods • Policy redesign			

3.4.1 Category 1: Smart Governance

3.4.1.1 Stakeholder collaboration and participation

According to Giffinger *et al.,* (2007), governance is crucial for smart city and there is need to frame policies and strategies through transparent governance to improve services to citizens. As determinants of smart governance, many authors (Sujata *et al.,* 2016; Letaifa, 2015; Lee *et al.,* 2014; Chourabi *et al.,* 2012; Giffinger *et al.,* 2007) consider the need to identify stakeholders for city's functioning. They emphasise on the role of stakeholder collaborations including public private partnerships, citizens and NGOs participation and identify a healthy collaboration as means for value creation in smart city (Letaifa, 2015) and sustainable eco-system (Lee *et al.,* 2014). Particularly in developing countries such as India, where political issues affect the completion of smart infrastructural initiatives, there is a need for stronger stakeholder involvement to drive the infrastructural projects to completion (Chatterjee and Kar, 2015).

Similarly, Zaman (2014) states that governance drives waste management process. There is research in waste management that indicates the need for stakeholder collaboration (Wilson *et al.,* 2015a; Guerrero *et al.,* 2013; UN Habitat, 2010; Shekdar, 2009; Sujauddin *et al.,* 2008; Joseph, 2006) and is an essential aspect in the concept of integrated waste management. Moreover, their active participation, collaboration, interest, and communication are vital for value addition to waste. Their inclusion in decision making for policy design is crucial to improve waste services in developing countries (Wilson *et al.,* 2015a). In addition to the formal waste collection authorities, private sector, NGOs and CBOs, the informal sector is an important group of stakeholders in developing countries' waste management (Wilson *et al.,* 2015a; Gupta, 2012; UN Habitat, 2010). The value addition and waste management activities can improve through a collective approach of these diverse stakeholders. Therefore, there is need to understand and measure the interactions between the stakeholder groups to improve waste services (Caniato *et al.,* 2014). In addition to the application of framework, identifying the interactions between the stakeholders that can help in value addition and smart transformation is needed. Hiremath *et al.,* (2013) and Yigitcanlar *et al.,* (2015) suggest that stakeholder identification and their communication is an indicator for achieving urban sustainability. Shen *et al.,* (2011) and Huang *et al.,* (2009) have emphasised on the need for stakeholder inclusion in policy design for the development of urban sustainability. These studies suggest stakeholder collaboration and stakeholder inclusion are important for achieving waste free city and its

governance. Hence, these are included in the current framework and the details of its sub factors and indicators are shown in table 3.2.

3.4.1.2 Stakeholder inclusion, Legal framework, Policy and Strategy

Most frameworks proposed for smart cities consider political and legal frameworks as central to smart governance (Sujata *et al.,* 2016; Chourabi *et al.,* 2012; Giffinger *et al.,* 2007). Participation of public in planning and implementation of municipal solid waste management is considered as an important social indicator (Desmond, 2006). With the growing importance to stakeholder inclusion and need for improved communication, Baud *et al.,* (2001), identifies the need for the development of legal framework and policy redesigns to improve urban sustainability in various urban sectors. Particularly in waste management, there are several works that insist on the need for legal frameworks that delineate the local actions with national due to the need for more local approaches (Wilson *et al.,* 2015a; Shekdar, 2009; Qdais, 2007). According to Thuzar (2011), participatory policy design can help in efficient resource management. Works by Wilson *et al.,* (2015a); Guerrero *et al.,* (2013); UN Habitat, (2010); Shekdar, (2009); Klundert and Anschutz, (2001) suggest that policy, strategy and legal frameworks have positive role in achieving effective waste management. Additionally, Wilson *et al.,* (2012) identifies waste management is a form of resource recovery thereby, strengthening of governance aspects for waste management is needed. Therefore, policy, strategy and legal frameworks are considered as a factor for smart governance. The indicators used to relate smart governance with waste management are derived from the studies of Wilson *et al.,* (2015a), Zaman (2014) and Shekdar (2009) and the details are provided in table 3.2.

3.4.1.3 Multilevel Governance

According to Chourabi *et al.,* (2012), there is a need for delegation of responsibilities between different governing levels to transform into smart cities. With the evidence from literature on the role of multilevel governance for the success of smart cities (Letaifa, 2015) and sustainable smart cities (Serbanica and Constantin, 2017), it is considered as a factor for waste free cities framework. According to Wilson *et al.,* (2015a), there are several indicators that influence the governance in waste management and notably, there is a need for setting guidelines for implementation of policies. The author pointed out organisational structure and institutional capacity are important for successful multilevel governance. Guerrero *et al.,* (2013) identified these aspects as constraints in developing countries waste management though they have significant role in improving the system.

Chourabi *et al.,* (2012), indicates that this can be overcome with clear milestones and measurable deliverables. Therefore, this framework considers multilevel governance as a factor for smart governance for both waste management and sustainable smart cities. It is measured using the indicator with organisational structure having defined roles, responsibilities and targets between national and local authorities.

3.4.1.4 Data Availability, Innovative governance and e-governance

Availability of waste related data is considered to be a problem particularly in developing countries (Wilson *et al.,* 2012) which restricts the assessment of current practices and comparison with other cities. Furthermore, developed countries have the potential to offer their service in the developing countries either through collaboration or with new business models. Such collaborations could bring in many advantages to the developing countries. The dearth of data availability on local waste management scenario results in lack of understanding on the requirements for improvement and this halts such developmental opportunities (DBIS, 2013). According to Kumar *et al.,* (2009), in India, most local authorities do not have accurate data on waste management activities and this restricts further planning to improve the operations. The concept of smart city stems up from the concept of digital cities (Eremia, *et al.,* 2017) and therefore, emphasises on the digitalisation, data gathering, and data availability. In smart cities of developing countries, data unavailability and issues with data security stand as major challenges (Chatterjee and Kar, 2015).

Smart cities see active citizens as producers of data and not just consumers emphasising on the need for data generation and availability and this is studied as a factor for governance. Consequently, this draws the need for active stakeholder communication and interaction (Lee *et al.,* 2014; Falconer and Mitchell, 2012). According to Nam and Pardo (2011) communication can be enhanced through the means of technology. Sujata *et al.,* (2016), considers social media as one such examples that can promote interaction between stakeholders. Eremia *et al.,* (2017) suggests the use of smart phones can improve waste management in smart cities. E- governance is seen as one such platforms as it uses technology and can facilitate improved interaction between the local authorities and citizens. It can also be seen as a form of smart governance (Chourabi *et al.,* 2012). There is a need for innovative governance which can improve communication and re-design policies to enable the use of such technology (Gil- Garcia and Pardo, 2005) and maintains the synergy between innovations and actors (Serbanica and Constantin, 2017).

Table: 3.2 Smart Governance (SG) (Source: Author)

Factor	Sub factor	Indicator	Measurement	Sustainability dimension
SGF1: Stakeholder collaboration and participation	Public private partnerships	Collaborations with private organisations for waste management activities	1=No collaborations	Environmental-economic
			2=Low collaborations	
			3= Low/Medium collaborations	
			4=Medium/High collaborations	
			5=High collaborations	
		Efforts to subsidise or incentivise recycling/recovery activities for private organisations and SMEs	1=Absent	Environmental-economic
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
	Citizen participation	Appropriate source separation practiced	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
	NGOs and CBOs involvement	NGOs and CBOs active in waste services or awareness campaigns	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
	Informal sector inclusion	Efforts to formalise informal sector	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Efforts to support informal sector through capacity building	1=Absent	Socio-economic
			2=Low	

			3= Low/Medium	
			4=Medium/High	
			5=High	
SGF2: Stakeholder inclusion in policy making		Extent of stakeholders' involvement in policy design for waste policies	1= Not involved	Social
			2= Stakeholders' involvement is present, but degree of involvement is unclear	
			3= Policies designed based on feedback on current services;	
			4= stakeholders are consulted before decision making with appropriate representation of their groups;	
			5= Stakeholders participate during decision making process	
		Citizens' opinion on the importance of their consultation or involvement in policy design for waste management	1=Very unimportant	Social
			2=Unimportant	
			3=Neither important nor unimportant	
			4= Important	
			5= Very important	
SGF3: Legal framework/ policy/ strategy		Presence of legal framework for waste management including at national and local level	1= No legal framework	Socio-environmental
			2=Legal framework present but no compliance	
			3=Legal framework present with low compliance	
			4=Legal framework present with medium compliance	
			5=Legal framework present with high compliance	
		Waste ban laws in place	1= No waste ban law	Socio-

			2= Waste ban law present but no compliance	environmental
			3=Waste ban law present with low compliance	
			4=Waste ban law present with medium compliance	
			5=Waste ban law present with high compliance	
		Regulation on user fees	1= No regulation on user fees	Socio-environmental
			2= Regulation on user fees present but no compliance	
			3=Regulation on user fees present with low compliance	
			4=Regulation on user fees present with medium compliance	
			5=Regulation on user fees present with high compliance	
		Regulations on landfill tax	1= No regulation on landfill tax	Socio-environmental
			2= Regulation on landfill tax present but no compliance	
			3=Regulation on landfill tax present with low compliance	
			4=Regulation on landfill tax present with medium compliance	
			5=Regulation on landfill tax present with high compliance	
		Regulations for organising informal sector	1= No regulation for organising informal sector	Social
			2= Regulation for organising informal sector present but no compliance	

			3=Regulation for organising informal sector present with low compliance	
			4=Regulation for organising informal sector present with medium compliance	
			5=Regulation for organising informal sector present with high compliance	
		Regulations for extended producer responsibility (EPR) for all consumer products	1= No regulation for EPR	Environmental
			2= Regulation for EPR present but no compliance	
			3=Regulation for EPR present with low compliance	
			4=Regulation for EPR present with medium compliance	
			5=Regulation for EPR present with high compliance	
		Regulations for cleaner production (CP) for all consumer products	1= No regulation for CP	Environmental
			2= Regulation for CP present but no compliance	
			3=Regulation for CP present with low compliance	
			4=Regulation for CP present with medium compliance	
			5=Regulation for CP present with high compliance	
		Presence of clear guidelines and targets at local level for policy implementation with timeline	1=Absent	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Access to required resources and infrastructure for	1=Absent	Economic
			2=Low	
			3= Low/Medium	

		successful policy implementation	4=Medium/High	
			5=High	
SGF4: Multilevel governance		Clear organisational structure with roles and responsibility and targets at local level	1=Absent	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SGF5: Data Availability		Availability for time series data for waste generation, recycling, treatment and disposal	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Central database system for waste data	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SGF6: Innovative governance	e-governance	e- governance including waste management and related issues	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
	Communication methods	Digital campaigns for awareness on waste management activities	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		New methods of communication with stakeholders	1=Absent	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
	Policy redesign	Changes to policies to use recycled/recovered materials in industries	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Policies focussing to integrate local secondary markets for supply of materials in government projects	1=Absent	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	

3.4.2 Category 2: Smart People

Smart cities aim at providing the best services for people to improve their quality of life and also focus on adding smartness to people and their wellbeing (Haque, 2012). There are several authors (Kummita and Crutzen, 2017; Sujata *et al.*, 2016; Chourabi *et al.*, 2012; Lombardi *et al.*, 2012; Giffinger and Gudrun, 2010) who consider that people play an extensive role in transforming a city to smart city by being flexible, creative, gaining knowledge and participating in public life. From waste management studies, people and communities are considered as important social factors and important stakeholder group. Many studies (Ahvenniemi *et al.*, 2017; Sanjeevi and Shahabudeen, 2015; Wilson *et al.*, 2015a, Zaman, 2014; Guerrero *et al.*, 2013; Zaman and Lehmann, 2013; Zaman and Lehmann, 2011; UN-Habitat 2010; Shekdar, 2009; Troschinetz and Mihelcic, 2009; Sharholy *et al.*, 2008) have identified several factors related to people and influence waste management process. They are categorised into awareness, adaptability and use of technology in waste free cities framework.

3.4.2.1 Awareness

Awareness of people and their participation are identified as key drivers for smart growth (Holland, 2008; Giffinger *et al.*, 2007) as well as urban sustainability (Yigitcanlar *et al.*, 2015) as they contribute towards social and environmental sustainability. Similarly, in waste management research, awareness of people has been prioritised. According to Shekdar (2009), people are waste generators and should be aware of their role in its management. In developing countries, it is claimed that people lack awareness on waste management activities (Pokhrel and Viraraghavan, 2005). For achieving zero waste or effective source separation which is a value adding activity, awareness of people is seen as an important social factor (Zaman, 2014). Waste generation is higher in affluent households (Medina, 1997), but awareness and knowledge about waste avoidance and better management of waste can help in decreasing per capita waste generation. In addition to awareness and knowledge, citizen participation is also important. Citizens participating in waste avoidance and waste management activities such as source separation or recycling, etc. help in reducing the amount of waste generated. However, as citizens' participation depends on individual's interests (Caniato *et al.*, 2014), their interest in environmental programmes is considered as one of the indicators for the framework.

3.4.2.2 Adaptability (Behavioural change)

Flexibility of people is considered as a factor for smart city (Giffinger *et al.*, 2007). Similarly, waste management studies indicate that change in habits, behaviours (Zaman, and Lehmann, 2011), lifestyles and consumption patterns (Troschinetz and Mihelcic, 2009) is important to move towards waste avoidance, minimisation (Zaman, and Lehmann, 2011), source separation and participation. People should be willing to participate in the policy implementation as well as waste managing solutions (Guerrero *et al.*, 2013). This willingness to change or adapt by people is seen as a managerial challenge for smart city initiatives (Chourabi *et al.*, 2012). Wilson *et al.*, (2015a), and Zaman (2014), have identified that behavioural change of people is required. This change is identified as their willingness to participate towards recycling, re-sale and waste reduction which can help in resource management and environmental sustainability through citizen led approach (Turcu, 2013).

3.4.2.3 Use of technology for waste services

As discussed in the smart governance (section 3.5.1), community participation and interaction are important for smart cities and sustainability (Block *et al.*, 2013). Several authors (Marsal-Llacuna *et al.*, 2015; Washburn *et al.*, 2010; Caragliu *et al.*, 2009; Hollands, 2008; Partridge, 2004) suggest that use of Information and Communication Technology (ICT) can promote citizen participation and sustainability, besides helping in improving the urban services. Use of social media (Sujata *et al.*, 2016) and e-governance (Chourabui *et al.*, 2012) have been suggested as smart ways of communication. Additionally, mobile applications through smart phones have been successfully used in some parts of the United Kingdom (DBIS, 2013) as communication channel by citizens for waste services. According to Chourabi *et al.*, (2012), the smart channels to communicate include digital campaigns and targeting active internet users. Therefore, use of technology for waste related issues is identified as one of the factors for smart waste management. One of the indicators used to address it is the use of internet by people for waste related issues.

There are also smart waste management techniques that use RFID tagging of products to facilitate source separation (Binder *et al.*, 2008) and in billing procedures (user fees). There are also challenges for its implementation as people should be willing to use such advanced techniques (Abdoli, 2009). So, as the acceptance to use such advanced technology by people can be an attribute in making them smart, this is also considered as an indicator in this framework.

Table 3.3: Smart People (SP) (Source: Author)

Factor	Sub-factor	Indicator	Measurement	Sustainability dimension
SPF1: Awareness	-	Per capita waste generation	1= >1.5 kg/capita/day	Social
			2=0.7 -1.5 kg/capita/day	
			3=0.4-0.7 kg/capita/day	
			4=0.2-0.4 kg/capita/day	
			5= 0-0.2 kg/capita/day	
		People aware of the environmental benefits of source separation	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		People interested in environmental programmes	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SPF2: Adaptability (Behavioural change)	-	People willing to change behaviour or lifestyle to protect environment	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		People willing to recycle without any personal economic benefit	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		People willing to sell recyclables	1=No	Socio-economic
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SPF3: Technology use for waste services	-	People willing to use RFID tagged daily products to improve source separation	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		People use internet to report or discuss waste and environmental	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	

		related issues	4=Medium/High	
			5=High	
		Use of ICT for communicating with citizens (Mobile applications, portals, social media, etc.)	1=No	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	

3.4.3 Category 3: Smart Living

According to Giffinger *et al.,* (2007), smart living is a category for smart cities. It comprises of various aspects associated to the quality of living in cities such as health conditions, security, education facilities, social cohesion, etc. Since efficient management of solid waste is associated with sustainability and quality of urban life (Baud *et al.*, 2001), it has an effect on smart living. So, the related factors that can help in improving the waste services and contribute to smart living are considered in this framework.

3.4.3.1 Waste service facility and healthy living conditions

All the three concepts- smart cities, sustainability and waste management play role in providing safe and healthy living conditions for the city's inhabitants. Sustainability (Richardson, 1989) and smart cities (Giffinger *et al.,* 2007) aim at promoting health of citizens. Waste management service particularly in developing countries focus on improving waste collection to protect public health by minimising their exposure to waste and associated diseases (UN-Habitat, 2010). So, the studies in waste management (Wilson *et al.*, 2015a and Zaman, 2014) have considered public health as well as safety of waste workers as indicators for waste management performance. Indicators like service provision, number of people covered with waste service, number of bins available, type of waste collection and appearance of waste or litter (Wilson *et al.,* 2015a; Zaman, 2014; Koushki, *et al.,* 2004) are also related to public health and are important managerial aspects. For service users such as citizens, the quality of waste service provided reflects quality of life and is measured by public satisfaction (Zaman, 2014). So, the framework included waste service facility and healthy living conditions as factors for smart living and is measured using several indicators as mentioned in table 3.4.

3.4.3.2 Education related to waste

Education facilities indicate smart living conditions for a city, and this has been measured to study the smartness of many cities across Europe (Giffinger *et al.,* 2007). The cleanliness, resource recovery and efficiency of the overall service depends on the participation of citizens and municipal authorities (Shekdar, 2009). It is a social factor and awareness is the key driver for promoting citizen participation (Moghadam *et al.*, 2009). Citizen awareness and education can help in improving operational efficiency of waste services and minimise waste generation. Similarly, knowledgeable authorities and staff contribute significantly to the efficiency (Guerrero *et al.*, 2013). This can be achieved through creating interest on city's initiatives and environment through communication and awareness campaigns to citizens and training to staff. Embedding education related to waste in school curriculum (Zaman, 2014) can help significantly as this could bring in behavioural change in children at an early age and inculcate good practices as habits. Hence, facilities for waste education are considered as a factor for smart living in waste free cities and is measured using the indicators such as community awareness programmes, waste workers training programmes and education on waste management in school curriculum.

Table 3.4: Smart Living (SL) (Source: Author)

Factors	Sub-factors	Indicators	Measurement	Sustainability Dimension
SLF1: Waste service facility	-	Percentage of households served with waste collection facility	1=< 10%	Socio-Environmental
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	
		Percentage of door to door or Kerbside collection facility	1=< 10%	Socio-Environmental
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	
		Presence of accumulated waste on streets or near bins	1= waste accumulation very prevalent and not cleared	Socio-Environmental
			2= waste accumulation generally occurs and cleared occasionally	

			3= waste accumulation generally occurs, but cleared every day	
			4= Waste accumulation generally absent, but seen occasionally or in some areas of the city and cleared every day	
			5= Waste accumulation never seen	
		Degree of public satisfaction on waste services	1=Extremely unsatisfied	Social
			2= Unsatisfied	
			3= Neither satisfied nor unsatisfied	
			4= Satisfied	
			5=Extremely satisfied	
		Degree of public satisfaction on the level of interaction with Local authorities	1=Extremely unsatisfied	Social
			2= Unsatisfied	
			3= Neither satisfied nor unsatisfied	
			4= Satisfied	
			5=Extremely satisfied	
SLF2: Healthy living conditions	-	Reduction in waste related diseases	1=No	Socio-Environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Personal protection equipment to waste handlers	1=No	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SLF3: Education facility related to waste	-	Community programmes to educate on waste avoidance, reduction, source separation, reuse and recycling methods	1=No	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	

		Education on waste management in school curriculum or activities	1=No	Social
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Regular training programmes for waste workers	1=No	Socio-Environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	

3.4.4 Category 4: Smart Mobility

Smart mobility includes the use of innovative transportation systems that are sustainable. It emphasises on safe and green transportation methods (Giffinger *et al.,* 2007). Waste transportation is an important step in waste management operations. As waste collection is a process of reverse logistics, it is more complex due to the number of waste producers and types of wastes produced unlike the forward logistics. Transportation of waste determines the resource recovery from it as separated waste should be safely transported without contamination to ensure its value is maintained. So, safe waste transportation and innovative transport systems are identified as factors for the framework.

3.4.4.1 Safe transportation system

Transportation of the collected waste is crucial for its further separation or final disposal. The developing countries suffer with poor roads and waste transport vehicles (Henry *et al.,* 2006) and lack efficient transport facilities. The waste collection vehicles are outdated, and waste is collected in open vehicles that may result in further littering and unsafe for public health. Source separation of waste is the critical step for resource recovery and value generation from waste (Zaman, 2014). The other aspect is the ability of service providers to collect separated waste either by different transport systems or co-collection. The collection complexity in waste collection and waste sorting can greatly affect the associated costs (Jahre, 1995). Contamination of separated waste will not only affect the collection and transportation costs, but also increase the complexity in central or secondary sorting units (or MRFs) by incurring additional labour costs. This is an important value adding activity that involves the role of waste collection and transportation workers to maintain the value chain of waste and types of waste collection vehicles. Hence, closed

transport system for waste and separate transport for waste categories are studied as indicators for safe transportation of waste.

3.4.4.2 Sustainable and Innovative Transport

Use of the new technologies to improve transport system and sustainability are the requirements of smart mobility (Giffinger *et al.,* 2007). The authors also emphasise on the greener modes of transportation that are environmentally friendly and minimise energy use. The framework included use of green transport that is measured using the number of non-motorised vehicles as they do not significantly contribute to greenhouse gas emissions and offers environmental benefit (Scheinberg *et al.*, 2010).

Table 3.5: Smart Mobility (SM) (Source: Author)

Factor	Sub-factors	Indicator	Scores	Sustainability category
SMF1: Safe transportation system for waste		Closed transport system for waste	1= Open transport only	Socio-Environmental
			2= Open transport vehicles, with arrangements to cover waste but chances for littering while transporting waste are present	
			3=Trial phase with few closed transport vehicles	
			4= Both open and closed transport	
			5= Closed transport only	
		Separate transport for waste categories	1= No separate transport	Environmental
			2= Temporary arrangements in transport vehicles to separate waste types, but changes of contamination present	
			3=Trial phase with few separate transport vehicles or schedules	

			4= Both separate and mixed transport exist	
			5= Separate transport only	
SMF2: Sustainable and Innovative Transport	Green transport	Percentage of non-motorised waste transport vehicles	1=< 10%	Environmental
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	
	Technology or ICT in transport	Percentage of vehicles enabled with GPS	1=< 10%	Environmental-Economic
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	
		Percentage of electric vehicles used for waste transport	1=< 10%	Environmental-Economic
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	

The non-motorised vehicles are often based on muscle power and due to high labour availability in developing countries it also offers social benefit such as employment opportunities. In addition, the advanced vehicles such as electric vehicles for waste collection are gaining attention due to the advantage they offer by being more environmentally friendly due to their low noise and emissions. Especially with the number of halts a waste collection vehicle requires, these vehicles are considered useful (Eltis, 2017). In waste transportation, route planning is a major operational challenge. GPS fitted waste collection vehicles are seen to provide a solution to manage the routing as well as to monitor the waste collection workers remotely (DBIS, 2013). So, waste collection vehicles fitted with GPS are seen as use of ICT in transports which contributes towards smart mobility. Therefore, these advanced systems in waste transportation are considered for the framework not only for their contribution towards environmental sustainability, but due to the operational advantages and cost efficiency offered by the system.

3.4.5 Category 5: Smart Economy

According to Giffinger *et al.*, (2007), a smart economy is one of the 6 categories for smart city which includes productivity, employment rate, innovation, entrepreneurship, labour

flexibility, etc. and drive the economic growth. Similarly, during the transformation of the city, the smart initiatives could also enhance the employment and entrepreneurship opportunities and improve the productivity (Chourabi *et al.,* 2012). The studies of sustainability also emphasise on economic development and is one of the dimensions for sustainability according to the triple bottom line concept (discussed in chapter 2). Therefore, indicators for economic dimension are included for measuring sustainability (Ahvenniemi *et al.,* 2017; Shen *et al.,* 2011). The integrated waste management concept also considers the economic aspect as an important category. The way this category is studied is different from the earlier two concepts. The studies mainly focus on the economic aspect as a barrier and emphasis is laid towards receiving adequate fund and budget for waste management (Shekdar, 2009; Kundert and Anschutz, 2001). Although this is true, there is other side of the coin where waste management activities contribute towards the economic growth of the city which is often ignored and not studied as an indicator except Zaman (2014). Therefore, in the waste free cities framework, the indicators that address economic growth for smart cities, sustainability and waste management are identified as productivity, employment generation, entrepreneurship and value addition to waste.

3.4.5.1 Productivity

Productivity is an important factor for smart economy and is measured using GDP per employed person (Giffinger *et al.,* 2007). Zaman and Lehmann (2011) identify GDP per employed person and purchasing power parity as indicators of economic aspects for zero waste and have successfully used them in developed nations. Although Wilson *et al.,* (2015a), have not considered it under the indicators, this information is still used by the authors as background information about the city during the comparison of five different countries including developed and developing. Therefore, these indicators are included in the current framework.

3.4.5.2 Employment generation

Zaman (2014) identified the number of employees in waste management and number of people employed in recycling are important indicators for human resources and Lombardi *et al.,* (2012) and Giffinger *et al.,* (2007) indicates the employment rate is an indicator of smart economy. According to Lombardi *et al.,* (2012), the employment rate in renewable energy sector is studied as an indicator for smart economy. This signifies that importance of circular flow of materials and their contributions for economic growth. Due to the same

advantage offered by waste, the employment rate in waste sector should be given importance towards the smart economy. Hence, it is identified as an indicator in this framework. In the developing countries, besides formal employment, there are a number of people who depend on waste managing activities such as informal sector and waste/rag pickers. Their exact number in the city is unknown but are seen to contribute significantly to the economic growth, circular flow of materials and subsidise the operational costs for the formal sector due to their activities (Ezeah *et al.,* 2013; Linzer and Lange, 2013; Gupta, 2012; Scheinberg *et al.,* 2010; Wilson *et al.,* 2009; Wilson *et al.,* 2006; Agarwal *et al.,* 2005). So, this is considered as an indicator for smart economy.

3.4.5.3 Entrepreneurship

Entrepreneurship and business creation indicate smart economy (Chourabi *et al.,* 2012; Lazaroiu and Roscia, 2012; Giffinger *et al.,* 2007). Lee *et al.,* (2014) suggests collaborated work in developing entrepreneurship can help in promoting economic growth. In developing countries, there are several small enterprises that trade waste. So, the framework considers the existence of small and medium enterprises in waste sector as an indicator for smart economy. The other significant contributor is the informal sector that comprises of waste or rag pickers and itinerant waste buyers. They can be registered with authorities if they are working with a private company (Velis *et al.,* 2012) or governing bodies but the major challenge in developing countries is the lack of organisations or formalisations of informal sectors. Organising the informal sector into cooperatives or associations are proven to be successful (Gupta, 2012), but the advantages of formalisation remain unclear from financial sustainability point of view (Agarwal, *et al.,* 2005) and the informal sectors still suffer. Therefore, existence of organised informal sector is considered as an indicator in this framework.

Table 3.6: Smart Economy (SEc) (Source: Author)

Factor	Sub-factor	Indicator	Measurement	Sustainability dimension
SEcF1: Productivity	-	GDP per employed person	As per country	Socio-economic
		Purchasing Power Parity (PPP) or Household per capita income	As per country	Socio-economic

SEcF2: Employment generation through waste services and activities	-	Percentage of city's population employed in formal waste management activities	1=0-0.3%	Socio-economic
			2= 0.3-0.5%	
			3=0.5-1%	
			4=1-4%	
			5= > 4%	
SEcF3: Entrepreneurship in waste management activities	-	Existence of SMEs in waste sector	1=No	Socio-economic
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Existence of organised informal sector	1=No	Socio-economic
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
SEcF4: Value generation from waste	-	Revenue generation from waste by informal sector	1= £0-£2000/month	Economic
			2=£2000-£4000/month	
			3= £4000-£6000/month	
			4=£6000-£8000/month	
			5=£8000-£10000/month	
		Revenue generated from waste by formal sector	1= £0-£2000/month	Economic
			2=£2000-£4000/month	
			3= £4000-£6000/month	
			4=£6000-£8000/month	
			5=£8000-£10000/month	

3.4.5.4 Value addition to waste

Waste is seen as resource and has a potential to recover value from it. There are many value adding activities in waste management. However, in developing countries, waste management is poorly organised, and these activities are not given importance. Nevertheless, citizen participation, private sector participation (Rathi, 2006), NGOs and informal sector participation (Ezeah *et al.*, 2013; Scheinberg *et al.*, 2010; Wilson *et al.*, 2009; Wilson *et al.*, 2006; Agarwal *et al.*, 2005) are seen to be potential value adding

stakeholders. The activities of informal sector are identified to create value to waste (Valorisation) (Scheinberg *et al.*, 2010). There are studies in waste management that consider operating costs (Wilson *et al.*, 2015a; Koushki *et al.*, 2004), cost benefit (Zaman and Lehmann, 2011), and unit cost measurement as economic aspects. Therefore, cost per unit method is selected to measure the value generated (in the form of revenue for monetary reference) from waste by different stakeholders as an indicator for smart economy.

3.4.6 Category 6: Smart Environment

Concern for environment has been one of the drivers for the concepts of sustainability and smart cities. These concepts emphasise on environment and according to Ahvenniemi *et al.*, (2017) the environmental indicators in sustainability and smart cities frameworks are 47% and 20% respectively. Smart cities aim at protecting environment and use advanced technology for sustainable resource management which is categorised as smart environment (Giffinger *et al.*, 2007). Although the author identifies sustainable resource management can help in achieving smart environment; waste is not seen as a reservoir of resources. Turcu (2013), identifies waste as a resource and its role in achieving environmental sustainability. Similarly, several authors (Wilson *et al.*, 2015a; Zaman, 2014; Zaman and Lehmann, 2011; Shekdar, 2009, Klundert and Anschutz, 2001) have identified environmental protection as the key driver in waste management and is considered important in the performance indicators (Sanjeevi and Shahabudeen, 2015) of smart city, sustainability and waste management. It is important to study the impacts on environment and frame strategies for its protection, assessment and monitoring. The shift from linear to circular flow of materials is required to reduce the environmental impacts as it reduces the burden of waste volumes and brings back the resources to the system (Ilic and Nikolic, 2016b). Hence, waste free cities framework considers environmental protection, sustainable resource management and smart waste infrastructure that include the use of technology as factors to achieve smart environment through efficient waste management.

3.4.6.1 Environmental Protection

Environmental protection includes controlling the environmental impacts, reducing the burden on environment and estimating the associated savings. Regular assessment and monitoring of the process and conducting audits can control the environmental impacts (Wilson *et al.*, 2015a; Zaman, 2014; Guerrero *et al.*, 2013; Kundert and Anschutz, 2001).

Reducing the environmental impacts and more efforts towards the top levels of waste hierarchy contribute towards avoiding energy use, CO2 emissions, saves landfill space, etc. which are regarded as environmental savings. Estimating such savings can help in prioritising the various feasible options and create awareness and interest. These savings are measured using various ranges for scoring purposes. These ranges are chosen from previous studies (Wilson *et al.*, 2015a; Zaman, 2014) and databases (EPA, 2016) and applied according to the best range with centrality that is suitable for developing countries. Additionally, identifying the causes of environmental burdens such as burning of waste and open dumping are crucial as they significantly contribute towards environmental pollution and is seen as a common practice in many developing countries (Shekdar, 2009). These are important as it can indicate where and how actions have to be taken to avoid such burden causing activities. These were also identified as indicators with high importance to achieve zero waste (Zaman, 2014).

3.4.6.2 Sustainable resource management

The environment is both a source as well as a sink for resources (Shekdar, 2009). Currently, the resource extraction rate and their waste generation are much higher than the environment's resource generation rate. Balance between the environment's ability as source and sink are being disrupted. To strike a balance between the two, resources are being extracted from waste and there is growing importance for the 3Rs- reduce, reuse and recycle. This indicates a form of sustainable resource management with the efficient use of waste. This can be achieved with an interaction between social and environmental dimensions which are the citizens' participation with environmental interest or formal and informal waste recovery processes. These can be indicated with the sale or exchange of unwanted household items (waste), number of source separation waste categories (Zaman, 2014), recycling rate and waste to energy. The measurement for recycling rate includes all the recycled products including dry and wet (Wilson *et al.*, 2015a). The waste to energy measurement range is given after reviewing the current performances of various cities (Annepu, 2012) in developing countries. This ensures the comparison is applicable to cities and are not being compared against the cities in developing countries which could result in a large difference in comparison and does not help in developing a tactical goal.

3.4.6.3 Smart waste infrastructure

There are several authors who emphasise technology as an enabler in smart cities (Kummitha and Crutzen, 2017; Albino *et al.*, 2015; Letaifa, 2015). According to Eremia *et*

al., (2017) and Falconer and Mitchell (2012), in smart cities, advanced technologies should be used in utilities services to manage the resources effectively. According to Sharpley (2000), technology can facilitate in achieving urban sustainability. There are several advancements in waste management, particularly in developed countries that use latest technology to improve collection efficiency and treatment processes are often termed as smart waste management (Navigant Research, 2014). Considering the problems in waste management in developing countries, achieving 100% waste collection and transportation are of prime importance (Ilic and Nikolic, 2016b; UN-Habitat, 2010; Sharholy *et al.,* 2008). Among the various smart waste techniques, use of smart bins or underground bins and RFID tagged public bins are considered applicable for developing countries as some of them are being used or tested. These are to be considered for their cost effectiveness and operational efficiency in developing countries' scenario. Therefore, these are considered as indicators for smart environment in the waste free cities framework.

Table 3.7: Smart Environment (SEv) (Source: Author)

Factor	Sub-factor	Indicator	Measurement	Sustainability dimension
SEvF1: Environmental protection	Assessment and monitoring	Assessment of environmental impacts from collection to disposal or recycling	1=No assessment performed	Environmental
			2=Assessment performed but no compliance	
			3= Assessment performed with low compliance	
			4=Assessment performed with medium compliance	
			5=Assessment performed with high compliance	
		Performance of regular waste audits	1=No audits performed	Environmental
			2=Audits performed but no compliance	
			3= Audits performed with low compliance	
			4=Audits performed with medium compliance	
			5=Audits performed with high compliance	
	Environmental savings	Reduced CO_2 emissions due to waste recycling	1= < 2000 CO_2e/year	Environmental
			2= 2000-4000 CO_2e/year	

			3= 4000-8000 CO_2e/year	
			4= 8000-20000 CO_2e/year	
			5= > 20000 CO_2e/year	
		Energy savings due to waste recycling	1= <2000 MW-h /year	Environmental
			2= 2000-5000 MW-h/year	
			3= 5000-10000 MW-h/year	
			4= 10000-20000 MW-h/year	
			5= >20000 MW-h/year	
		Potential substitution of virgin materials due to recycling and composting	1=< 2000 T/year	Environmental
			2=2000-10000 T/year	
			3=10000-30000 T/year	
			4=30000-80000 T/year	
			5= > 80000 T/year	
		Avoided landfill space	1= < 0.5 acres/year	Environmental
			2= 0.5-1 acres/year	
			3= 1- 2 acres/year	
			4= 2- 5 acres/year	
			5= > 5 acres/year	
	Environmental burdens	Illegal burning of waste	1= Very common practice to burn waste	Socio-environmental
			2= Common practice to burn waste	
			3= Neither common nor uncommon practice to burn waste	
			4= Less/uncommon practice to burn waste	
			5= Never practiced burning waste	
		Open dumping of waste	1= Very common practice to dump waste in open	Socio-environmental
			2= Common practice to dump waste in open	
			3= Neither common nor uncommon practice to dump waste in open	
			4= Less/uncommon practice to dump waste in open	
			5= Never practiced dumping waste in open	

SEvF2: Sustainable resource management	Efficient use of waste	Occurrence of exchange or sale of waste from households	1=No	Socio-environmental
			2=Low	
			3= Low/Medium	
			4=Medium/High	
			5=High	
		Number of categories of source separation for waste	1= No categories	Socio-environmental
			2= 2 categories	
			3= 3 categories	
			4= 4 categories	
			5= > 4 categories	
		Recycling rate	1= < 10%	Socio-environmental
			2=10-20%	
			3=20-40%	
			4=40-60%	
			5= > 60%	
		Waste to energy	1= 0-10 MW	Environmental-economic
			2= 10-50 MW	
			3= 50-100 MW	
			4= 100-200 MW	
			5 = > 200 MW	
		Percentage of household waste collected sent for controlled disposal	1= < 10%	Environmental
			2=10-40%	
			3=40-70%	
			4=70-90%	
			5=90-100%	
SEvF3: Smart waste infrastructure	-	Use of underground bins or smart bins	1=Not in use	Socio-Environmental
			2= Under consideration/planning for use or trail	
			3=Trial phase with few smart or underground bins	
			4= Both normal and smart or underground bins in use	
			5=Only smart bins or underground bins in use	
		RFID tagged bins	1= Not in use	Socio-Environmental
			2= Under consideration/planning for use or trail	
			3= Trial phase with few RFID tagged bins	
			4= Both RFID tagged and untagged bins in use	
			5= Only RFID tagged bins in use	

3.5 Conclusion

The waste free cities framework depicts how various factors can drive effective waste management and also lead to smart growth and sustainability of the city while ensuring an effective waste management. The framework can be used to understand the status of the city's waste management with smartness or sustainability or compare them between cities. This allows benchmarking between the cities or the same city over a time frame. As there are many challenges and barriers to achieve integrated sustainable waste management, it is highly likely to have the same problem while applying this framework. The application of the framework also needs to identify the potential problems and take them into account before designing strategic and operations plans. The framework can help in easy detection of where the problem is arising from. Example, if the problem is from the governance or people, etc, and can further narrow it down to see what is exactly causing the problem. Since problem detection is the first and essential steps for providing solutions, this framework provides this advantage. As shown in figure 3.1, it can help in policy designs for long term solutions. Though this framework takes into account the advanced techniques that are being used in developed countries, it does not simply consider the transfer of technology. The indicators chosen are carefully studied and tailored to the local situations. For example, use of compactor trucks for waste collection, though successful in developed nations is not considered in this framework due to its inefficient applicability in developing countries due to the differences in the waste compositions between the developing and developed countries. Hence, this waste free cities framework is particularly useful and applicable for the cities in developing countries that are in the state of transition towards smart cities.

Chapter 4: Research Methodology

4.1 Introduction

The current research stems from the practical issues that arise from the stakeholder engagement in waste management and its importance in developing smart cities. In chapter 2, the theoretical perspectives on the concepts of urban sustainability, smart cities and waste management are considered. It shows there is a need to develop waste free cities particularly in the developing countries. In the preceding chapter a framework for the empirical research has been described. The research focuses on the applicability of the framework by choosing three cities in India for the empirical setting and this chapter underpins the philosophies of methodology used for the research. It justifies the research methods used to meet the research objectives mentioned in chapter 1. The chapter also explains the research strategy, data collection methods and provides a rationale to the approaches used in this research. This section reiterates the aim and research objectives of the study. Section 4.2 clarifies the ontological and epistemological stances along with justification of pragmatic philosophy that are followed in this research. Section 4.3 explains why case study is the chosen research strategy. The criteria used for selecting the cities (as case studies) is justified and the use of benchmarking methodology in this research is explained. Section 4.4 describes the data collection methods followed by discussion of how the data is analysed in 4.5. Then section 4.6 points out the enhancement of reliability and validity. Finally, Section 4.7 presents a summary with all the discussions in the chapter thereby highlighting the link between research methods and methodology of the research.

Table 4.1: Research aims, objectives and questions

Research Aim	The aim of the research is to contribute to existing knowledge by developing a theoretical framework that integrates urban concepts with waste management to achieve waste free cities in developing countries context.
Research Objectives (RO)	*RO1*. To map the value generating process of waste and identify the stakeholders *RO2*. To investigate the role of stakeholder collaboration in value adding activities *RO3*. To identify the indicators and factors that influence the transforming smart cities to become waste free cities *RO4*. To enrich the theories by drawing relationship between waste management, smart and sustainable cities *RO5*. To provide best practices as practical recommendations for achieving a waste free city

4.2 Research paradigm and philosophical underpinning

The philosophical stand of a researcher will impact the research in all stages (Lee and Lings, 2008). As theory and reality are interconnected, the philosophical stand influences the research and drives the selection process for data collection, research design and data interpretation techniques. It promotes the feasibility of the research plan by adjusting various situational constraints in a research (Easterby-Smith *et al.,* 2008). Research assumptions are capable of differentiating various philosophies followed in a research (Saunders *et al.,* 2016).

Ontology and epistemology are two types of research assumptions considered to differentiate the pragmatic philosophy selected for this research. Both epistemology and ontology are important elements in the philosophy of knowledge. They have clear distinction where ontology is about '*what things are'* while epistemology is about '*the way we know'* things. Ontology represents assumptions about the nature of reality (Saunders, *et al.,* 2016). The ontological assumptions shape the way of how the research objects are seen and studied. Moreover, the ontological assumptions mean focus on how an issue or a problem be harnessed to benefit (ex: organisation, governing body) rather than looking for ways to eliminate the problem. Epistemology refers to assumptions about knowledge and concerns what makes the knowledge valid, acceptable and legitimate. It looks into how we can communicate knowledge to others. Ontology is rather abstract, so the current research is more epistemological as waste management concept is a multidisciplinary context (Shekdar, 2009) of business and management. The research comprises of different types of knowledge ranging from textual, visual and numerical data from facts to interpretations. It also includes narratives and opinions of stakeholders which can all be considered legitimate as it has been successfully used by authors like Caniato *et al.,* (2015) and Troschinetz and Mihelcic (2009). The research includes the communication of knowledge for stakeholder engagement and participation. Hence, this research can be justified as an epistemological assumption.

As mentioned in the earlier paragraph the research assumptions differentiate philosophies. The philosophy of pragmatism asserts that concepts are only relevant where they support action (Kelemen and Rumens, 2008). The advantage with this philosophy comes from the flexibility to reconcile subjectivism (facts) and objectivism (perceived facts), values and facets, rigorous and accurate knowledge and different contextualised experiences. Pragmatism also does this by considering ideas, concepts, theories, research findings and

hypothesis not in the abstract form but in the form of instruments of action and thought. In this philosophy, reality also matters as knowledge and practical effects are valued to enable actions that are to be carried out successfully (Elkjaer and Simpson, 2011). After a careful thought process, it is evident that research followed a pragmatic philosophy.

The research takes a broader spectrum and the intention is to comprehend, elucidate and envision the waste management process in three case studies. Pragmatism suits the current research as the research starts with a problem which is growing waste volumes and its ineffective management in cities. This research aims to contribute to practical solutions for future practice. Pragmatism provokes a thought to the researcher that a problem exists in the society and a practical solution will help in resolving the problem (Elkjaer and Simpson, 2011). Therefore, this research considers effective management of waste in transforming smart cities as a problem and looks for a solution from a practical approach through the application of proposed theoretical framework to achieve waste free cities.

Pragmatism refers to practical outcomes than abstract distinctions and has variation in terms of how subjectivist or objectivist it turns out to be. If the research has to consider pragmatism as a research philosophy, the research strategy and research design should relate to the research objectives which are trying to address research problem (Saunders *et al.*, 2016). In the current research, the research objectives in turn incorporate a pragmatic emphasis of practical outcomes.

4.3 Research design

The research design provides a framework for data collection and analysis. It helps in prioritising the various dimensions of the research process (Bryman and Bell, 2007). Basing on this concept, the research followed a qualitative approach and adopted case study as the research strategy to understand the stakeholders' role, their interactions and the resulting effect in achieving waste free cities. Three case studies were chosen in line to the waste management and smart cities concepts. The data was collected using both primary and secondary sources which was analysed to validate framework for waste free cities and map the value generation through stakeholder activities. The study gives scope to explore the best practices across the world to benchmark and improve the current activities. The research design and methodology for the research are shown in the figure 4.1.

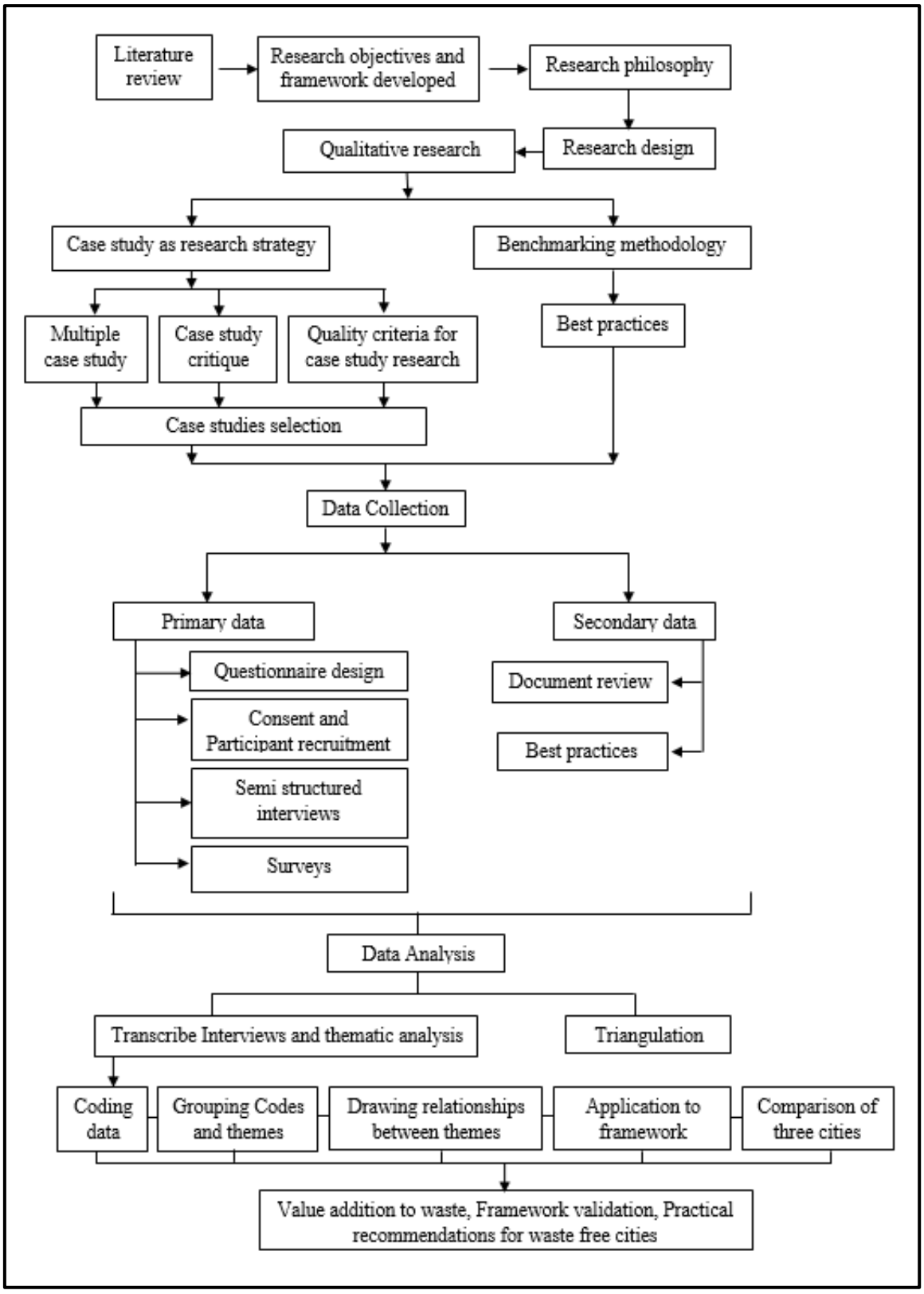


Figure 4.1 Research design and methodology (Source: Author)

4.3.1 Qualitative research

"Research methods cultivate healthy scepticism about research evidence, because it enhances the ability to evaluate how one arrives at their research finding" (Singleton and Straits, 2005). Qualitative research is a situated activity which locates the observer in the world (Creswell, 2007) and emphasises on social interactions (Guba and Lincoln, 1989). It is intended to study the experiences of individuals or groups, their knowledge or practices and to study the interaction or communication between them in the natural setting i.e., real world (Flick, 2006).

When adopting a qualitative methodology for research, there are specific methods for gathering data such as conversations, focus groups, photographs, observations, interviews, field notes, documents and memos. These methods are believed to make the world more visible and help in transforming the world (Denizin and Lincoln, 2003a). The qualitative research drives a naturalistic yet interpretive approach to the world. Hence, qualitative research and multiple case study are used in the current research.

The researcher justifies undertaking a qualitative approach as it begins with assumptions with a worldwide view and uses a theoretical lens as shown in figure 2.1 in chapter 2. The researcher sees the problem of increasing waste volumes in the world in its natural setting without causing any changes to the current situation of waste management. The researcher also inquiries into the individual or a group of people ascribing to this human or social problem by studying the interactions among the key stakeholders. Qualitative analysis generates concepts and ideas whereas quantitative methods provide samples of data that represents wider population in order to make inferences about behaviour, attitude and characteristics (Creswell, 2003). The research generates the concept of waste free cities through the qualitative study. Hence qualitative research is apt for this study.

According to Creswell (2009), qualitative researchers tend to collect data in the field at the site where the issues or problems are experienced by the participants. This major characteristic of qualitative research suits the current research as it was experienced in a natural setting. It also gives a holistic account as qualitative research tries to establish a complex picture of the problem (waste management) by reporting multiple perspectives. This includes factors involved in a situation which later emerges as a larger picture of the existing problem. So, qualitative analysis helps to understand multi-dimensional, dynamic and complex nature of the waste management phenomena. The research followed an

inductive approach as the study comprise of humans attached to events. The data collected is of qualitative nature and there is more flexibility in structure to permit changes of the research emphasis as the research progresses. In deductive approach there is more concern with the need to generalise unlike inductive approach. So, following an inductive qualitative approach gave a closer understanding of the research context.

4.3.2 Case study as a research strategy

According to Yin (2014, p15) a case study is defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". In the current research, it is difficult to separate "process" (for example, waste generation, behaviour, interaction) from "context" (for example, efficient management and transformation into smart cities). So, the relationships among these involve crossing various processes to achieve the final goal which is to achieve a waste free city. Moreover, the current study tries to understand the social interactions in the real-life context in its empirical setting. Yin (2003) also states that case study provides answers to why or how questions, when asked to study the contemporary phenomenon and the researcher has no or little control on the events occurring. The research answers the questions on how (as already stated in table 4.1) and the researcher does not have any control on the events or processes such as value addition or waste minimisation occurring in the real world and is studying the current interactions among the stakeholders and not changing them, thereby making it appropriate to select case study as the methodology. There are several studies (Ilic and Nikolic, 2016a; Ilic and Nikolic, 2016b; Caniato *et al.*, 2014; Zaman, 2014; Koushki *et al.*, 2004) related to stakeholder collaboration, zero waste assessment and waste management that used case study as research strategy.

"Case studies are generalizable to theoretical propositions and not to populations or universes. In this sense, the investigator's goal is to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)" (Yin, 1994a, p 10). When limited analytical work exists on a phenomenon, a case study facilitates to explore its complexities and thereby help to generate new theories and concepts. The preliminary efforts to gather existing literature have shown a reason to investigate a range of inter-disciplinary academic sources. To establish a conceptual vocabulary, the institutional and organizational theory was filtered to act as a scaffold to develop a theoretically led case study. The research develops waste free cities concept and

defines it by using institutional and operational aspects related to smart cities and waste management.

4.3.2.1 Multiple case studies

Single case study method is often considered to lack analytical conclusions and therefore treated vulnerable (Yin, 2003). According to Stake (1995), single case studies provide more trusted generalisations than the comparison between different case studies. However, Yin (2003) argues that conclusions from multiple case studies provide more compelling and analytical conclusions. Similarly, Miles and Huberman (1994) indicate that multiple case study research provides a deeper understanding of the outcomes from the cases and the overall study is considered to be robust (Firestone and Herriott, 1983).

Yin (2003) argues that multiple case studies can be compared to multiple experimentation as both provide a replication logic. Yin (2003) also states that when choosing multiple case studies, the results should be predicted to have either literal replication (get similar results from different case studies) or have a theoretical replication (get contrasting results from different case studies, but the reasons should be predicted). Therefore, when using multiple case studies, if the results are in line to the predictions, it supports that the variables or prepositions chosen are correct and are useful for producing a rich theoretical framework. The current research choses a multiple case study approach with a predicted theoretical replication. Three cities are chosen as case studies with varying stakeholder collaboration levels and interactions. The three cities (case studies) also differ in the ways waste in managed. Hence, the units of analysis in this study include the scores assigned to the cities chosen as case studies and the value added to waste with different levels of stakeholder collaboration. There are other researchers who used multiple case studies to study the waste management activities (Wilson *et al.*, 2015a; Zaman and Lehmann, 2013; Troschinetz and Mihelcic, 2009). They used case studies ranging from 3-12 to study different aspects of sustainable and zero waste management. This indicates multiple case studies are applicable to the current research due to the similar areas of study.

4.3.2.2 Quality criteria for case study research

Yin (2003) mentioned guidelines about good case study research. Firstly, in line to the adherence of those guidelines the research followed multiple sources of evidence from two or more sources but converged them as same set of findings. In this research, data is collected from various stakeholders as well as documents for analysis. Secondly, use of a case study database which is a formal assemble of evidence distinct from final case study

report was suggested (Yin 2003). Therefore, data from interviews, organizational research, academic journal publication, etc. were evolved and assembled in this research. Finally, Yin (2003) also suggested a chain of evidence where explicit links between the question asked, data collected, and the conclusions drawn be established. Interviews, surveys, thematic analysis, triangulation, etc. were all interlinked to construct a framework for waste free cities using three case studies selected.

4.3.2.3 Criteria for case studies selection

According to Yin (1994b) a case study protocol is required to enhance the reliability of the case study research. It also helps in providing guidance to the data collection procedures and questions. Hence, case study protocol has been used. One of the aspects of the protocol is the rationale for selecting case studies. Hence, predefined selection criteria with a rationale have been designed for this study in line to the research context and resource constraints.

With rapid influx of people to cities and changing lifestyles, there is abnormal increase in waste generation in cities as explained in chapter 1. On one hand, effective management of this growing waste is a challenge to local authorities and on the other hand, attempts are being made to transform cities into smart cities including developing countries. The research context is to include waste free cities as an important element of smart cities. Therefore, the following criteria are taken as the basis for selecting case studies.

- **Rapidly urbanising cities in developing countries**

  Urbanisation trends have been witnessed in the cities of developing countries as well as Asian countries. India is classified as a developing country according to the International Monetary Fund. There are studies (Annepu, 2012; Shekdar, 2009 and Rathi, 2006) that indicate India suffered with a burst in unmanageable waste volumes due to urbanisation. Hence, cities from India are chosen for this study. Further details and background of India and details of the chosen cities (case studies) are provided in chapter 5.

- **Transforming existing cities into smart cities**

  The research intends to study the smart cities and their transformation in developing countries. The Ministry of Housing and Urban Affairs (MoHUA) of Government of India (GoI) has initiated ‘Smart Cities Mission’ to transform over 100 cities in India into smart cities. The objectives of the mission include driving economic growth,

improving quality of life, infrastructure and services and providing sustainable and inclusive development in the cities (Smartnet, 2018). Hence, the cities that are included in the smart cities mission are selected as case studies for the research. They are either planned to or currently transforming into smart cities with extra funding to improve the infrastructure including waste management. Details of the smart initiatives in India are provided in Section 5.3.3. Therefore, this enables the researcher to study how waste management infrastructure and services are improved when the cities in developing countries are transforming to become smart cities and how that can contribute in becoming waste free city.

- **Common legal framework**

  There is a common legal framework in India for waste management. The Central Public Health & Environmental Engineering Organisation (CPHEEO), a part of the Ministry of Urban Development (MoUD), sets out the manual and policies for waste management in India. The main policies for managing household solid waste include Municipal Solid Wastes (Management and Handling) Rules, 2000 (MSW Rules, 2000) and Solid waste Management Rules, 2016 (SWM Rules, 2016). In addition to these, a national wide cleanliness drive '*Swachh Bharat* Mission' (Clean India Programme) was implemented by MoUD for urban areas (Smart Cities Mission, 2016). The local authorities operate in line to the policies and clean India programme. Therefore, the case studies chosen are ensured that they are following the common legal framework and are a part of Clean India Programme. Additionally, to understand the participation of the cities in the waste management, it was added to the selection criteria to select the cities that are participating in *Swachh Survekshan* (Cleanliness Survey). This is carried out by MoUD and aimed to foster a healthy competition between cities for improving cleanliness standards. The survey ranks the cities on cleanliness and other aspects of urban sanitation annually. The ranking is based on the report given by local authorities, observations made by monitoring authorities and feedback from citizens (Swachh Survekshan, 2017). Hence, this is also included in the selection criteria to choose the cities that are participating in waste management activities as well as transforming into smart cities.

Yin (2003) stated that it is important to select case studies that are comparable. The three case studies chosen here are comparable due to similar weather conditions and geography as they influence waste composition and generation patterns. Moreover, all the three cases

studies chosen to have common legal framework and they are participants of the Clean India program (*Swachh Bharat* Mission) and Cleanliness Survey (*Swachh Survekshan*). Moreover, they are listed in India's Smart Cities Mission. This enables the case studies to be comparable as there are no differences in their governing factors or funding abilities. In addition, all the three case studies chosen are rapidly urbanising and have bursting volumes of waste. The background of India and the three case studies chosen are provided in detailed in chapter 5.

4.3.3 Benchmarking as a research method

"Benchmarking is a systematic process used to identify, understand and adapt practices to improve performance and efficiency" (Lewis and Naim, 1995). There are four distinct types in benchmarking namely internal, competitive, parallel industry and best practices. The current research dealing with waste management employed best practices type of benchmarking methodology. Best practices provide breakthrough ideas resulting from new insights, targets, perspectives, better practices and motivation achievable from areas to focus on and methods for overcoming barriers. This approach is important in improving the waste management process as same solution is not applicable everywhere and should be framed according to the identified local problems in the case studies. The combination of case studies methodology and benchmarking methodology have been successfully used by authors in the field of waste management such as Filho *et al.*, (2016), Wilson, *et al*., (2015a) for urban waste management and Zhou *et al*., (2007) for battery recycling in china. The benchmarking methodology is useful to meet the RO5 which is to provide strategic recommendations based on the best practices with similar empirical structure. Hence, benchmarking is being used in combination with case study methodology.

4.4 Data collection methods

According to Yin (2003), the research which employs multiple case study should not limit data from a single source but derive from various sources to make analysis more valid. Miles and Huberman (1994) stated in line to Yin (2003) that obtaining data from different sources helps in counteracting biases while analysing or presenting the data. To attain the research objectives mentioned in table 4.1, the study has used various methods to gather data including primary and secondary sources. The primary data collection included interviews and surveys with key stakeholders and secondary data collection through excerpts from reviewed documents and official websites. Flick (2006) concurs that

integration of several sources of information will allow data triangulation which will thereby enhance the validity of the research.

4.4.1 Primary data: Semi-structured interviews and surveys

4.4.1.1 Semi-structured interviews

The principle method employed to collect primary data is through interviews which followed 'method talk' (qualitative concept) and a pragmatic paradigm to interpret the data to identify the waste management practices and stakeholder participation in the selected three case studies. Boyce and Neale (2006) stated that in-depth interviews involve data elicitation from a number of respondents to explore perspectives with respect to a particular idea, situation or program. This also includes images with perceptions and feelings of others (Gubrium and Holstein, 1997). The research targeted to collect primary data in conversational approach. Structured interviews limit the degree of freedom of elaborating the interviewees' response and unstructured interviews gives more unfocussed information which will not serve the purpose of this research (Powell and Lovelock, 1987). Hence, semi-structured in-depth interviews are selected as data collection method for this research as they encourage respondents to recount their views freely (Longhurst, 2009). The aim of discovering than checking is more in semi-structured interviews (Denscombe, 2002) and that coincided with the aim and objectives of this research. The semi-structured interviews also helped the researcher for on the spot probing and amplifying a conversation which can continually clarify meanings (Kvale and Brinkmann, 2009). As prescribed by Kvale and Brinkmann (2009) a review was undertaken to meet the criteria of a good informant. This included that informants having experience, knowledge with the capability to articulate and reflect waste management practices in those respective cities and expected to have role in the value addition process to waste. Data was collected from different stakeholder groups through interviews. The selection of participants was made to include all the actors (stakeholders) in waste management in all the three case studies. Three questionnaires used for the interviews and table 4.2 indicates the composition of stakeholders and number of interviews and respondents for each of them. The table also indicates which questionnaire had been used for each group and what research objectives are addressed using them.

Interviews and participant selection process

Through an intensive field work carried out during March- April 2018, face to face interviews were conducted in all the three case studies. Potential participants were initially

contacted by telephone and letters which mainly included the local authorities. The other stakeholder groups such as informal waste sectors and retailers were chosen at random. With the snowball approach, interviews led to introductions to interviewees during the field research. This includes all the stakeholder groups interviewed. Consent was obtained from the participants before the interviews and participant information sheets were given to them (included in appendix 1).

Data was collected from local authorities through semi structured interviews using questionnaire 1 (appendix 2) for all the three chosen case studies. The interviewees included Zonal Commissioners, Chief Medical Officer of Health (CMOH), Assistant Medical Officer (AMO), City Sanitation Planner and Advisor of the local governing bodies (municipalities in all the three chosen case studies). The interviewees were selected based on their experience in city's waste handling operations, having interest and power in the waste related aspects. The interviewees are also responsible for the smooth functioning of the national Clean India Programme of MoUD and its survey. They are also involved in the local aspects of the Smart Cities Mission developed by the MoHUA as described in the earlier section 4.3.2.3. The interviewees have the authority to amend or implement the governance at city level, as well as aware of the participation of the citizens as they regularly monitor the solid waste management activities. In case study 1, where the city is divided into administrative zones, the participants were chosen to represent all the zones of the city.

Semi structured interviews using questionnaire 2 (appendix 2) were conducted for data collection from private businesses, small and medium sized businesses that are classified as waste retailers, waste wholesalers and waste suppliers have been selected. The participants have experience in waste trading, including buying, sorting, packaging, transporting and are the means of transforming waste to resource and value addition. Public private partnerships and active participation of NGO is observed only in the case study 3 who share similar experience of waste handling like the small and medium businesses. In addition, they also have more knowledge and experience in citizen engagement.

The other groups of stakeholders are the informal waste sector that includes waste or rag pickers and itinerant waste buyers who are skilled and experienced in waste collection and segregation from households and streets. Hence, they are interviewed using questionnaire 3

(appendix 2). Due to the varied roles, experiences and knowledge each group of stakeholder possesses, it can be justified that the interviewees were selected appropriately for the interviews.

4.4.1.2 Surveys

As mentioned earlier in 4.4.1.1 structured interviews help the researchers to focus on the subject targeted in the research and confines the interviewees to answer with predetermined set of answers. Surveys having closed ended questionnaire are a form of structured interviews which saves time for the interviewees (Saunders *et al*., 2016). These types of surveys suit the citizens who participated in the primary data collection as it is easy for the interviewees to have an opinion. However, closed-ended survey questions provide respondents with fixed number of responses. Therefore, the interviewer must full fill two properties while doing surveys which include question and answer options to be mutually exclusive and also exhaustive. Mutually exclusive will mean that no two answers overlap in their conceptual meaning and being exhaustive will mean answer choices should cover all the logically possible answers for that question. To limit the scope to an achievable aim, the survey focussed mainly on household waste management, recent developments of smart city and citizen engagement.

a) Surveys and participant selection

Data is collected from citizens through surveys to collect opinions and triangulate the data collected from the other stakeholders of the city. The surveys are conducted using the online survey tool (Surveymonkey). The questionnaires having a group of 30 closed ended questions with Likert scale is employed to collect various perspectives. The range of Likert scale is maintained to provide centrality and extreme options for each question to ensure the quality of the survey (Likert, 1932). The main reason for using Likert type is because it is scaling the responses to measurable term. Surveys targeted the citizens of the three selected cases to obtain the service user' perspective of the problem. Nearly 600 questionnaires were sent to citizens from each case selected and nearly 70-100 responded to the online survey from each case.

b) Surveys for triangulation

The notion of triangulation makes use of multiple methods for assessing convergent and divergent validity (Denzin, 1978). However, distinguished with the basic methods of triangulation namely data triangulation, investigator triangulation, theory triangulation,

methodological triangulation, the between method triangulation meets the overarching research method needs (e.g., the survey and case study).

The rationale in combing case study with surveys in this research is that this "between-method triangulation" offers advantages in dealing with validity threats coming from biases inherent in any single method. Denzin, (1978) explained that by combining relatively diverging methods, the relative strength of one will counter-balance the weaknesses of the other(s). Jick (1979) supported the above procedure by suggesting that triangulation between case study and survey methods provide relatively potent means of assessing the degree of convergence. They also mentioned that it will provide opportunity for elaborating on divergences between results obtained. In this research, surveys are used to improve understanding of the citizens' perspective as well the current interaction levels and waste management problems stated by other stakeholders. Hence, the survey results are used to draw a conceptual relationship with the findings of the case studies. Though surveys suit the studies with deductive approach, its ability for triangulating case studies justifies its use in the current research. Moreover, the combination of surveys with case study has been successfully used by Caniato *et al.*, (2014) when studying about a waste incinerator and stakeholder analysis in Bangkok.

4.4.1.3 Questionnaire design and content for primary data collection

The primary data collection process is carried out using four questionnaires. The first three sets of questionnaires are used for semi structured interviewees with different stakeholder groups. The fourth questionnaire is used for surveying citizens who constitute an important stakeholder group but are in large numbers. Hence, sample groups of the large populations using surveys has been used for data collection. The details on the objective of each questionnaire, its content and targeted respondents are discussed below.

Questionnaire 1

The objective of this questionnaire is to determine how the local authorities are acting towards waste management in the city. The questionnaire designed to know about the strategic and operational aspects of the current and future waste management related programmes. The questionnaire addresses issues regarding the legal structure, national programmes, infrastructure, stakeholder awareness and collaboration, operational costs, resource availability and use of technology for operations and stakeholder engagement. The answers to this questionnaire provide insights of the key challenges for technology

upgrade for waste operations, value generation from waste and stakeholder engagement including the informal waste sector, citizens and private sector from local authorities' or service providers' perspective. Hence, this questionnaire provides answers to RO1, RO2 and RO3.

Questionnaire 2

The objective of this questionnaire is to examine how value is added to waste by the waste buyers, small and medium sized waste traders, NGOs and public private partnerships. The questionnaire also helps in mapping the value chain for waste and the use of technology during this process. It provides details of the transformation process of waste to resource, the actors involved in it and their roles during this process. The questionnaire helps in estimating the amount of waste transformed into resource and the corresponding value addition in each step. The questionnaire draws details on the challenges faced by the waste handlers during this transformation process and this provides the business's perspective. Therefore, this questionnaire addresses RO1, RO2.

Questionnaire 3

The objective of this questionnaire is to study the role of waste pickers/ rag pickers in value addition to waste. The focus of this questionnaire is to understand the barriers for the integration of this level of informal waste sector to the formal sector. This questionnaire helps in drawing answers to RO2.

Questionnaire 4

This questionnaire is used to conduct citizen surveys to draw their opinions on the current waste management activities. The other purpose of this questionnaire includes triangulation of the data collected using Questionnaires 1 and 2. The questionnaire also provides details of challenges or barriers for citizen participation, interaction with other stakeholders and use of technology for the interaction. Moreover, it provides the service user's perspective. Hence, this questionnaire is useful in answering RO1 and RO2.

Table 4.2: List of stakeholder groups, number of interviewed or survey respondents in each case study and the corresponding research objectives and questions answered (Source: Author)

Stakeholders groups interviewed/ surveyed		Case study 1	Case study 2	Case study 3	Questionnaire Used	Research objectives (RO) answered
Local authorities		6	3	2	1	RO1, RO2 & RO3
Informal waste sector	Waste pickers or rag pickers	17	4	6	3	RO2
	Itinerant waste buyers	4	2	5		
Private businesses (Small and medium sized)	Retail waste buyers	3	2	3	2	RO1 & RO2
	Wholesale waste buyers	4	3	4		
	Suppliers of waste	2	-	-		
Recycling units or manufacturing units (waste users)		1	-	1	2	RO1 & RO2
Public private partnership (PPP)		-	1	-	2	RO1 & RO2
Non-Governmental Organisation (NGO)		-	1	-	2	RO1 & RO2
Citizens		103	94	79	4	RO1 & RO2

4.4.2 Secondary data

According to Vartanian (2011), secondary data is general data gathered by research institutions, governments and in some cases, agencies, providing researchers with readily available resources for examining aspects like statistics, characteristics of populations, etc. Secondary data is useful in order to build a context where primary data is collected, analysed and reported (Patzer, 1995). It provides data which complements and, in some cases, would not be available from the primary data set (Vartanian, 2011).

The research uses benchmarking methodology in addition to case study to identify the best practices followed in other parts of the world including the cases of developing countries and other smart cities. This will enable to identify the best practices that can be transferred to the smart cities in developing countries if they meet the local needs. Secondary research using existing government documents, research reports and journals through document

review have been used for this purpose. Moreover, the secondary data was also used to triangulate the primary data collected in the case studies by reviewing documents. The secondary research has also helped in designing questionnaires and generating themes for analysis. The theoretical framework proposed for waste free cities (mentioned in chapter 2) is used for the comparison of three case studies and to answer RO2. The data for some factors in the framework required the use of secondary data (such as infrastructure details, trainings, resources, CO_2 emissions, etc.). Therefore, secondary data was used to answer RO2 and identify best practices.

4.4.2.1 Document review

According to Lincoln and Guba (1985) document review is a contextually relevant source of information. Document analysis is important for gathering more information on initiatives on stakeholder engagement. Yin (2003) stressed the necessity of using documents as they allow researcher to corroborate and augment evidence from other sources. Rapley (2007) reminds that researcher's interest must be on how they address specific issues. Moreover, Rapley (2007) also mentioned the importance of issues raised to be organised, structured and most importantly be in a way to persuade the reader's authority to understand those particular issues. Therefore, to provide a comprehensive information, the data must be compiled from various relevant publications.

For the current research, the documents reviewed are derived from

- Government sources (Detailed project reports (DPR), publications and national statistics.
- Print media, online articles and websites
- Policy guides (ex: Waste management and handling policies, public private partnership policies, etc.)
- Bulletins and Leaflets circulated to the public
- Documents on Municipality initiatives and targets (ex: consultation frameworks, community partnerships etc.
- Research papers produced by private research organisations and research scholars giving details of the waste management practices as well as smart city initiatives in other cities and countries.

Yin (2003) however cautioned that the inferences can only be treated as clues rather than being definitive findings. The reason was quoted as a document and might be usually

written for purposes other than what they are meant for in the case studies undertaken. The advantage however is that this initial descriptive information consequently provided bearings to form interview question and were thoroughly investigated further to make them reliable. Then the review of documents used thematic analysis to support theme identification and theory elaboration.

4.5 Data analysis

The research employs thematic analysis for analysing the data collected through interviews and documents reviewed.

4.5.1 Thematic analysis

Thematic analysis is a qualitative analysis method of identifying similar themes and patterns in the data. It aids in organising and describing the data to obtain rich details (Braun and Clarke, 2006). It follows a flexible and orderly process of organising data using codes and categorising them into themes in order to understand the relationships between them. It also gives importance to the frequency of words or certain phrases that have been used during the interviews (Bryman and Bell, 2007). Thematic analysis helps in analysing small to large amounts of qualitative data and leads to rich explanations and theory building. Moreover, it is not restricted to the philosophical stance taken by the research (Saunders *et al.,* 2016).

For analysing the data, the procedure for thematic analysis given by Saunders *et al.*, (2016) has been followed and the same is tabulated in table 4.3. The research followed an abductive coding approach and therefore had a theoretical framework that has been developed from the literature review. Initially, '*a priori'* coding was followed. This means the codes were formed from the theoretical framework. As the analysis of data began, new codes were formed from the transcribed interviews using the key words that arrived from the interviewees. Therefore, the next level of coding followed an '*in vitro'* coding process (Saunders *et al.,* 2016). A hybrid approach which is a combination of theory driven and data driven codes are used in the research. This enabled the researcher to use the prior research, stakeholder theory and factors related to sustainable waste management and smart cities for articulation of meaningful themes. This allows researchers to depend on thoughts, perception or ideas and also allows researcher to compare and contrast the data attained form the selected case studies (Boyatzis, 1998).

Table 4.3: Process of thematic analysis (Source: Saunders et al., 2016 and its application to research)

Steps Involved	Description of each step	Steps undertaken in the research
Familiarising with data	Reading and re-reading the data and includes transcribing the data	The data collected through the interviews was transcribed. First the data collected from the local authorities was transcribed to understand the managerial perspective of the problem. Then, the remaining interviews were transcribed.
Coding the data	Forming codes and assigning data to the relevant codes.	The researcher developed few codes from the existing literature and therefore used *'a priori'* codes. As the coding process continued, the researcher included terms used by the participants and frequent words found in the data. Hence, '*in vivo*' codes were also used for coding. During the process, the researcher manually assigned the codes line by line to the data by underlining and highlighting the data with different colours and assigning codes to each of them.
Searching for themes and relationships	Identifying and categorising the codes into fewer themes that are related to the research question.	On completing the coding process of all the transcripts, the codes were listed and then grouped into themes. The themes were drawn based on the relevance to the codes used and the research objectives that are being addressed. After grouping into themes, the relationships between the themes was drawn as perspectives from different stakeholders, role of different factors, interaction levels, collaboration, etc.
Refining themes	Reviewing the current themes and combining few initial themes and forming new themes by regrouping the codes	There are few themes that were formed in the initial stages such as funding, which was later merged into the resources. Hence, further review of the themes and closer relationships between themes and research questions was studied.

The first step includes carefully listening to the recordings from the interviews, transcribing followed by reading transcripts from the interviews. The interviews and transcripts are coded to ensure the anonymity of the interviewee. Then raw data from extracts of documents reviewed is coded. During this process the noted themes are established in line to prior research. Moreover, key points mentioned by the respondents are identified to merge with the themes.

Second step involved analysis of merged themes where researcher identifies patterns of experience extracted from direct quotes or ideas from transcribed interviews. These differences in patterns or similarities in the views among groups of data helped the researcher (for example, to understand the issues in citizen engagement practices from different perspectives).

The third and final steps involved gathering more data for classified patterns which made use of quotations and expounded data for combining them into sub-themes. The emerged themes are then pieced together to establish a comprehensive picture of collective experiences from the respondents. The researcher then used them to link together and construct a conceptual framework. Therefore, it assisted researcher to interpret the practices in stakeholder engagement and for theoretical evaluation. This approach is selected as it allows and assists elaboration of correspondences which will bring out the differences among various groups studied (Boyatzis, 1998).

For example, figure 4.2 shows the coding process for the theme 'Value addition to waste'. From the literature, the value adding activities, revenue generation and pricing are identified to have an effect on value addition to waste. Hence, *'a priori'* coding was followed to frame these codes (second order codes). From the literature, the processes for value addition are identified. Using the interview scripts that indicate such activities, the first order codes like segregation or sorting, processing are developed by following '*a priori'* coding process. The other codes like scope of 'business for waste traders', 'fluctuations in waste trades' are developed from the context of interview and followed *'in vitro'* coding process. Similarly, '*in-vitro'* coding process is followed in developing codes such as 'Amount of waste trade and profit' and price determination based on their frequent occurrences of the words and their contexts in the interview scripts. Depending on the similarities or relevance to the second order codes, or the cause and effect relation between them, the first order codes are merged to second order codes and finally to the theme which

is ‘value addition to waste’ in this example being discussed. Their differences and similarities in views are noted and analysed further. The themes and codes used in this research, their merging pattern from first order codes to themes relevant to theoretical context of the research presented in the form of figures in Appendix 3. An example of the process is shown in the figure 4.2.

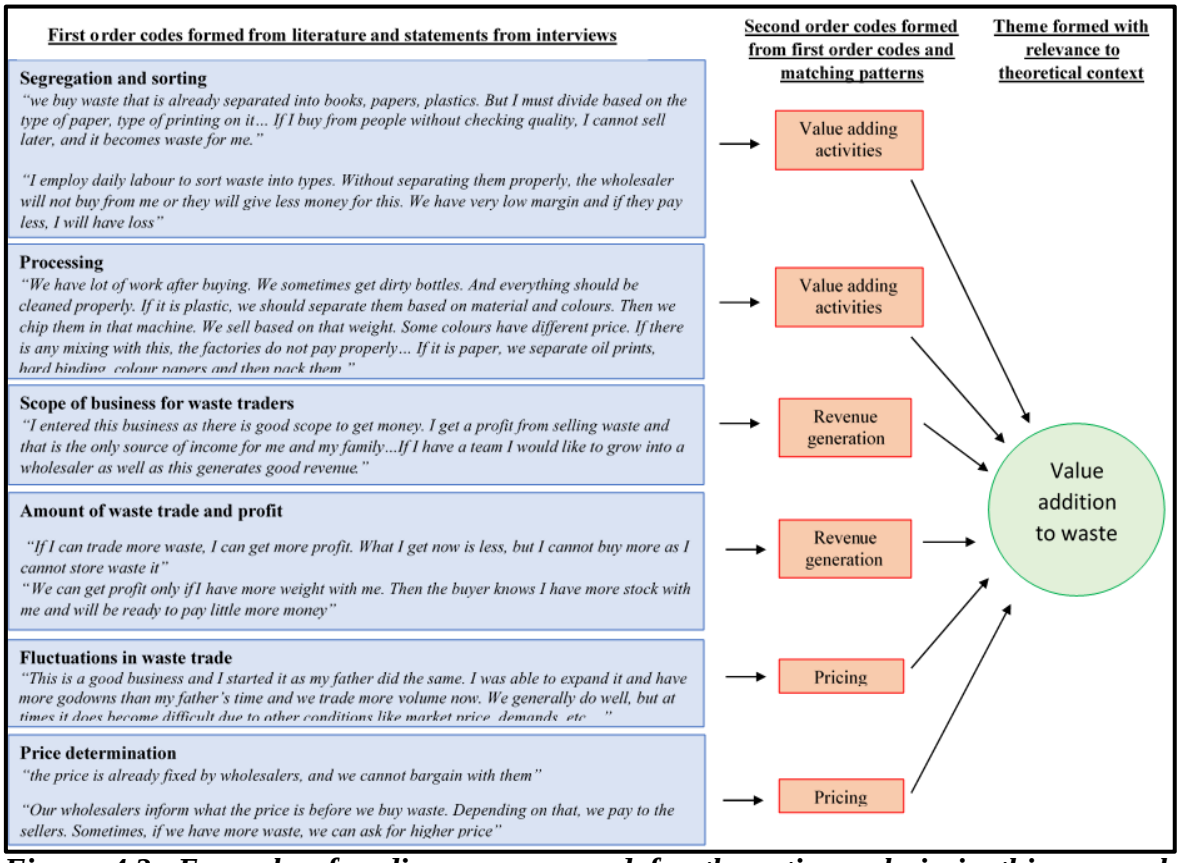


Figure 4.2: Example of coding process used for thematic analysis in this research (Source: Author)

4.6 Reliability and validity of research

According to Creswell (2003) to maintain quality of a research project two key aspects need to be addressed i.e. validity and reliability. Validity addresses accuracy in measuring a specific concept and reliability addresses consistency from one measurement to the next. When it comes to trustworthiness or validity of a research project, Lincoln and Guba (1985) refers to the tenets namely credibility, transferability, dependability and conformability.

Credibility is the adequate representation of the constructions of the social world under study (Bradley, 1993). Pitney and Parker (2009) support the above statement that the research should take measures to verify their findings are accurate and backed with

essential evidence. Lincoln and Guba (1985) suggested steps to enhance credibility to qualitative analysis in similar way. This includes triangulation, persistent observation, peer debriefing, member checking, interpreting raw data and negative case analysis. This research employed triangulation to improve credibility and used more than one source of data or methods so that findings can be cross checked. Triangulation can be achieved through methods, data, theory, and investigator. To affirm the data from secondary sources triangulation is employed within data collected from local authorities, waste suppliers, buyers etc. Additionally, the data is collected from all stakeholder groups of urban waste management thereby contributing to the validity and credibility of the outcomes.

Transferability according to Pitney and Parker (2009) addressed the ability of the research finding to be transferred to other contexts. However, Zhang and Wildermuth (2009) argued that although it is not the task of the researcher to satisfy transferability, providing perspectives of transferability will project the research as rich data. The transferability is possible in this research as the contributions to knowledge on waste management domain can be applied to various scenarios. Moreover, transferability of this research is assured as the framework developed is applied in more than one case study. *Dependability* is similar to reliability according to Contento (2011), where other people are able to follow the decision trail of original investigator and also understands how findings are obtained. This includes interview transcripts and photos from field work. *Confirmability* addresses objectivity and it is an auditable approach bound to dependability (Guba and Lincoln, 1989). It confirms the extent to which data provided by the researcher can be confirmed by the reviewers and audience (Bradley, 1993). This is also satisfied by keeping the notes, transcripts, interview records for audit trial in this research.

4.7 Chapter Summary

This chapter provided a detailed explanation on methodologies used for the research. The philosophies of methodology used for the research are justified in line to the research objectives. The research strategy, data collection methods and approaches used in this research are explained in an elaborative way. The chapter also reiterated the research aim and objectives which the study attempts to answer. The ontological and epistemological stances along with pragmatic philosophy are justified in this chapter. Moreover, case study as research strategy and the criteria used for selecting the cities are justified. The chapter also emphasised the need of semi-structured interviews and closed ended surveys to enable relevant data to be collected in order to achieve the objectives of the study. The discussion

of how the data is analysed is underpinned and an account of the basis for the selection of three case studies is also strengthened in this chapter. The chapter wraps up with the background information of how reliability and validity is achieved during the tenure of the research.

Chapter 5: Background of case studies

5.1 Introduction

The research adopts case study methods as mentioned in chapter 4. Three Indian cities are selected as case studies. This chapter highlights the profiles of India and the three cities (namely Visakhapatnam, Warangal and Kakinada). It addresses the key aspects of population, waste management and smart city initiatives.

5.2 India

5.2.1 Background of India

India is officially known as the Republic of India and is situated in South Asia. It is the seventh largest country in the world with the area of 3,287,263 sq. km. The governance is federal parliamentary republic and the country is divided into 29 states and 7 union territories as administrative divisions. India is the second populous country in the world. The population in India was 1,21,01,93,422 (Census, 2011a). There was an increase of 17.64% in the population between 2001 and 2011 and the estimated population in 2016 was 1,266,883,598 (CIA, 2017). The population growth in India is shown in the figure 5.1.

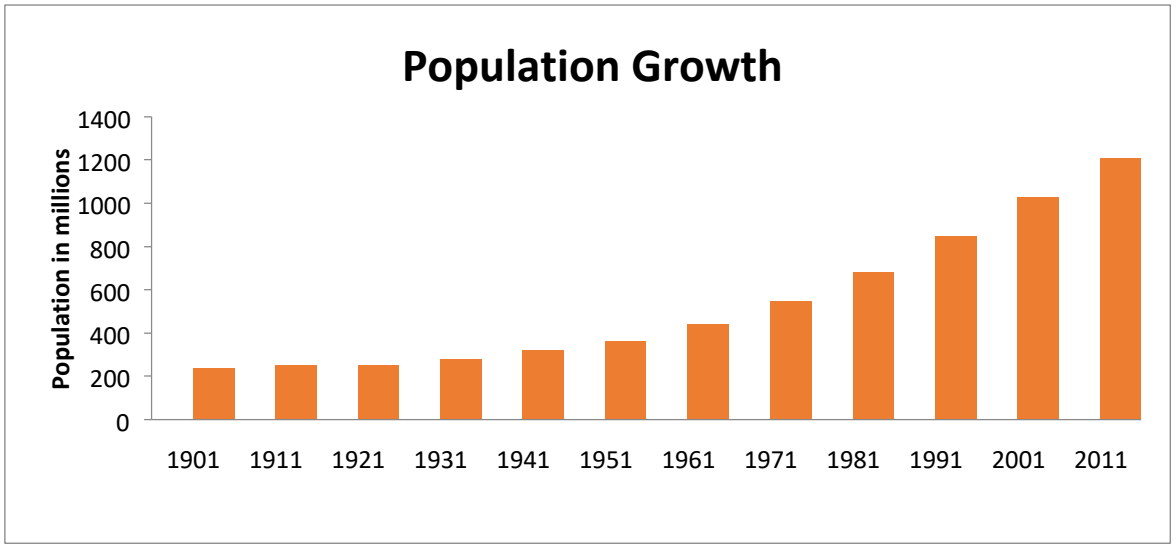


Figure 5.1: Population growth in India (Source: Created using the data from census, 2011a)

According to the Central Statistics Organisation (CSO) and International Monetary Fund (IMF) India emerged as one of the fastest growing countries in the world. India's gross domestic product (GDP) grew by 7 percent during the fiscal year (FY) 2015-16 and

projected to slowly accelerate with structural reforms, improvement in economic activity and higher disposable income (India Brand Equity Foundation, 2017). India's per capita income was US$ 1,593.3 in 2015 (The World Bank, 2017a). According to the World Bank, 21.2% of the population of India were below the poverty line (in 2011).

India has seen a rapid urbanization over the last 50 years as shown in figure 5.2. It is a remarkable phenomenon that occurred during the 20th century and has changed the lives and living styles of people in India. About 28% of the Indian population is residing in the urban areas (Census, 2011b) and these numbers are assumed to accelerate in the future. This trend resulted in the development of the large or mega cities with rich history and diversity. Although the country has made progress, it struggled to make the best of the opportunity which urbanisation provides. Urbanisation has not helped the country to transform the economy to join richer nations in both liveability and prosperity (The World Bank, 2015). Additionally, it left new challenges to deal with to provide a better living in the urban areas.

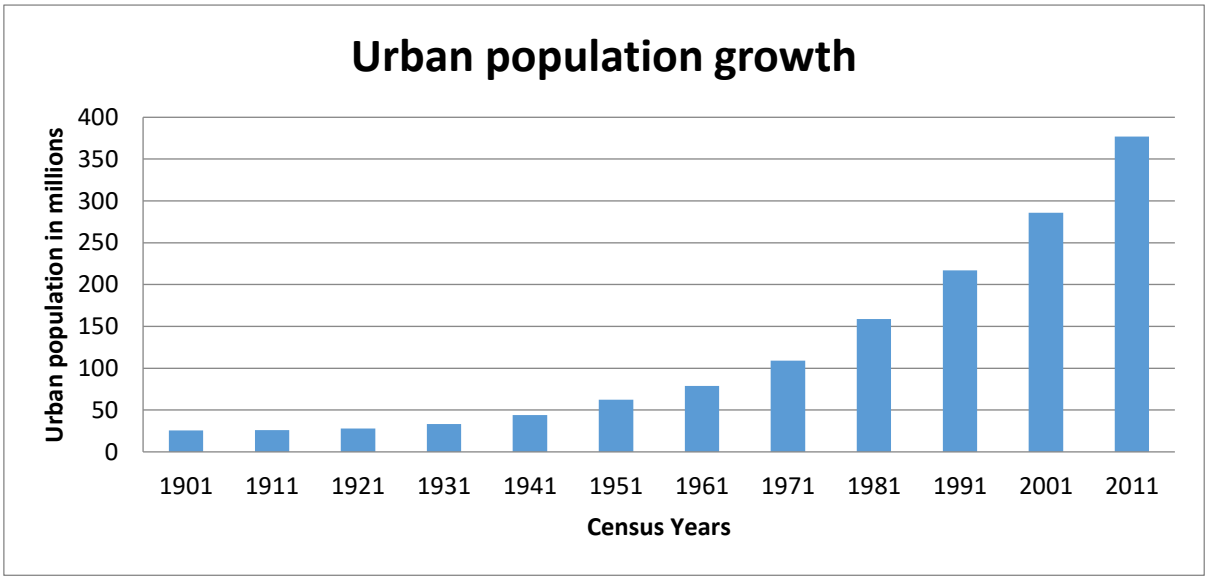


Figure 5.2: Urban population growth in India (Created using the data from Census 2011b)

The urbanisation process in India lead to haphazard developments in some cities. The lack of space and housing facilities for the overgrowing population gave rise to the development of slums. Almost all the Indian cities have seen the people of lower economic status living in the slums. Congestion of roads and traffic issue has also grown with urbanization. Traffic related problems not only cause inconvenience to the people but lead to the over exploitation of the resources like petroleum products adding up to global warming and

environmental degradation. The urban areas have also faced lack of civic amenities including continuous water supply, sanitation, sewerage system and huge piles of uncollected garbage. As the living conditions change, the garbage generated in the cities is estimated to be twice the population growth (Jaysawal and Saha, 2014). These problems exist in almost all the Indian cities irrespective of the size. It is estimated that the demand for urban services would increase drastically and $1.1 trillion of capital is required to meet the demand. By 2030, it is estimated that the demand for housing will increase by 4 times the supply. Private transportation is estimated to double and public transportation will exceed by 2.5 times. Demand for water is expected to double the supply and sewage treatment needs will be 3.5 times (Mckinsey Quarterly, 2010).

5.2.2 Waste management status in Indian cities

The urban areas in India produced 31.6 million tonnes of waste in 2001 which increased to 47.3 million tonnes in 2011 (Annepu, 2012). This is also expected to rise by 5% per year with changing lifestyles and increase in population (Planning Commission, GoI, 2014). In India, waste collection, transportation, processing and disposal are the responsibilities of local authorities Urban Local Bodies (ULB), but the authorities find it challenging to manage the waste in cities (UMC, 2015). Public health in India is the main driver for waste management. The local authorities spend Rs 500–1000 per tonne on solid waste management with 20% spent on transport and 70% on waste collection. Solid waste disposal is at a critical stage of development in India. Major part of waste (90%) in India is dumped in an unsatisfactory manner. So, there is a need to develop facilities to treat and dispose of increasing amounts of municipal solid waste (Sharholy *et al.*, 2007). There is no doubt that the current status of solid waste management in India is poor as the infrastructure and appropriate methods from waste collection to disposal are not in place. Lack of accountability is also evident in current solid waste management systems throughout India (Khajuria *et al.,* 2010). Although the municipal or local authorities are managing waste in India, the insufficient budget to cover the costs related to it are confining the progress to minimal extent. Low budget and limited environmental awareness combined with low motivation among the citizens have inhibited adoption of newer technologies which can transform the status of waste management in India.

Table 5.1: Waste generation of top 10 Indian cities (Source: Annepu, 2012)

Rank	Metropolitan area	State/Territory	Tons per day	Kg/person/day
1	National capital region (NCR)	Delhi, Uttar Pradesh, Haryana	11,558 (Delhi)	0.65 (Delhi)
2	Mumbai Metropolitan Region	Maharashtra	11,645	0.51
3	Kolkata Metropolitan Region	West Bengal	12,060	0.66
4	Bangalore Metropolitan Region	Karnataka	3,501	0.45
5	Pune Metropolitan Region	Maharashtra	2,724	0.53
6	Hyderabad Metropolitan Region	Telangana	5,154	0.65
7	Chennai Metropolitan Region	Tamil Nadu	6,404	0.71
8	Surat Metropolitan Region	Gujrat	1,815	0.47
9	Visakhapatnam Metropolitan Region	Andhra Pradesh	1,250	0.67
10	Kanpur Metropolitan Region	Uttar Pradesh	1,839	0.49

The presence of informal sector is significant in waste management in India. According to the definition of Scheinberg *et al.*, (2010), the informal waste sector is comprised of individuals or group or enterprises that are working with waste management activities by providing services and are not supported, acknowledged or recognised by the formal waste management authorities. It comprises of several actors such as rag pickers, itinerant waste buyers, small and large-scale waste dealers. Such informal recycling is performed by

marginal groups and outcastes. In India, *Harijans* are the caste who perform the informal waste collection (Wilson *et al.*, 2006) and they are given low social status and are often ill-treated. They are also considered as a menace by the formal sector and their contribution to recycling is not identified (Gupta, 2012).

5.2.3 Waste management governance and legislations in India

Waste management in India is managed by many organizations and local bodies but centrally governed and monitored by Ministry of Environment and Forest (MoEF) and Ministry of Urban Development (MoUD), which are the ministries in Government of India (GoI). Several institutions are involved in governing cities such as urban local bodies or local authorities, state government departments and parastatals. Government orders (GO) and Acts of legislatures are used as a medium to enact laws in state governments and central government of India.

The legal structure usually involves Ministry of Urban Development (MoUD) to issue policy guidelines. Centre for Public Health and Environment Engineering Organization (CPHEEO) is the technical wing for MoUD and prepares the manuals, funds, service standards for managing waste (MoUD, 2017). Central Pollution Control Board (CPCB) is a department of MoEF that monitors the compliance with benchmarks of service delivery as set by MoUD at state and central levels. Though state pollution boards are autonomous, they follow the guidelines given by CPCB (APUFIDC, 2016).

The overarching framework to manage the solid waste in urban areas was crafted by MoEF in 2000 with the enactment of Municipal Solid Waste (Management & Handling) Rules, 2000. This was done under the Environment Protection Act, 1986 which entrusted Urban Local Bodies (ULB) with responsibilities of managing municipal solid waste (CPHEEO, 2017). After 16 years, the policy was redefined and enforced the rules pertaining to duties of waste generators. Ministries of several departments (like environment, forest, climate change, etc), local authorities, CPCB, solid waste management processes and service, environment, etc. formed the Solid Waste Management (SWM) Rules, 2016. The framework further stated that the urban local bodies need to organize awareness initiatives to segregate waste and promote recycling of segregated materials. According to CPHEEO (2017) the municipal authorities must undertake phased programs for ensuring community participation within waste management process.

5.2.4 Swachh Bharat Mission and Swachh Survekshan

Swacch Bharath (Clean India) Mission and *Swachh Survekshan* are initiatives taken by MoUD, to improve waste management and sanitation in India and to bring them to the top of agenda for all local authorities (AIIPL, 2016). The objectives of *Swachh Bharat* include eradication of manual scavenging, 100% collection and scientific processing/disposal/reuse/recycle of municipal solid waste (MSW), to bring behavioural change in citizens and awareness about sanitation and its link to public health.

Swachh Survekshan is the ranking of cities for those with population of 100,000 or more (national ranking) and the one having below 100,000 (it is state and zonal rankings). The assessment is based on the progress year to year under *Swachh Bharat* Mission. The primary intention is to encourage cities to proactively implement *Swachh Bharath* initiatives in a timely manner. The other objectives are to create awareness to citizens about the necessity of their role to make their city a better place to live in and thereby encourage large scale citizen participation. Additionally, the survey intends to foster spirit of healthy competition within the towns and cities for improving their service delivery to citizens in the process of creating cleaner cities. It will help the Urban Local Body (ULB) in assessing their performance and identify areas of improvement. The findings will also enable the ULBs to learn about best practices being implemented in other cities and to adopt them, tailored to their own requirements (APUFIDC, 2016). The scoring is based on service level status (45%), independent direct observations (25%) and citizen feedback (30%). Citizens can also participate towards making the city waste free by using the mobile application (app) called *Swacchata* app. The *Swachhata* app is the official app launched by MoUD.

The various initiatives such as Smart Cities Mission, Swachh Bharat Mission and existence of informal sector associated with increased waste volumes caused by rapid urbanisation, makes it suitable to consider the case studies from India. Hence, three South Indian cities that are rapidly urbanising, face growing waste as a challenge and are also included in Smart Cities and Swachh Bharat Missions are considered as case studies. The three cities are Visakhapatnam, Warangal and Kakinada. The following sections provide their city profiles.

5.2.5 Smart Cities Mission and smart initiatives in India

Smart Cities Mission is retrofitting program for urban renewal by the Government of India. It has a vision to develop 100 cities in the country and make them sustainable and citizen

friendly. The MoUD plans to address current problems like sanitation, waste management and upgrade the infrastructure with advanced technology in Indian cities. The core elements in a smart city would include robust IT connectivity and digitalisation, adequate water supply, solid waste management, assured electricity supply, efficient public transport, affordable housing for the poor, sustainable environment, e-governance and citizen participation. Proposed smart solutions as shown in figure 5.3, include technology, information and data for the improvement of infrastructure and services. Comprehensive development aims to create inclusive cities which generate employment to enhance income for all, improve quality of life especially for the poor and disadvantaged. Some of the initiatives that are being planned and implemented include traffic mobile app, smart parking, creating walkable localities, public transit management centre to improve the transportation system and reduce traffic congestion. To ensure security there is an increased CCTV surveillance. Improving citizen engagement by promoting interaction platforms, e-governance and public information system came into existence. Use of smart meters for utilities is also considered in some cities. Particularly for waste management, mobile applications for cleanliness monitoring, optimisation of garbage truck routes, GPS tracking, RFID tags for bin monitoring, waste to energy plants for waste processing are being applied as smart waste management techniques (Smart Cities Mission, 2016). The Smart City Mission in India can be considered as a remarkable initiative for developing cities and foster economic growth. It included a number of urban services in its initiatives but prioritised the hard domains of the city in each service sector identified. According to Chatterjee and Kar (2015), although the smart initiatives indicate progress for a country like India, there is also a concern on the extent of ICT use. Since India is a country where a significant number of people are not digitally literate, there is also a need to prioritise on education and people skills without halting on the ICT developments.

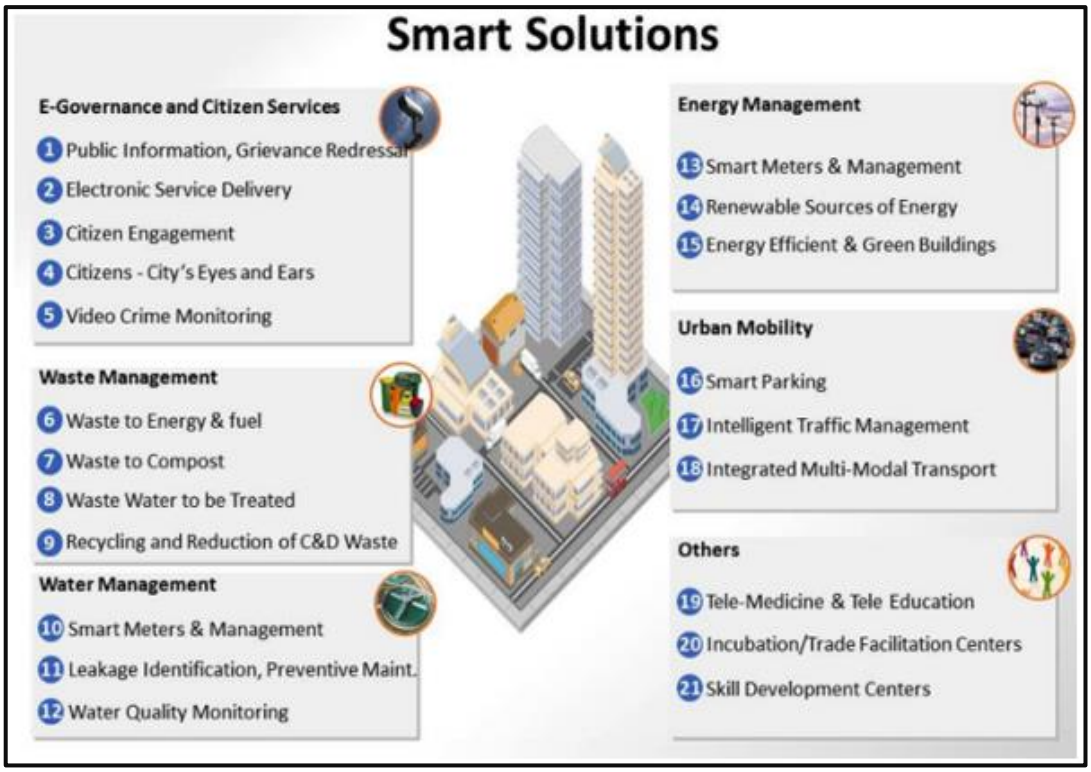


Figure 5.3: Figure showing smart solutions proposed in Smart Cities Mission in India (Source: Smart cities Mission, 2016).

5.3 Case study 1: Visakhapatnam City (addressed as city 1)

5.3.1 Visakhapatnam (City 1) background

Visakhapatnam is the largest city in the state of Andhra Pradesh and is the administrative headquarters of the Visakhapatnam district. It is located on the eastern coast of India in the southern peninsula. It is also called as Vizag or The Jewel of the East Coast. It is spread across an area of 550 km² with a population of 1,728,128 (Census, 2011a). The decadal growth (2001-2011) of the city population is increased by 4%. Visakhapatnam Municipality was set up as early as in 1858 which was later converted into Municipal Corporation in 1979. In 2005, the boundaries of Visakhapatnam have been extended by merging the neighbouring villages. The administrative body is called Greater Visakhapatnam Municipal Corporation (GVMC). GVMC is the local authority of the city and is divided into 6 zones and the zones are further divided into a total of 72 wards (GVMC, 2017). The city is listed in the Smart Cities Mission of India by MoUD. It is the first city in India to implement e-governance. In addition, it has also started several citizen friendly initiatives (MoUD, 2017).

Figure 5.4: Map showing position of Visakhapatnam city in India (Source: DPR, 2016a)

Economic activity in Visakhapatnam is spread across different sectors and is developed into special economic zone. It is primarily an industrial city and hosts steel plant, pharmaceutical industries, oil refineries, power plants, fertilizer and agrochemical-based industries. Visakhapatnam being situated on the coast, it has one of the busiest ports which aid imports and exports through sea route. Information Technology (IT) sector is fast developing in the city and several IT companies have established and actively providing their services contributing to the economy as well as generating employment opportunities (NIC, 2017). The city, therefore, provides opportunities to employment and is facing rapid urbanisation. The city also faces the problems related to the urbanization. One of them is the increase in waste generation.

5.3.2 Existing waste management system in city

The waste generated in Visakhapatnam city is heterogeneous and comes from numerous sources. They are broadly classified as domestic waste, street waste, market waste, industrial waste, agricultural waste and animal waste. The total waste generated from Visakhapatnam is 920 tonnes per day for which GVMC is responsible for its management. The per capita waste generated is 0.47 kg/capita/day. It is estimated that 60% of the waste comes from households accounting to 552TPD (DPR, 2016a). Generally, source segregation is not practiced in the city. GVMC offers primary waste collection to 80% of the households and nearly 70% of them are offered a door to door collection service. This is performed using non-motorised vehicles such as pushcarts and trolleys. The waste is

then transported to the collection points. During this process, the collection staff voluntarily segregate the waste to recover recyclables and sell for their personal gain. So, the quantity of waste segregated, or the recovered recyclables are not noted or known. The remaining waste is then transported from collection points to transfer sites and finally to dumping yard which is 25km away from the city for open dumping which is performed using large motorised vehicles. There is no formal waste processing in the city and an NGO operates a compost plant. It receives 5-6 tonnes of mixed waste per day which is manually separated into dry and wet waste and out of which the wet waste is being composted. The remaining waste is transported to the dumping yard for disposal. In addition, the only other source of recycling or material recovery is through the informal sector. However, there is absence of data on the number or amount of waste recycled.

5.3.3 Smart city initiatives and *Swachh Survekshan* participation

The city has used several smart initiatives in managing traffic, online communication system, installed solar panels for energy generation etc. In solid waste management system, the initiatives are limited to installing GPS, tracking of the common bins and transport vehicles. The waste to energy plants under private partnership are proposed. However, under the Swachh Bharat initiative, the city is an active participant and has been consistent with its performance. In *Swachh Survekshan* 2016, it was ranked 5 out of 73 participating cities and achieved 82% in the measurement. In 2017, the city moved up to rank 3 out of 434 participating cities with an overall score of 90%. It has introduced training and ICT based attendance system to the waste workers. It has also started active community awareness programmes through the CBOs and by providing additional hoardings. It has used *Swachhta* mobile application to improve the overall waste services and to provide a faster complaint redressal system. This enabled a better communication system. Though the Swachh Survekshan report (2017) addresses the engagement of informal sector and user charges collection is fully addressed, it is not seen in practice. This makes the city suitable as a case study to understand the user collection and transition of role of informal sector through engagement and to know if they were fully achieved. It is also interesting as it uses of ICT as communication channel for waste management, but at the same time the city does not follow source segregation though it is participating in the Clean India Programme and prioritises waste management.

5.4 Case study 2: Warangal City (addressed as city 2)

5.4.1 Warangal (City 2) background

Warangal is a city in Indian state of Telangana. The city is the district headquarters of Warangal urban district spreading across 406.87 km^2 (157 sq. miles) with a population of 819,406 and population density of 283 per square km. The decadal population growth (2001-2011) of Warangal City is 5.4%. The population is projected to surge 2.34% every year with the growing economic activity (Census, 2011a). The city is famous for its rich culture and heritage which attracts nearly 2.3 million people annually for tourism (DPR, 2016b). Warangal city has one of the oldest municipalities established in 1899 which was upgraded to Municipal Corporation in 1994 and became Greater Warangal Municipal Corporation in the year 2014. The city was selected under the Smart Cities Mission of MoUD and is eligible for additional investment in order to improve industrial opportunities and urban infrastructure.

Figure 5.4: Geographic location of Warangal in India (Source: DPR, 2016b)

Warangal has geographical advantage of being located 145 km from Hyderabad, the State Capital and is one of the major urban centres of Telangana state. It addresses the medical, educational, cultural and trading needs of the people and has emerged as a regional hub for educational facilities. Warangal City witnessed significant growth in the recent past which created opportunities for local economic development along with improved quality of life. The city's economic activity is dominated majorly by rice mills, leather tanning, silk weaving etc. The unplanned linear growth and huge floating population contributed to several issues in the city and addressing such issues will need enhancing existing

infrastructure (DPR, 2016b). Although the City Development Plan (CDP, 2011) aimed to promote overall development, the city would need to consider framing strategies to improve living conditions of the poor and to manage the growing waste volumes with the growing population.

5.4.2 Existing waste management system in city

The waste generated in the city comes from multiple sources such as households, commercial establishments, drains and street sweepings. The total waste generated in the city is estimated to be 220 TPD and the per capita waste generation is approximately 0.251kg/day (DPR, 2016b). The primary waste collection service is offered by GWMC and includes collection from roads, bins and door to door. The waste collection service is offered to 83% of the households in the city (CDP, 2011), but the door to door collection service is offered only to 60% of the households. The primary waste collection throughout the city is performed using manual transport system such as pushcarts and tricycles (DPR, 2016b). There is no significant source segregation in practice. So, to promote source segregation, the households were distributed with free twin bins that are colour coded for wet and dry waste. In addition to GWMC, Well-being Out of Waste (WOW), a public private initiative offers dry waste collection to the city. After the primary waste collection, the waste is stored at secondary collection points from where motorised transportation using tractors or tippers transport the waste to transfer stations and finally to dumping yard. The vegetable waste from commercial establishments is sent to bio-methanation plant with a capacity of 12KW (DPR, 2016b). There is absence of waste processing of household waste performed by GWMC and the waste is sent for open dumping. The household waste recycling is dominated by the informal sector and private small-scale waste dealers. There is no data on the number of informal sector or on the amount of waste they trade. It is estimated by the GWMC, that their number exists in 1000's.

5.4.2.1 '*Well-being Out of Waste'* (WOW) initiative

'*Well-being Out of Waste*' (WOW), is a national recycling initiative intending to reach the recycling rate of 70% in India on par with developed nations. The initiative aims to inculcate behavioural change with respect to post-consumer waste. The programme identifies key changes needed for source segregation, efficient collection system and sort waste to promote recycling. The WOW is a collaboration between an NGO (ESree Foundation), CSR activity of private company (ITC Limited) and GWMC, the Local Authority of Warangal. Hence, WOW is addressed as a Public Private Partnership (PPP)

and is registered with a MoU (Memorandum of Understanding) (ITC, 2015). The responsibilities in WOW are shared. NGO works for conducting awareness programmes and training staff and entrepreneurs while private company (PPP) is responsible for collection, sorting, packaging and marketing collected waste by encouraging entrepreneurs and staff. The local authority (GWMC) is responsible for providing infrastructure for collection as well as allocation of space. The operational model of WOW is shown in table 5.2.

Table 5.2: Operational model of WOW (PPP) (Source: Author)

	Source segregation	**Collection**	**Sorting**	**Transport**	**Processing**	**Disposal**
Operations	Residents	Employed PH workers	Trained rag pickers	WOW staff	Trained rag pickers	WOW and GWMC
Monitoring	NGO and PH workers	WOW	WOW	WOW	WOW	WOW and GWMC
Financing	WOW	GWMC and WOW	WOW	WOW	WOW	WOW and GWMC
Infrastructure	-	GWMC	Private company and GWMC	Private company and WOW	Private company and GWMC	-
Awareness Campaigns and training	NGO	NGO	NGO	-	NGO	-
Health and Safety Equipment	GWMC	GWMC	GWMC	GWMC	GWMC	GWMC

The WOW process involved three main steps. Firstly, propagation which is led by NGO to spread awareness to households about source segregation. The members of the propagation team visit door to door to educate the households about segregating waste. The educated households are marked with stickers for future monitoring and identification

by collection staff. They are informed about the amount they would get paid for the dry recyclables to motivate them in getting extra money for segregating the waste. They are paid according to a fixed rate matrix depending on the category of recyclable.

Secondly, Physical Health (PH) workers perform the collection system step for additional wages given by WOW. They are formal waste collection workers who are trained for dry waste collection by checking its quality and to communicate with households for poor participation.

Thirdly, sorting and recycling step involves bringing the waste to Dry Resource Collection Centre (DRCC), where DRCC operators weighs and records the recyclables. Informal waste pickers are trained and employed to manually sort into 6-7 grades of dry recyclables. There are 18 DRCCs and a collection route is planned depending on volume of recyclables in each DRCC from where sorted waste reaches the Dry Resource Central Hub. Further separation and processing occurs and sold to factories or manufacturing units.

5.4.3 Smart initiatives and *Swachh Bharat* programmes to improve waste management

The city has been selected for Smart Cities Mission of India and the proposal of smart initiatives includes application of technology and upgrading the infrastructure (Smart Warangal, 2018). As a part of such smart initiatives, underground waste collection bins that work with hydraulic system are planned in 12 places of the city with 1.1 tonnes capacity each. This intends to decrease the health hazards that result from the overflowing street bins and to create a healthy environment (Reddy, 2017). In addition, it has also planned to increase the transfer stations and fleet vehicles. Moreover, a detailed project report was submitted to the World Bank under the smart cities initiative to improve the overall infrastructure for waste collection and transport. For waste processing, bio-methanation plants have been proposed.

Warangal city is also an active participant in the Swachh Bharat programme of India. It has made significant efforts to improve the overall waste management and sanitation conditions of the city. In 2016, the city was ranked 32 out of 73 participating cities (Swachh Survekshan, 2016) and achieved a score of 61%. In 2017, the city was ranked 28 out of 434 cities and significantly increased its score to 77% (Swachh Survekshan, 2017). The city has also launched Swachh Warangal campaign and divided the city into 10,000

Swachh units ensuring a dedicated team with clear roles and organisational structure. The aim of the Swachh units is to bring behavioural change among the people to participate in source segregation, make the city clean, litter free and ensure public health (Smart cities council India, 2018). The city also conducted awareness programmes to a number of schools and households. The city was the first to host a Clean City Championship (CCC) which was a seven-day challenge to tackle the solid waste. It brought several stakeholders including school children to a common platform to perform the appropriate methods of managing waste through a competition. This is regarded as a success due to the improved recycling rates in 7 days. The multi stakeholder participation and the intervention and extent of local authority's participation is regarded as the success factor for the championship (NSWAI-ENVIS, 2014).

The city shows a remarkable progress and development to improve its waste management through, awareness, upgrade of technology, exploiting smart waste technology and through stakeholder collaboration. However, the city struggled to maintain a better ranking in the country for its practices in Swachh Survekshan results. This makes it an interesting case study for making it a waste free city. Since, it is a city in developing country and trying to improve the waste sector on the whole, it can help in drawing comparisons with other competing cities. This city will be addressed as city 2 in the thesis.

5.5 Case study 3: Kakinada City (addressed as city 3)

5.5.1 Kakinada (City 3) background

Kakinada is a city and a municipal corporation in the state of Andhra Pradesh, India. Kakinada was an erstwhile Dutch port and has a population of 325,985 as per the latest census in 2011 (DPR, 2016c). Kakinada City has witnessed a decadal growth (2001-2011) of 1% in population. The economy majorly depends on port-based industries. Kakinada's economic potential comes from diversified industrial presence which includes auto parts, steel, fertilisers and textile along with a strong maritime sector. The economy also revolves around aquaculture, fishing, sugar and edible oil refineries. The primary exports are fertilisers and seafood. Oil and Natural Gas Corporation's (ONGC's) eastern offshore hub is richly recognised for its potential in petroleum industry.

Figure 5.5: Map showing position of Kakinada city in India (Source: DPR, 2016c)

The city is spread across an area of 63 square miles and has a population density of 10287 persons per square kilometre. The urban governance structure in the city is administered by Kakinada Municipal Corporation (KMC), which is divided into 50 administrative wards (DPR, 2016c). It was chosen for the first phase of Smart City Mission of MoUD along with 20 other cities. The project aims to bring transformational changes by efficient citizen services and real-time governance. Kakinada is also a part of Special Economic Zone (SEZ) and is named as a proposed Petroleum, Chemical and Petrochemical Investment Region (PCPIR). This helped the city to see a gradual growth with the merger of surrounding villages. The increased development and urbanization caused more motor vehicles, lack of sanitation drive etc. Kakinada being a part of Smart Cities Mission, the municipal authorities aim for a city that has smart infrastructure that can drive better industrial growth and urban planning (FFMR, 2016).

5.5.2 Existing waste management system in city

The sources of solid waste generation are offices, function/marriage halls, institutions, restaurants, commercial properties, markets and local households etc. Households are the main contributors of solid waste (DPR, 2016c). The waste generated in the city is estimated to be 205TPD. Waste collection is the responsibility of KMC and it offers primary collection service through manual transportation methods and serves nearly 88% of the households. It provides a door to door collection service, but it is limited to 70%

(FFMR, 2016). The collected waste is accumulated at community bins or open points from where secondary transportation is carried using motorised vehicles. The waste reaches transfer site and finally sent for open dumping (DPR, 2016c). Waste is not treated or processed before disposal except for vegetable waste produced at markets. Approximately, 1TPD of vegetable waste is composted and sold to farmers. There is absence of recycling activity through the formal sector (KMC) and particularly the household waste. The contribution towards recycling of household waste is through the informal waste sector. However, there is no data available on the amount of waste or the number of waste traders in the informal sector. The NGOs are involved in promoting awareness campaigns, but the significant effect on citizen participation in source segregation is not seen.

5.5.3 Smart city initiatives and *Swachh Survekshan* participation

The city plans to upgrade the waste management infrastructure under the smart city's initiatives. It has considered using GPS tracking on waste collection vehicles and common bins to improve monitoring. It has also proposed the use of smart bins that can monitor the overflow by using sensors. The details on the number of such bins or the operational model are not known (FFMR, 2016). It has also laid road with recycled plastic which helped in reducing the plastic waste and decreased the expenditure in laying roads (Sankar, 2017). The city has also taken part in the *Swachh Survekshan* rankings conducted by MoUD, in 2017 and secured 43rd rank in India. It was considered as the cleanest city in the south zone with population ranging between 2-10 lakhs in India and achieved a score of 73% in the assessment (Swachh Survekshan, 2017). The city still suffers from several problems such as lack of source segregation, waste transport and treatment facilities, open dumping, lack of awareness and citizen participation, inadequate resources and organisation of informal sector despite its ranking and smart initiatives. The city offers opportunities to be considered as a case study for waste free cities research due to its poor waste management process despite the investments and ranking. This city is addressed as city 3 in the following chapters.

5.6 Summary

The trend in urbanisation has witnessed increased waste volumes with cities mostly in developing countries like India. The unimaginable waste volumes and poor execution of waste management activities makes the above three cases very suitable for the research context. Due to the closeness in geographic location of the three cities, they share similar

climatic conditions and the variations in waste composition are minimal. Besides that, India has a common legal framework for waste management making it ideal for the cases to be compared. All the three cities are listed cities of *Swacch Bharath Mission* (Clean India) and they participate in *Swacch Surveykshan* (Cleanliness Survey). So, the deliverables are measured on a common scale to know the current situation and justifies the case selection.

Chapter 6: Results and Discussions

6.1 Introduction

This chapter presents the results obtained for the waste free cities concept using three case studies. A comparison between the results for the three cities is made, analysed and discussed using a common framework. The results and discussions are divided into the following three parts to meet the research objectives.

The first part deals with results where the proposed theoretical framework for the study is applied on three Indian cities chosen as case studies (as explained in chapters 4 and 5). This part includes an analysis of how each of the three cities is performing and reasons justifying their performance. The results are presented in radar diagrams which allow comparisons between cities or various categories within a city. This also indicates how each stakeholder group is performing their role.

The second part focuses on who the stakeholders at city level are, their roles in waste management operations and how it affects value addition (valorisation of waste). In this study, the value added to waste is calculated in terms of average monetary gain for each participating stakeholder group. The results are presented in the form of a value map indicating how each stakeholder group's activity is contributing to valorisation of waste. The three cities considered have different models and different levels of stakeholder collaboration in managing their waste. Hence, the comparison between them highlights how different collaboration levels affect the waste value chain.

The third part of the results highlights on problems faced by the system for a successful implementation of waste free cities framework and in gaining highest value addition to waste. The study records the problems faced by each stakeholder group. It comprises of managerial and institutional issues faced by local authorities as well as the issues faced by other stakeholder groups such as citizens, private businesses and informal sectors. These problems are identified using the waste free cities framework and the primary data collected through interviews (as mentioned in chapter 4). The solutions are proposed for the identified problems by reviewing best practices based on their appropriateness and applicability.

6.2 Application of theoretical framework

The waste free cities framework is used to evaluate the waste management status in cities that are on the path towards transforming into smart cities. Hence, the framework includes various factors that play a role in urban waste management process particularly in developing countries context. They are grouped into smart city categories and sustainability dimensions (as explained in chapter 3). These factors include all levels of waste management ranging from basic service provision to all the households to advanced infrastructure for waste management which is often addressed as smart waste management.

Scores have been assigned to each factor using qualitative and quantitative indicators after a careful examination and judgement for its appropriateness. The quantitative indicators are scored using official documents issued by the local authorities, ministries and governing bodies. The data available from the company reports and research articles are also used for the study. When further calculations are required, standard formulae or formulae from published works and books are used. For assigning scores to qualitative indicators, document review, interviews of local authorities, Small and Medium Enterprises (SMEs), informal sectors are used along with citizens' surveys. This is to ensure the framework embeds top down approach as well as bottom up approach to get best scores for the framework and this ensures data triangulation. The same measurement criteria and time frames for data collection from all three cities are used to maintain consistency. If the data is found different for the same factor in multiple sources, the lowest value is taken for scoring to ensure no factor is being overrated for its performance.

The results of the framework are presented in radar diagrams as shown in figure 6.1. It includes smart categories and sustainability dimensions to draw an easy comparison between cities and to understand which category or dimension is performing well in the city and what needs improvement. This enables to identify which stakeholder is responsible for the performance and helps local authorities and decision makers to design strategies for improving the performance. The comparison between cities can help in identifying how other cities are doing better and investigate reasons behind their performance. Hence, the comparison using this framework is only to identify best practices and benchmark against each other or compare between different categories and dimensions for each city but not to rank the cities.

6.2.1 Case studies for application of framework

To illustrate the application of the waste free cities framework, three case studies have been chosen with different strategies and stakeholder collaborations for waste management (as explained in chapter 5). The above criteria are considered due to their importance in waste management studies as these could affect the performance of waste management. All the cities taken are entitled to similar funding facilities due to their participation in *Swachh Bharat* Mission which is a national wide waste management programme in India. Moreover, they are also entitled towards funding that can help them in modernising waste management infrastructure as all the three cities are listed in the Smart Cities Mission of India (as explained in chapters 4 and 5). Since waste generation is affected by the climate, the case study cites chosen are geographically closer with similar climatic conditions to ensure the waste composition and generating patterns do not change significantly.

6.2.2 Results and discussions

A comprehensive picture of the performances of three case study cities in smart categories and sustainability dimensions are shown in figure 6.1. Generally, City 2 can be observed as a better performing city in both sustainability and smart categories. The details on each of them are discussed further.

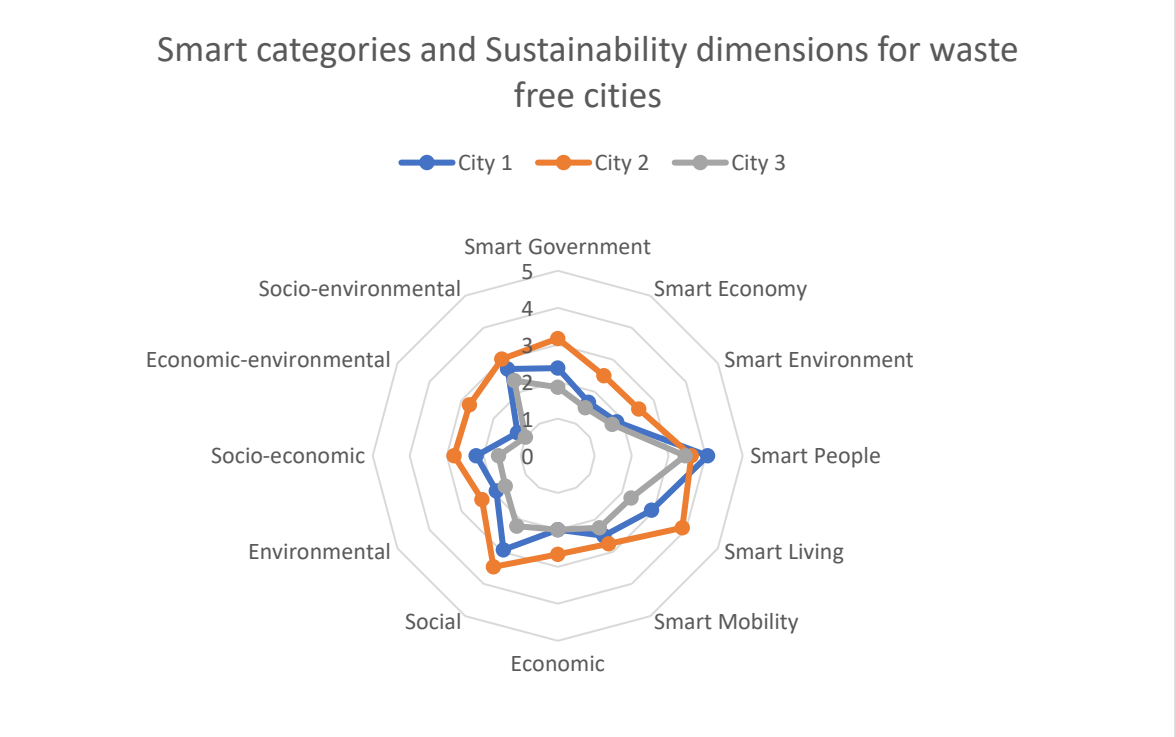


Figure 6.1: Radar diagram showing results for smart categories and sustainability dimensions for waste free cities for three cities (Source: Author)

6.2.2.1 Smart categories

There are six smart categories in waste free cities framework as explained in chapter 3. Figure 6.2 shows the performances of the three cities in different smart categories. City 2's performance in smart categories is generally higher than the other two cities. However, city 1 exceeds the performance of city 2 in smart people category. City 3 appears to be performing similar to city 1 in smart mobility and smart economy and has a similar performance of city 2 in smart people category. Each category is analysed below by comparing the three cities and the reasons behind their performances.

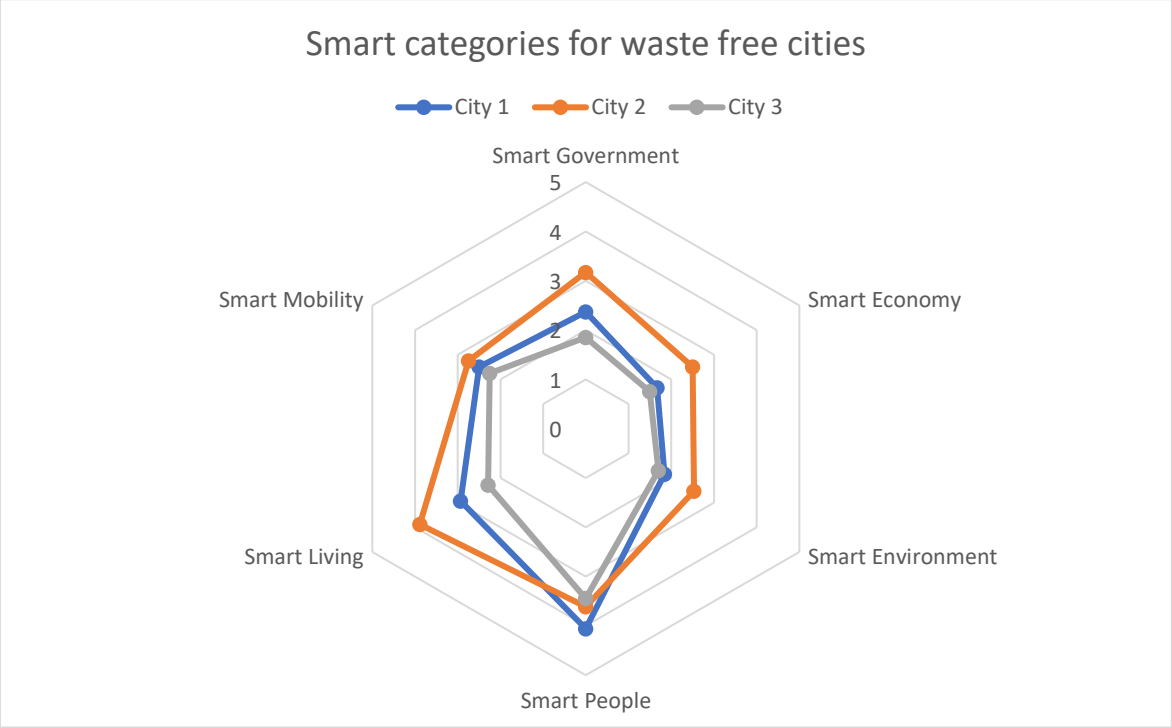


Figure 6.2: Radar diagram showing results for smart categories for waste free cities for three case studies (Source: Author)

a) Smart Mobility

Safe and advanced methods of transportation are driving factors for smart mobility. Similarly, such systems are important for waste transportation and therefore studied under smart mobility in waste free cities. Comparison for the three cities is made based on safe waste transportation system and sustainable and innovative waste transport as shown in figure 6.3.

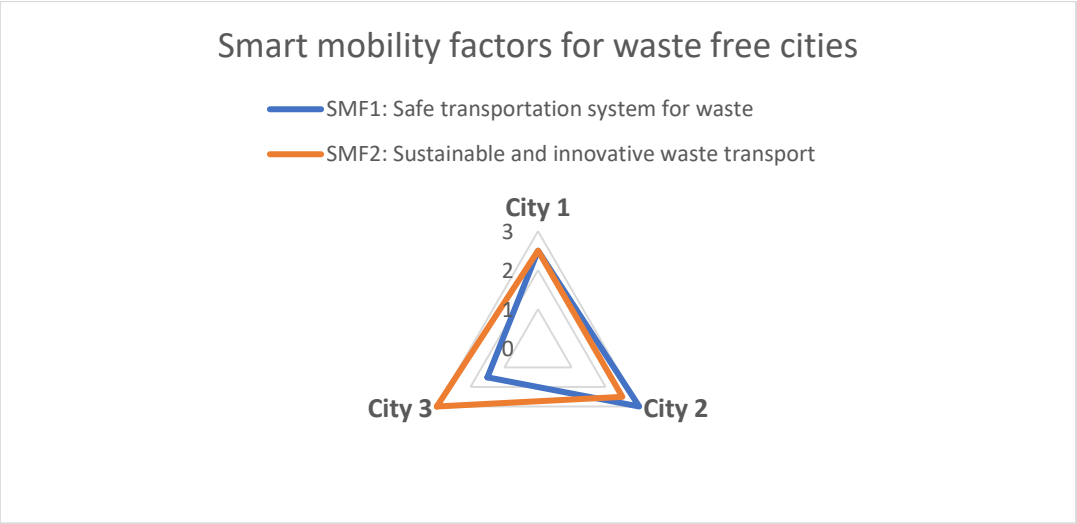


Figure 6.3: Radar diagram showing the results for smart mobility in waste free cities (Source: Author)

Safe waste transportation ensures the waste collected is transported in closed vehicles and in separated manner for each of source segregated waste categories. In all the three cities, there is no closed waste transport system identified and only temporary arrangements to cover the collected waste is made during its transportation. City 2 has separate as well as mixed waste transport systems. This is due to two different channels for waste collection that are existing in the city. One is the formal waste collection performed by employed workers, where mixed waste collection is carried out and the other is the dry waste collection performed by the trained staff of PPP (explained in chapter 5). The separate transport of waste categories helps in maintaining the quality of waste that is sent for recycling and maximises the recycling rate (Zaman, 2014). It is evident in city 2 as it has separate transport system for waste categories and highest recycling rates among the three cities. Besides ensuring quality, it motivates citizens to segregate waste at source. According to the citizens survey conducted for this study, 64% and 57% of the surveyed citizens in cities 1 and 3 respectively, reported the reasons for not segregating the waste at source is due to the mixing of separated waste by collection staff and feel there is no use of doing it. Waste workers handling patterns and separate transportation system affect the citizen participation (Troschinetz and Mihelcic, 2009). Since these practices are observed to be in implementation, city 2 performs well. City 1 has started them but are in trial phase and have not fully implemented. These practices are completely absent in city 3 and therefore show the lowest performance. According to Dowlatshahi (2000), waste collection and transportation are reverse logistics processes and should be economically and environmentally beneficial. Jahre (1995) identified that separate collection of waste would

result in higher operational costs and would not benefit economically. The results are in line to the studies of Aphale *et al.,* (2015) and Linderhof *et al.,* (2001), who confirmed in their studies, that though the operational costs for collection are higher for separate collection of waste categories, it decreases the processing and disposal costs. So, the overall costs would be decreased. Safe transportation is not only environmentally beneficial due to higher recycling rates, but also economically beneficial as it reduces the overall operational costs which are discussed further in smart environment and smart economy sections.

Sustainable and innovative waste transport comprises of the use of green transport means such as non-motorised vehicles. The innovative transport in the context of study refers to the use of GPS fitted vehicles and electric vehicles for waste collection. The primary waste collection in all the three cities is carried out using manual modes that depend on mechanical energy of waste workers. 84%, 85% and 94% of the total vehicles used for waste collection and transportation are non-motorised in cities 1, 2 and 3 respectively (DPR, 2016 a, b and c). City 3 contributes significantly towards the green mobility in waste services. The use of the non-motorised vehicles could be related to several factors such as adequate labour availability and associated employment generation, low investment for local authorities for purchasing non-motorised vehicles and ease of accessibility to congested lanes to provide door to door collection service. Irrespective of the reasons, the use of such vehicles results in greener modes of transport as it does not contribute towards carbon footprints (Scheinberg *et al.,* 2010). They do not use the energy from fossil fuels thus contributes towards the goals of smart cities. This can be related to the growing green cities concepts, where Rode and Burdett (2011), also suggested the use of non-motorised transport as important transport system. Similarly, the UN-Habitat (2010) has studied waste systems of many cities in the world and found non-motorised transport not only contributes to the green mobility, but also provides access to overpopulated areas when compared to motorised transport systems. In addition, Scheinberg *et al.,* (2010) have identified use of non-motorised transport system can help in reducing carbon footprints and provide greater employment opportunities which is also seen to be true in the findings of all the three cities.

The other innovative means such as GPS fitted vehicles are reported to be in use in all the three cities and according to the interviews with local authorities, such vehicles have improved their operational efficiency as the collection crew are monitored remotely. These

findings are in line to the findings of Yuan-Young *et al.*, (2010) who studied on zero waste in Taiwan and are similar to findings reported by Navigant Research (2014), where use of GPS fitted vehicles for waste collection have reduced the fuel costs and overtime expenses of collection staff by 13%. In this study, such estimations were not made due to lack of data on the exact number of the vehicles. Electric vehicles for waste collection are seen to be future for sustainable transport methods. Their use is observed to be limited to developed countries and the three cities studied have not adopted them yet. So, city 2 (Warangal) and city 3 (Kakinada) appear to be performing well in each of the two factors towards the smart mobility.

b) Smart Environment

The smart environment category is important for smart cities particularly for achieving sustainability and smart waste management. The study considers three main factors for achieving smart environment namely, smart waste management that refers to the use of advancements and modernised infrastructure, environmental protection and sustainable resource management through waste reutilisation.

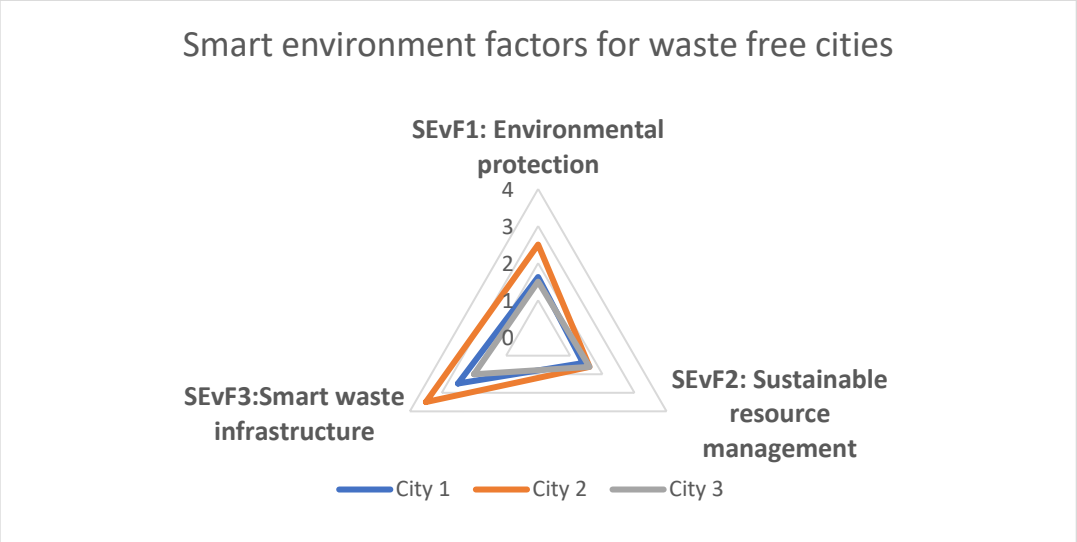


Figure 6.4: Radar diagram showing results for smart environment in waste free cities (Source: Author)

From figure 6.4, it is evident that city 2 is performing better than the other cities in two of the three factors. There is a significant difference in the use of smart waste infrastructure. This difference is due to the use (in pilot stage) of underground vacuum bins in city 2 (according to the interviews with local authorities) while the other two cities have not considered such infrastructure for the near future. Though, city 3 did not consider

underground bins, it plans to implement smart bins with sensors for waste collection under smart initiatives (according to the interviews with local authorities with city 3) which is one way of improving its operational efficiency and environment. City 2 is also striving to extend the door to door service provision besides upgrading the current infrastructure. The new infrastructure in city 2, not only keeps the collection bins out of sight, but also avoids littering of waste around the bins which is observed to be a common practice (DPR, 2016b) resulting in its loss from waste collection. It is estimated that only 91% of the waste generated is collected in the city 2 (CDP, 2011) and 75%-80% in city 1 (DPR, 2016a). Low collection efficiency of waste is not only a problem in cities 1 and 2 but is generally a problem in most developing countries and it is important to improve collection and transport efficiencies (Ilic and Nikolic, 2016b; UN-Habitat, 2010; Sharholy *et al.*, 2008). As reported by Navigant Research (2014), the use of underground vacuum bins has improved the operational efficiency of waste collection in Sweden where the fuel costs, collection vehicles and staff have reduced. In addition to the operational advantages, it also offers environmental advantages. According to Iriarte *et al.*, (2009), the underground vacuum bins have lesser environmental impact when compared to door to door collection. This depends on the distance or area covered by the service. As the distance travelled by waste in the vacuum system increases, it may have higher environmental impact. But this system suffers from higher energy demand for its operation than the door to door collection system. Since the underground vacuum bins are still in trial phase and not fully operational in city 2, the area covered by them is not known. So, the environmental benefit cannot be fully understood at local level, unless the area covered by the underground vacuum bins is known.

The other advancements are the use of RFID tagged bins to ensure the bins are available at required place to increase their availability to citizens. The availability of communal bins is an important factor and affects the littering behaviour of people and waste storage. It can also affect its recycling, resource recovery and safe disposal (Zaman, 2014). Hence, to improve the monitoring of bins' location, RFID tagging is used in cities 1 and 2 (according to the interviews with local authorities). City 3 is still lagging in its performance as it is in the planning stages for RFID tagged bins as a part of smart city projects (FFMR, 2016). According to the interviews with local authorities in city 1, the RFID tagging has helped them in managing the location of bins and improved their operations. This finding seconds Sorbom (2003) who indicated that waste disposal behaviour is influenced by the

availability and nearness of the facility. In this context, the proximity and availability of the bins is monitored by RFID tagging which has helped in minimising litter. Hence, appropriate smart waste infrastructure that can provide solution to local problems are gaining importance in developing countries as they can help in operational efficiency and improving socio-environmental sustainability.

The other factor for smart environment in waste free cities framework is the environmental protection where city 2 is performing better than the cities 1 and 3. The differences between the cities are due to the level of environmental monitoring, reducing the environmental burdens and increasing the environmental savings. The environmental monitoring through regular waste audits and environmental impact assessment are performed in both cities 1 and 2, but there is higher degree of compliance in city 2 than in city 1. In city 3, except for the studies of waste composition and quantity, there is no evidence of waste audits. Hence, city 3 performs lowest in this category. These results are in line to Zaman (2014), which shows monitoring and auditing of waste processes and their compliance are important for maintaining environmental sustainability. Similarly, from the *Swachh Survekshan* results (Swachh Survekshan, 2016), it is evident that assessment and monitoring procedures can help in improving waste management activities by both citizens and local authorities and towards a smart transformation.

In addition to monitoring, increasing environmental savings and minimising environmental burdens are important for a smart environment as they prevent further resource exploitation and pollution. Through recycling, the energy saved in city 2 is 5115.776 MW-h/year as shown in table 6.1. This is 0.06% of the annual energy demand of not just the city but the entire state it belongs to (74,081,000 MWh/year demand, GoI and GoTS, 2017). Therefore, increasing recycling results in reducing the energy demand for material production and the associated resource or virgin material consumption. Potential substitution of virgin materials due to recycling and composting is higher in city 1 than cities 2 and 3 though recycling rate in city 2 is the highest. Similarly, though the reduction in CO_2 emission in all the cities is in same measurement range in the waste free cities framework, the reduced CO_2 emissions is higher in city 1 by 300-400 CO_2e/year. These differences in environmental savings could be attributed to the differences in the composition of recyclable waste. It is observed that the paper and compost are highest in city 1 though total waste recycled is lower which contributed to higher environmental savings. These results seem to be consistent with the work of Zaman and Lehmann (2013), where virgin

material substitution and CO_2 emission reduction were higher in cities with higher paper and compost in recycling. In addition, the other form of environmental savings that is observed to be high in city 2 is the avoided landfill space. Due to recycling, city 2 saves approximately 2 acres of land/ year where the current landfill site in use in city is only 36 acres. Hence, the current recycling practices are saving approximately 5% of the area annually and increasing the life of the landfill. The findings of the study are not only consistent with Zaman and Lehmann (2013), but also with Contreras *et al.,* (2008) where greenhouse gas emissions and landfill savings are considered to be important environmental savings in research conducted in Boston.

Table 6.1: Environmental savings due to dry waste recycling in the three cities (Source: Author, calculated using primary data collected)

Environmental savings	City 1	City 2	City 3
CO_2e/year	1697.25	1328.20	1305.79
Energy savings (MW-h/year)	1915.622	5115.776	4669.23
Potential virgin material substitution (Tonnes/year)	2360.91	1522.18	1528.42
Saved landfill space (Acres/year)	1.66	2.12	2.0

The environmental burdens in most developing countries are caused due to open dumping and illegal burning of waste which could be caused due to an opposition for waste collection user charges (Aphale, *et al.,* 2015). Though city 2 appears to perform better than cities 1 and 3, there still seems to be a significant burden on environment as practices like open dumping and burning of waste are still widely prevalent even in city 2. Since, user fee collection is absent in city 2, the reasons behind such practices remain unclear. This could be monitored through effective fining system which was successful in lowering the open dumping and burning of waste in Netherlands according to the study of Linderholf *et al.,* (2001).

The other important factor in smart city and for sustainability is the sustainable resource utilisation. In waste free cities, this is identified as efficient utilisation of waste as a resource. Though there is no significant difference between the cities is observed in figure 6.4, city 2 has higher recycling rates than the other two cities as the recycling rates in cities

1, 2 and 3 are 1%, 4% and 3.7% respectively (according to primary data collection and DPR 2016 a, b and c). Higher recycling rates not only indicate resource reutilisation, but also environmental health (Giovanis, 2015). The common activities in all three cities seem to rely on an informal sector that is actively contributing to the city's recycling rates. The driver for higher recycling rates in city 2 is due to the presence of a PPP that increases the capacity of recycling and the separate collection of waste is carried out where two categories of segregated waste is collected (as discussed in smart mobility section). According to the interviews conducted in city 2, a monetary gain is offered to the citizens for appropriate source segregation. This finding is in line to the findings of Dahlen *et al.,* (2007) and Joseph (2006) that source segregation is affected by economic incentives. Since the number of categories for source segregation are two, it does not complicate the separation process for households. In addition, the local authorities have distributed two colour coded bins per household for free to improve source separation. This could also be considered as a driver for source separation as these results are in lines to the explanation of Zaman (2014), that number of bins per households, their ease and number of segregation categories affect recycling. City 3 has highest occurrences of exchange or sale of waste to waste buyers despite its low population among the three cities. Waste to energy is one of the ways to convert waste to resource, but it is still under planning and construction stages in all the three cities except for small scale bio-methanation plant which is in operation in city 2.

c) Smart Living

Smart living is a category which relates to the living conditions of people and includes access to public services, wellbeing and education facilities (Giffinger *et al.,* 2007). In the context of waste free cities, smart living is measured using the facility for waste services and education that is required to improve awareness and interest in waste management. It also includes healthy living and working conditions the city offers to its citizens and waste workers. The performances of the three cities can be seen in figure 6.5. City 2 performs higher to cities 1 and 3 in providing education facilities and healthy living conditions but city 1 performs better in providing waste service facility. Though percentage of households covered with waste service facility is similar in all the three cities, the door to door collection service offered in city 1 and 3 are around 70% while it is 60% in city 2. This shows a significant difference in the level of service provided to the citizens.

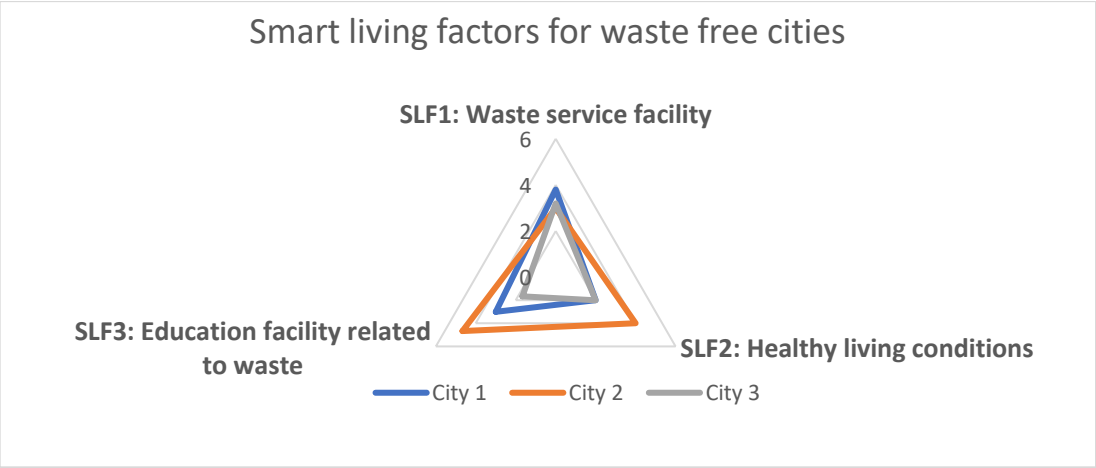


Figure 6.5: Radar diagram showing results for smart living in waste free cities (Source: Author)

In addition, it is also reflected in the responses given by citizens in the surveys. Public satisfaction levels for service provision was high in cities 1 (66.7%) and 3 (60.26%) as shown in figure 6.6. Though city 2 has a different operating model where higher level of stakeholders' involvement is present, the level of public satisfaction was relatively low. It could be related to the extent of door to door collection service provision which is not as high as the other two cities. The visibility of service to the citizens is low resulting in lower satisfaction. This is also true according to the indicators given by Zaman (2014) where public satisfaction could be a result of area covered by waste collection service. Moreover, satisfaction with the level of interaction between local authorities and citizens is significantly high in city 1 (79%) when compared to cities 2 (22%) and 3 (43%) as shown in figure 6.6. The findings are consistent with the study of Armijo *et al.*, (2011) in Mexico where a relation between the waste collection service provided and communication with citizens have an effect on their satisfaction levels.

Though there are a greater number of campaigns and awareness programmes organised in city 2, the key difference between the cities is the mode of interaction between local authorities and citizens. Though both the cities offer e-governance, the level of interaction through internet and particularly social media is higher in city 1. From the citizen surveys conducted, 31%, 33% and 49% of the citizens in cities 1, 2 and 3 respectively have chosen social media as the preferred channel for interaction with local authorities (figure 6.7). 59% of the citizens in city 1 have reported using social media to interact with local authority, while the majority in city 2 (53%) reported that they never or rarely use social media. In city 3, 33% of citizens reported to use social media but sometimes. This shows

that the citizens opinion on the satisfaction for level of interaction is affected by meeting them through their preferred channels which is social media in all the three cities. So, this could be considered as an important reason for low performance in waste service facility in city 2.

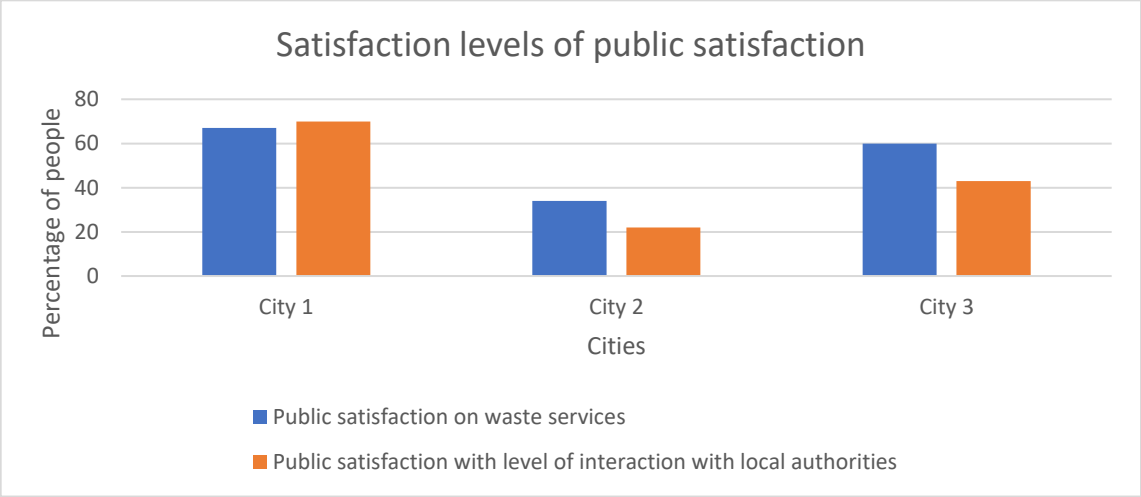


Figure 6.6: Graph showing percentage of people and their satisfaction on waste services and interaction with local authorities in three cities (Source: Author)

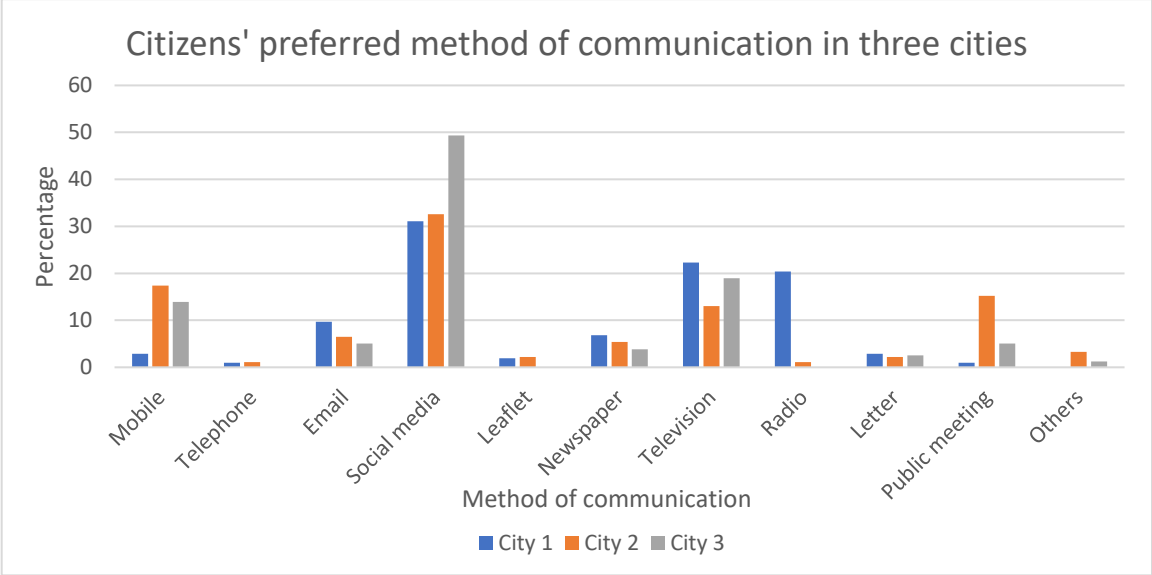


Figure 6.7: Graphs showing percentage of people and their preferred methods of communication in three cities (Source: Author)

In providing education facilities related to waste, city 2 is performing better and city 3 shows lowest level of performance. The reasons could be due to the community

programmes conducted to educate citizens on source segregation and recycling. A different approach of educating citizens is adopted in city 2, where trained staff or volunteers from the PPP go door to door to educate the citizens through face to face interaction and marking the house with stickers to indicate they are aware and expected to participate better in source separation, etc. The social interaction and awareness programmes where the households are indicated with stickers, creates social pressure to recycle. According to Aphale *et al.,* (2015) such interactions and pressures help in improving the citizen participation and recycling rates. The same is observed in city 2. In cities 1 and 3, the most common ways of educating citizens are through trained CBOs which could have resulted in their lower performances.

Additionally, city 2 offered a 7-day challenge called Clean Cities Championship to improve the city's waste management activities. The championship promoted a competitive sport through waste management by integrating several actors such as state and local authorities, private organisations, school students and communities. This resulted in active participation of citizens in source segregation and workers through improved collection efficiency. As a result of the championship, the participating communities together with local authorities reduced 30%-40% of the waste sent to the final disposal (Patel, 2012). Furthermore, in city 2 there are numerous educational workshops conducted in schools to emphasise on waste reduction, reuse and source segregation. According to the study of Grazhdani (2016), with an increase in education by 1% on waste management can result in reduction of annual per capita waste generation by 3kgs and increases the recycling rates. A similar trend in reduction of waste is seen through the programme conducted in city 2. Moreover, according to Joseph (2006) and Srivastava *et al.,* (2005) integrating CBOs, NGOs, local authorities, citizens and particularly students is a strengthening activity for stakeholder collaboration which is also seen to be true in city 2. There are works by Starr and Nicolson (2015) in Massachusetts and Yuan-Young *et al.,* (2010) in Taiwan where there is a positive relationship between recycling and awareness. The same is observed in city 2. The authors emphasise the importance of educating school children for achieving better recycling rates. Though there are few awareness programmes conducted in cities 1 and 3, it is not adopted completely in any of the three cities.

Staff training is an important aspect in managing waste. It is also identified important under the *Swachh Bharat* Mission and is therefore, one of the criteria for *Swachh Survekshan* (Swachh Survekshan, 2017). Though there is training provided to staff in all

the three cities, in city 2 there is additional training carried out by the volunteers and PPP through a more structure step by step process. So, the staff in city 2 are well trained than the staff in cities 1 and 3 as they are also required to identify the recyclable property of dry waste before collection. Due to this higher and more specialised training offered in city 2, it performed better than cities 1 and 3 in providing waste related education facilities.

Healthy living conditions are essential for both staff and citizens. Provision of personal protection equipment is provided in all three cities. However, city 2 appears to have a better performance as it provides similar equipment not only to the formal workers but also to the identified informal waste pickers who are employed for dry waste segregation by PPP (according to the interviews). This is absent in cities 1 and 3. In the context of waste free cities, healthy living of citizens can be studied by observing the reduction in diseases caused due to waste or its exposure. This is also considered important in the zero waste studies conducted by Zaman (2014). Due to lack of availability of time-series data on such diseases it was not included in this study. It can be suggested that health and safety of the waste workers and citizens are important for healthy living. Such lack of information is not limited to the three cities, but most Indian cities and is considered as a weakness in the waste management system by Srivastava *et al.*, (2015).

d) Smart People

Smart people are category in smart cities as people are important in smart transformation and improving waste management. In the context of waste free cities, aware and adaptable people and their willingness to use technology are considered to measure their performance. The overall performance for smart people is higher in city 1 as shown in figure 6.8. Waste generation is affected by various factors. One of them is interest and awareness of people which helps in following the appropriate waste management practices and in waste reduction as mentioned in section 3.5.2 of chapter 3.

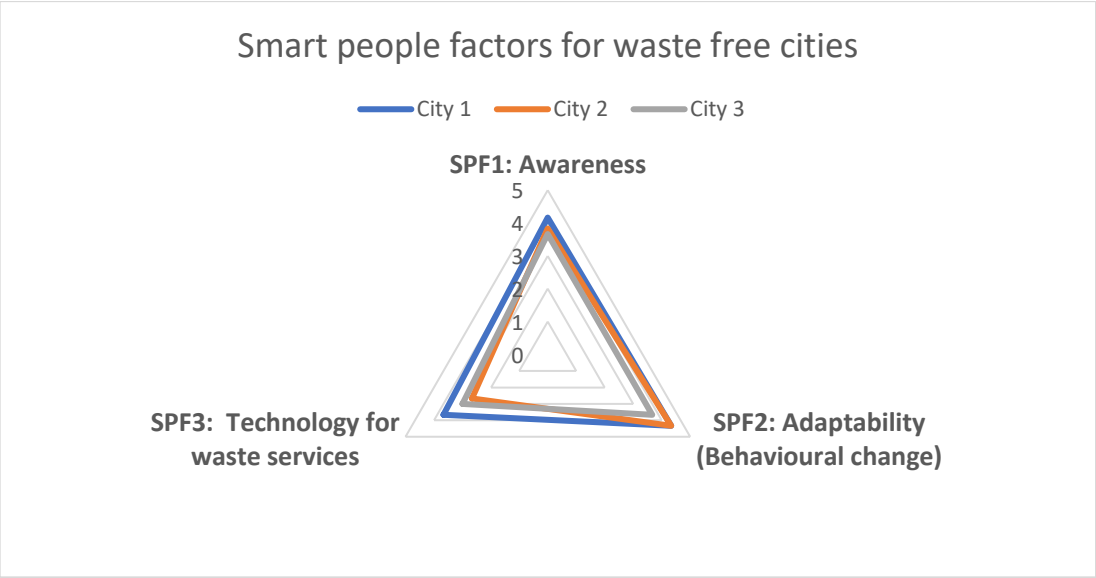


Figure 6.8: Radar diagram showing results for smart people in waste free cities (Source: Author)

City 2 has the lowest per capita waste generation among the three cities which is 0.25 kg/capita/day (DPR, 2016b) and the cities 1 and 3 produce 0.45kg/capita/day (DPR, 2016a) and 0.42 kg/capita/day (Aruna *et al.,* 2013). The population growth is expected to have a direct effect on the waste generation. Among the three cities, city 2 has the highest population growth rate per decade as shown in chapter 5, but it has lowest per capita waste generation. This could be attributed to the level of awareness brought among citizens due to the various campaigns. Moreover, since source segregation is incentivised in city 2 depending on quality of products and segregation, it could also lead to behaviour change resulting in lower waste generation. According to the citizen surveys as shown in figure 6.9, 84% in city 1 and 78% in city 2 have reported that they are aware of the environmental benefits of source segregation of waste. Similarly, citizens in all the three cities showed interest in waste management activities with 80%, 89% and 78% in cities 1, 2 and 3 respectively. The results also show a relation between the awareness and interest of the citizens and therefore can affect their participation. A similar finding is reported by Caniato *et al.*, (2015) where stakeholders with knowledge on effective waste management and its benefits were found to have a positive attitude towards their participation. Hence, in practice environmental awareness and interest can be considered as important factor for promoting citizen participation. In addition, city 2 provides economic incentives for appropriate source segregation. It is observed in the findings of Yuan-Young *et al.,* (2010), Dahlen *et al.,* (2007) and Joseph (2006), that rewarding or economic incentives for source segregation were proved to have a positive impact on the citizen participation and

recycling rates. So, coupled with awareness, economic incentives for appropriate source segregation can be considered as contributing factors for lower per capita waste generation and higher interest in recycling in city 2.

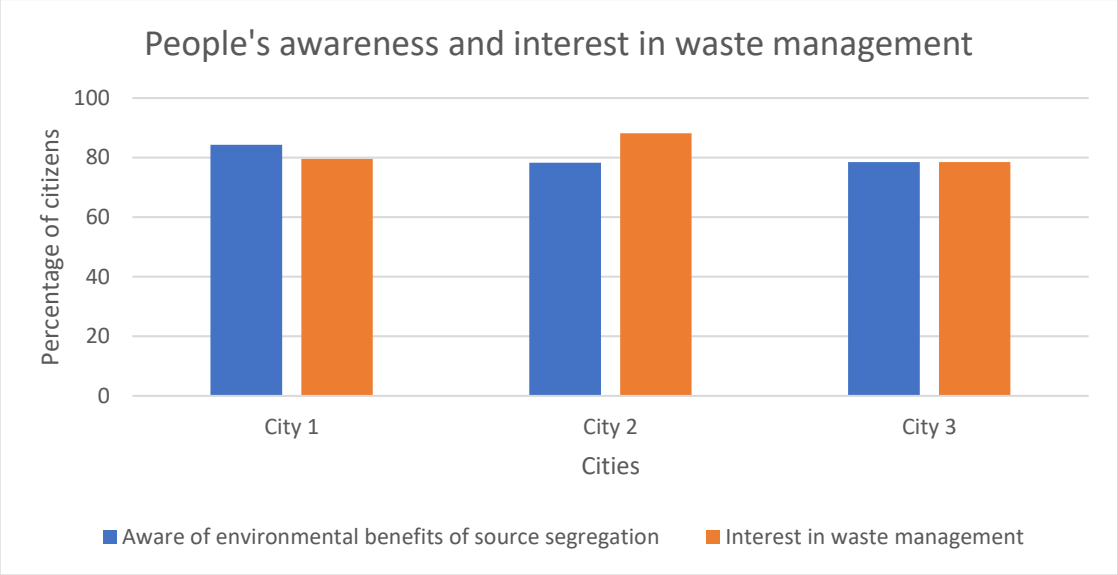


Figure 6.9: Graphs showing percentage of citizen's awareness and interest in waste management in three cities (Source: Author)

Adaptability of people to change is an indicator for smart people category. The adaptability of citizens is greater in cities 1 and 2 than in city 3. Main reason for this difference is the people's willingness to change behaviour. Waste minimisation and source segregation are behavioural issues and can be brought through people's willingness to change their habits or adapt to changes. According to the surveys conducted, most citizens are willing to change behaviours and consumption patterns to minimise waste. It is highest in city 2 with 89% and in cities 1 and 3 with 75% and 81% respectively (as shown in figure 6.10). This indicates that both cities 2 and 3 have a better performance than city 1 in citizens' adaptability which is essential for a smart transformation. It also indicates that awareness campaigns and activities can not only help in educating citizens but also promote interest which can lead to their behavioural change. According to Srivastava *et al*., (2015), lack of willingness in citizens to change or participate is a weakness for waste management system. The survey results of all the three cities show citizens' willingness to change and this can be seen as an opportunity for their better performance in managing waste.

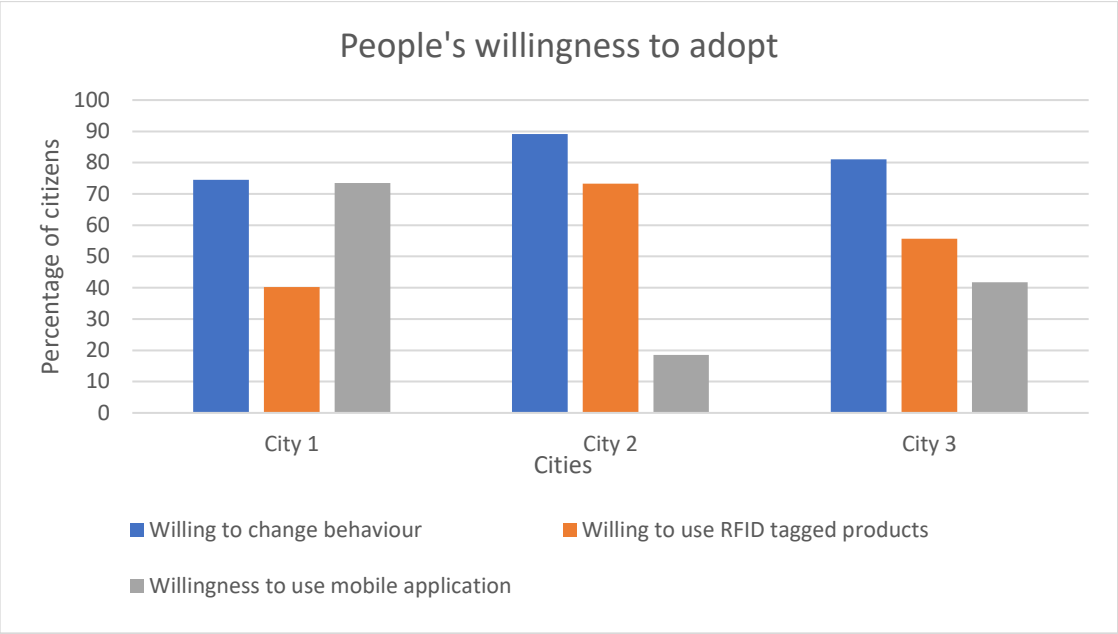


Figure 6.10: Graphs showing percentage of citizen's willingness to change behaviour, use RFID tagged products and mobile application for communicating on waste issues in three cities (Source: Author)

The people's role in smart transformation is not only in changing their waste generating behaviour, but also their willingness to use technology for enhancing waste services. As shown in figure 6.10, willingness of people is observed to be highest in city 1 followed by city 3 and then by city 2. This is due to their level of acceptance to use internet and mobile applications to communicate their waste problems. 68% of the citizens in city 1 are willing to use internet to discuss environment related issues and 74% of them are active users of mobile application to communicate their waste problems with local authorities. Citizens of cities 2 and 3 do not seem to be willing to adopt such ICT based communication due to the majority of the surveyed were not in favour of such technological adaptation. This transformation is essential as e-governance is gaining importance and seems to be successful in most parts of the world. Similar initiatives are being implemented in the UK to communicate through mobile applications to improve communication between local authorities and citizens for waste management issues (DBIS, 2013). As previously discussed, citizens of both cities 2 and 3 indicate social media and mobile phones as their preferences for communication with local authorities (figure 6.7) but, their willingness to use mobile applications is low. According to *Swachh Survekshan* results in 2017 (Swachh Survekshan, 2017), cities 1 and 3 received 78% and 66% for the citizens feedback and use of mobile application. These results are consistent with the citizens surveys conducted in both cities. But there is a significant difference in the findings of city 2 which could be

advocated to the methodological differences or due to the strong public dissatisfaction in using the mobile applications to report waste related issues. Citizens of city 2 show less willingness to adopt to such technology-based communication but they show the highest willingness of 73% to use RFID tagged products that can improve source segregation. Cities 1 and 3 also show their willingness with 40% and 56% respectively. This indicates the importance given to source segregation by citizens of city 2, which could be the impact of awareness campaigns and incentives provided for source segregation. The overall performance of the city 1 in smart people category is higher than cities 2 and 3. Though this shows a positive trend towards a smart transformation in city 1, the success of such initiatives remains uncertain due to the contrasting results of cities 2 and 3.

e) Smart Economy

Smart economy is important for smart cities where productivity, entrepreneurship and employment generation in city contribute to it. In the context of waste free cities, these are measured using the waste service sector and waste managing activities. The performances of all the three cities for smart economy in waste free cities is shown in figure 6.11. Among the three cities, city 2 performs higher while there are no significant differences in the performances of cities 1 and 3.

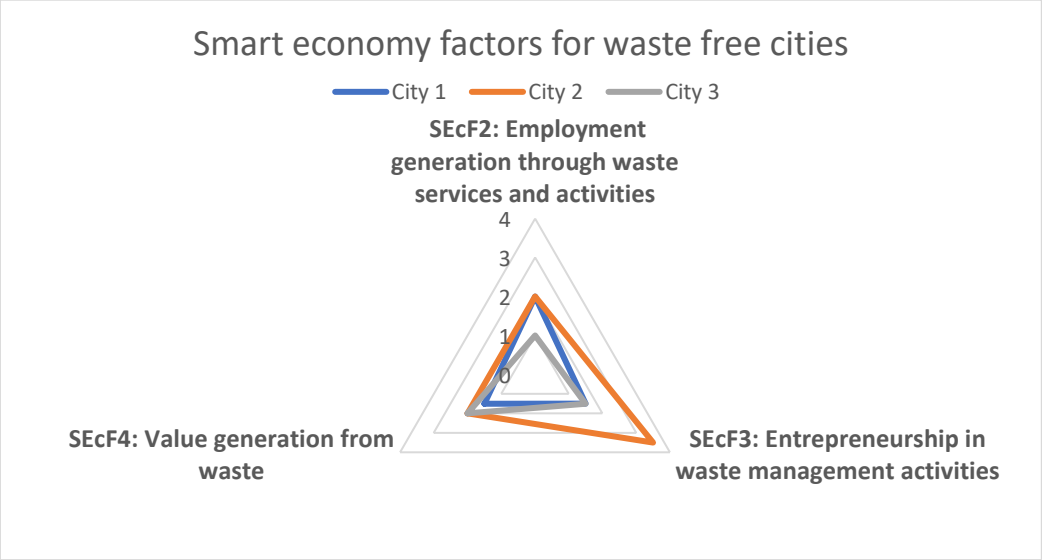


Figure 6.11: Radar diagram showing results for smart economy in waste free cities (Source: Author)

The notable aspect for city 2's performance is due to high entrepreneurial opportunities in waste managing sector. The existence of SMEs in city 2 is higher than the other two cities which could be attributed to two reasons. One reason being support extended by government and private organisations to form PPP (the PPP's business model resulted in the formation of several small enterprises with required training and funding) as explained in chapter 5 and the second reason is to integrate waste pickers, formal waste collectors, trained staff and factories or manufacturing units (this ensured appropriately skilled workers are performing their roles in PPP). By integrating factories or manufacturing units which are large scale buyers of recyclable waste, regular contracts and forecasts of the required recyclables were achieved. In addition, this ensured shortened supply chains for waste trade by bypassing the suppliers who according to Agarwal *et al.,* (2005) are generally the large-scale waste traders or stockists and obtain maximum profit for the trade. According to the interview with PPP in city 2, this increased the profits to small enterprises. The informal sector is more organised in city 2 due to PPP. The informal sector is employed by PPP to perform dry waste segregation according to required quality grades. In cities 1 and 3, due to the absence of PPP, no such employment generation to informal sector is present. Cities 1, 2 and 3 employ approximately 0.42%, 0.35% and 0.26% of the population in formal waste management services (Calculated using primary data collected and DPR 2016a, b and c). Both the cities 1 and 2 offer high employment through formal waste collection and transportation services than city 3. Forming SMEs, employing informal sectors and generating employment to workforce is an opportunity for economic growth, building recycling rates and recovering value from waste (Wilson *et al.,* 2009; Srivastava *et al.,* 2005). This is also proved to be successful in cases of Cairo and Brazil as mentioned in Wilson *et al.,* (2007). Similarly, city 2 has also proved to be successful in the formation of PPP and employment generation, thus adding to the smart economy through waste services besides helping towards the social uplifting of informal sector.

Transforming waste to resource is not only a benefit to the environment, but also a value generating activity to efficient waste managers. The value generated by waste is calculated as revenue to the formal and informal waste managing sectors. However, in all the three cities under study, there is no significant value generated by the formal sectors. The waste to energy plants are under planning and implementation status and small-scale composting and bio-methanation are in practice while there are no formal dry recycling activities. The

key players in all the three cities is the informal waste sector and private waste traders. The revenue generated through waste valorisation is higher in city 2 due to the revenue contributed by the PPP. Therefore, city 2 performs better and contributes towards a smart economy through waste managing activities mainly due to the existence of PPP and a relatively better organised informal sector than the other cities. There are studies on the value adding activities performed by UN-Habitat (2010), Rathi (2006) and Wilson *et al.,* (2006) that show the PPP have been more successful in value addition when compared to the formal sectors. Similar findings are seen in comparing the three cities as city 2 is more capable of adding value to waste due to presence of the PPP. This highlights on the role of PPP in income and employment generation in addition to waste reduction.

f) Smart Governance

Good governance is important for building a smart city as well as to manage waste effectively. It constitutes stakeholder collaboration, their inclusion in policy design, monitoring and innovative governing models. In the context of waste free cities, smart governance is also considered as an important factor and the performances of the three cities are studied. City 2 shows a better performance for smart governance than cities 1 and 3 as shown in figure 6.12.

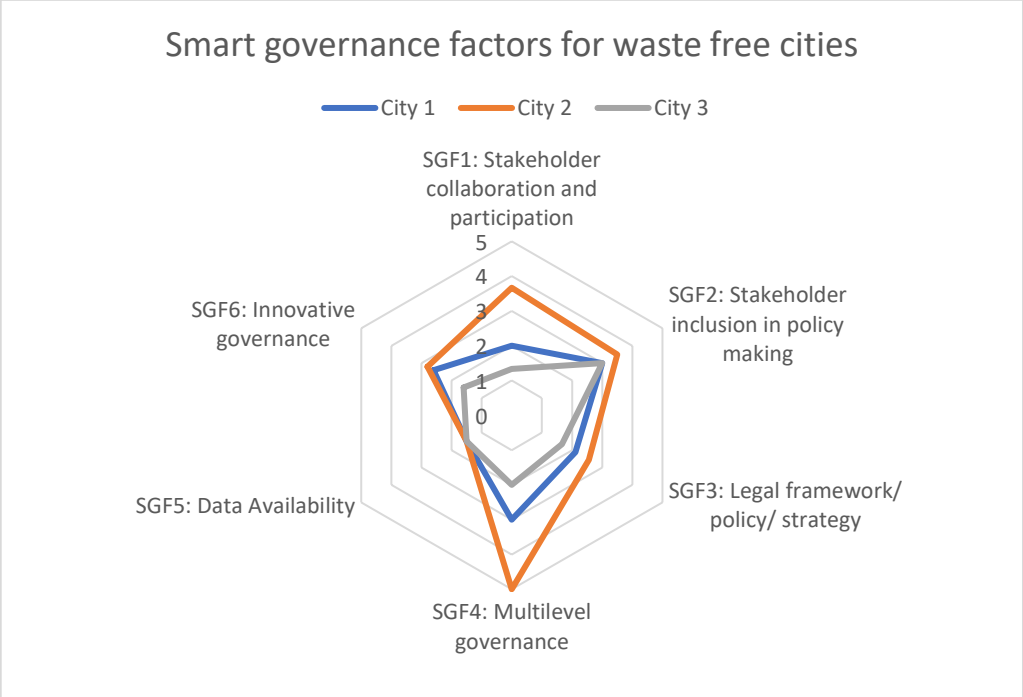


Figure 6.12: Radar diagram showing results for smart governance in waste free smart cities (Source: Author)

The difference in performances of the three cities is mainly due to stakeholder collaboration. In city 2, there is presence of PPP which made a significant difference to its overall governance. The PPP model integrated government, private organisations, NGOs, CBOs, SMEs, informal waste sector and factories or manufacturing units (as mentioned in chapter 5 and earlier sections of this chapter). This also contributed to active participation of citizens thereby, integrating all the key stakeholders. There is no formal collaboration of private organisation in cities 1 and 3. Yet, city 1 has made informal collaborations with NGOs and private sector for waste collection and this is confined to only one specific area for trail purpose and was unsuccessful as the private sector did not earn profit from this activity and was economically not viable (according to interviews with local authority in city 1). Comparing cities 1 and 2, the collaborations with private sectors and their success are influenced by several factors. City 2 has a greater level of collaboration as more stakeholder groups are involved. Moreover, the collaboration existed throughout the life of waste starting from its generation to recycling or disposal. Since city 1 restricted private sector to collection phase, it was not successful like city 2 as further revenue generating models from the collected waste were lacking. Furthermore, NGOs and CBOs are active in both cities 1 and 2 and the role they play in city 2 is notable. City 1 involved CBOs for awareness programmes and NGOs in waste processes such as sorting and composting. Though their role is important and 51% of the surveyed citizens in city 1 reported as being aware of NGOs and CBOs activities, it did not show its effect on citizen's participation through waste segregation or recycling activities. In city 2, they are specially trained and are used exclusively for awareness campaigns while sorting of collected waste is performed by employing waste pickers.

The citizen participation in city 2 is higher than cities 1 and 3 but needs improvement as the recycling rates are still low when compared to the city's potential to recycle. The other notable reason for effective stakeholder collaboration in city 2 is the local authorities' support for capacity building. This was brought by providing infrastructure and incentives for the operations of PPP and informal sector. Such capacity building support from local authorities is absent in cities 1 and 3. Though all the three cities have reported to make efforts to formalise informal sector, the informal sector is not fully identified or formalised in any of the three cities. In comparison to cities 1 and 3, city 2 has identified and generated employment to informal sectors through PPP. So, an effective stakeholder collaboration involving various actors with support from local authorities has played an

important role in city 2's performance. These findings are in agreement with the works of several authors (Wilson *et al.*, 2015a; UN-Habitat, 2010; Yuan-Young *et al.*, 2010 and Contreras *et al.*, 2008). According to Wilson *et al.*, (2015a) identification and involvement of stakeholders' is an important governing aspect and proved to be successful in achieving higher performance in various cities in different parts of the world. Similarly, UN-Habitat (2010) has indicated the role of PPP in Bangladesh which helped in creating employment and reducing the carbon footprints. Their PPP model is similar to the PPP in city 2 as the government has provided the infrastructure and operations are managed by the private sector. This also helped in capacity building for the small enterprises that are a part of the PPP with low capital-intensive approaches. According to Yuan-Young *et al.*, (2010) and Contreras *et al.*, (2008), such economic incentives and support of government had a positive effect on the recycling rates in Taiwan and Massachusetts respectively. These experiences and findings are proved to be in-line to findings of city 2 and the results of the support extended by the government through PPP can be seen as improved recycling rates, employment generation and small enterprise development.

In addition to stakeholder collaboration, their inclusion in policy making is important for bottom up approach of governance. Among the surveyed citizens, 72%, 83% and 88% in cities 1, 2 and 3 respectively felt it is important to involve them in the policy design. According to the interviews with local authorities, cities 1 and 2 reported to involve stakeholders by taking their feedback on current services, but the level of such consultation and type of inclusion is unclear. According to Contreras *et al.*, (2008), stakeholders' role has been transformed over time and they are not mere recipients and are contributors for policy design. The author also stated that conducting surveys and collecting opinions is only a form of information gathering and should not be regarded as a way of stakeholder inclusion in policy design. The same is observed to happen in cities 1 and 2 and therefore, according to Contreras's the stakeholder inclusion is absent as it only appears to be information gathering as the form of their involvement in policy design is not clear. Due to the varied roles played by each stakeholder group, their involvement in policy design for waste management is important to improve governance structure as it affects social and environmental aspects (Caniato *et al.*, 2015; Joseph, 2006). Hence, all the three cities need to consider inclusion of stakeholders in policy design with more formal approaches.

Presence of clear legal framework with well-defined roles and timeline is important for achieving policy implementation. Such frameworks are present in all the three cities, but

there is better compliance with legal frameworks in city 2 when compared to cities 1 and 3. It was also reported in the interviews that required resources and infrastructure are provided to the local authorities for effective policy implementation in city 2. A clear organisational structure for resource utilisation and policy implementation is greater in city 2 and therefore, a multilevel governance structure is followed. This is also evident from the compliance with regulation to organise informal sector as it is higher in city 2. City 1 has higher compliance with regulation of user fee. Though it is not fully implemented in city 1, it has been tested by collecting user fees for waste collection services in few areas. From the previous studies effective monitoring of policies enforcement through fines system are proved to be successful in Netherlands (Linderholf *et al.,* 2001). Similar findings were suggested by Yuan-Young *et al.,* (2010) where source segregation when made mandatory had a positive impact on recycling rates in Taiwan. City 1 showed a better performance in collecting user fees for waste collection. The collection of such user fee is seen to be successful in decreasing waste generation and increasing source segregation which contributed to recycling rates (Starr and Nicolson, 2015; Linderholf *et al.,* 2001). Therefore, careful pricing for user fees according to the local needs and its enforcement can encourage the participation of private sector for waste collection in city 1 as it can improve economic viability for the business. It can be observed that all the three cities suffer with ineffective policy enforcement which can be improved by close monitoring.

Further to this, another notable problem identified in all the three cities is the data unavailability. There is absence of a database to access waste related data. Moreover, there is lack of time series data for waste generation, recycling and disposal in all the three cities and such data availability and its access to public are important for smart governance. Nevertheless, on a comparative note, city 2 shows an overall higher performance towards smart governance in waste free cities.

6.2.2.2 Sustainability dimensions

The sustainability performance for all the three cities are measured using waste free cities framework as it has significant role in achieving sustainability. Six sustainability dimensions are used as explained in chapter 3. Figure 6.13 provides the details on sustainability dimensions and each city's performance. City 2 shows highest performance in all the six sustainability dimensions compared to cities 1 and 3 which do not show a significant difference in their performances between them. Particularly in the economic-environmental dimension, the performance of city 2 is remarkably high than cities 1 and 3

which are performing in a similar fashion. The reasons behind this can be attributed to the stakeholder collaborations and efforts to incentive recycling performed in city 2. Due to the collaborations with private sector to improve the waste services and providing incentives to them, it helps in economic gain and environmental protection contributing towards economic and environmental dimension of sustainability.

Figure 6.13: Radar diagram showing results for sustainability dimensions for waste free cities for three case studies (Source: Author)

There is higher performance of city 2 towards the economic dimension. This is due to the government's support in providing required resources for improving waste management and revenue generation through recycling by the informal sector. In all the three cities, there is absence of formal recycling of waste. Hence, there is no significant contribution of the formal sector towards economic sustainability as it does not generate revenue through resource recovery. In the socio-economic dimension, governing factors such as efforts to support informal sectors for capacity building, entrepreneurial growth through waste managing activities and a relatively more organised informal sectors have improved the social conditions of living. This helps in providing a dignity and creating better sources of income and thereby in improvement of economic conditions. These can be seen as the evident reasons for the better performance of city 2.

In the socio-environmental dimension, though the performance of city 2 is higher, cities 1 and 3 are observed to perform better than in other dimensions. The performances of cities 1 and 2 could be attributed to the active roles taken by NGOs and CBOs, presence of e-governance for waste services, digital campaigns to promote awareness and RFID tagging of bins. However, city 2 performs higher to city 1 due to the level of awareness campaigns, citizen participation in source segregation of waste, trial of underground vacuum bins and less environmental burdening activities. These activities constitute an interface between social behaviour and environmental protection and result in higher performance of city 2 in socio-environmental dimension. Similarly, city 2 shows a higher performance in environmental dimension. The indicative reasons are the energy savings and avoided landfill space due to waste recycling and regular environmental auditing with relatively higher compliance that are seen in city 2. The other important contributor towards the environmental sustainability is the use of non-motorised vehicles for waste collection that are prominent in all the three cities.

The performance of city 2 is high in the social dimension of sustainability. The contributing actors are mainly governance and people. The clear institutional factors, communication methods, awareness, educational and training, health and safety of waste workers are seen to be higher with better enforcement in city 2 than in cities 1 and 3. Informal sector, particularly the rag pickers (waste pickers) are deprived of social status and suffer from lack of dignity for the work they do. They do not usually receive any form of support from the government. In city 2, there are efforts to support them by providing daily contract work for the same work they do. Therefore, significant efforts are made to organise them, and opportunities are provided to help them in capacity building that could bring more profits. In city 1, though there are efforts to identify the informal sector, they are not formed into organisations or supported by the government. The only step taken was to issue identity cards to the identified waste pickers and no further steps to help them are seen. This negatively affects the social dimension of sustainability. The same scenario is seen in city 3, where only 100 waste pickers are identified and issued identity cards when their estimated population in the city is in the ‘000s. Furthermore, city 2 incorporates innovative means to communicate with the citizens such as face to face interaction, social media and mobile applications. Various strategies have been designed to ensure both technologically equipped and unequipped people are communicated. Moreover, city 2, has a better institutional structure and targets with a defined timeline and monitoring which

improves the performance. All these steps are being taken in city 1, but city 3 is lacking in most as it has not started them or in the initial stages of planning and implementation. Due to a better organisation of informal sector when compared to cities 1 and 3, it resulted in higher performance of city 2 due to its impact on social sustainability.

All the factors studied for improving waste management or for transformation into smart cities, have an impact on achieving sustainability of the cities. The main contributors towards the sustainability of city 2 are the governing aspects, peoples' participation, organisation of informal sectors, collaborations with private sectors which eventually helped in higher enterprises development, employment generation, recycling rates, value recovery and environmental savings. Although these contribute to different sustainability dimensions, the main reason behind these are the stakeholders' collaboration. The second part of results and discussions (section 6.3) focuses on the details of the collaborations between the stakeholders and the associated value chain for waste.

6.3 Stakeholder interaction and its impact on valorisation of waste

Waste has a proven potential to become a resource. As mentioned in chapters 1 and 2, it is gaining more importance due to the development of circular economy and sustainable development initiatives. During this process, the role of stakeholders has transformed, and more emphasis is given to their interactions and collaborative working. Similarly, in the results for the application of waste free cities framework (section 6.2), it is clear that stakeholder contribution has a significant effect on the overall performance of waste management and has a role in social, environmental and economic sustainability. The same is seen in sustainable waste management as stakeholder collaboration affects the value chain of waste.

The value chain refers to all the activities required from the conception to final disposal of products or services (Kaplinsky and Morris, 2001). The value chain for waste includes its generation, processing, recovery, value addition and disposal. Moreover, resource recovery from waste can be seen as a reverse logistics issue (Bautista and Pereira, 2006) and several stakeholders affect its value chain. So, the waste value chains for cities may be different. Mapping the value chain for waste using flow charts will help in identifying the direction of material flow, the transformation process of waste to resource and the stakeholders involved in it. Value chain for household solid waste for all the three cities are mapped using standard procedures. Use of flow charts for mapping value chains are used by

authors like Jaligot *et al.,* (2016) and Scheinberg *et al.,* (2010) to study informal sectors' recycling. This approach helps in identifying various steps, processes and stakeholders involved. This also helps in visualising and determining value adding activities performed by stakeholders during valorisation of waste. The stakeholder collaborations are suggested by several authors for value addition (Ezeah *et al.,* 2013; Scheinberg *et al.,* 2010; Wilson *et al.,* 2009; Rathi, 2006; Agarwal *et al.,* 2005). Due to the presence of a number of stakeholders with variation from city to city and different levels of collaborations between them, it is important to know how stakeholders should collaborate to maximise the value addition. So, the below section 6.3.1 maps waste value chains and explains the interactions between stakeholder groups by comparing the three case study cities and finds the importance and drivers for such interactions.

6.3.1 Results and discussions

6.3.1.1 Value chain for waste

Value chain for waste in case study cities 1, 2 and 3 are mapped using flow chart method by identifying the point of its generation, collection, transportation, processing and disposal. The value chains also indicate the activities of both the formal and informal waste collection services. In addition, the involvement of CBOs, NGOs, and public private entrepreneurs are also mapped. The value chain for waste in city 1 is shown in figure 6.14. The map shows both upstream and downstream activities along with the stakeholders involved. The upstream activity is the waste generation and collection which is performed by citizens, formal waste collection workers, rag pickers, itinerant waste buyers and waste retailers. There are activities like cleaning and manual sorting which are performed by the rag pickers and waste buyers according to the waste categories (such as paper, cardboard, books, soft plastic, hard plastic, glass and metals types). Further sorting and processing occur in the intermediate levels such as waste wholesalers. They employ people to sort the waste categories further into quality grades and colours, such as transparent, black and coloured and depending on the thickness. It is then processed either by shredding, bailing/compaction or chipping depending on the waste types. The waste then reaches the suppliers who are stockists and influence the market dynamics. They send the processed waste to downstream as secondary raw material for remanufacturing to factories or manufacturing units.

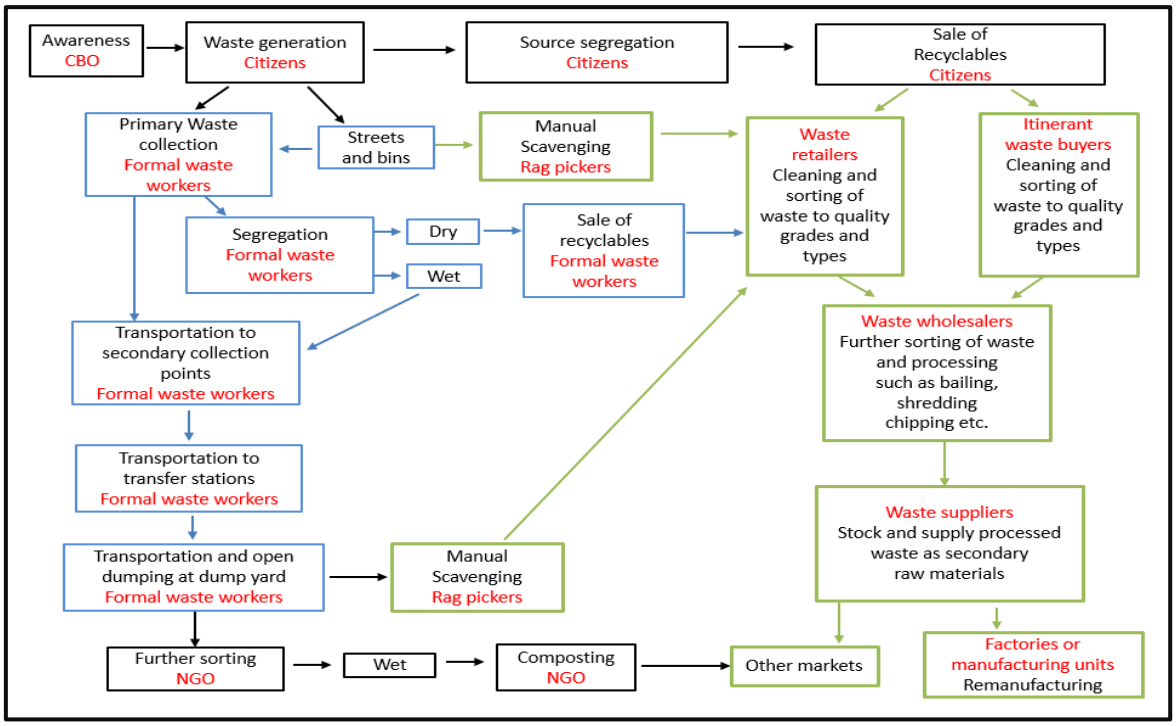


Figure 6.14: Waste value chain in city 1 (blue indicates flow of materials through formal sector; green indicates flow of materials through informal sector and registered waste traders; black indicates other routes; red indicates participating stakeholders) (Source: Author)

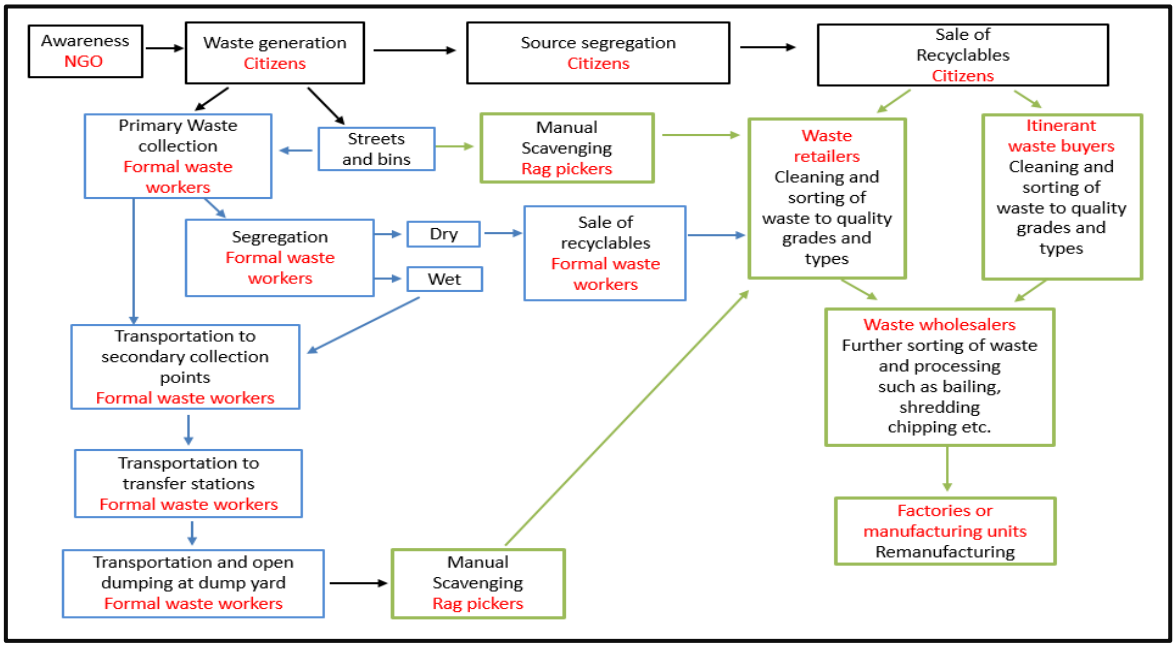


Figure 6.15: Waste value chain in city 3 (blue indicates flow of materials through formal sector; green indicates flow of materials through informal sector and registered waste traders; black indicates other routes; red indicates participating stakeholders) (Source: Author)

A similar flow of material and stakeholders is observed in city 3 as shown in figure 6.15. The key difference observed between the two is the role of CBOs and NGOs. In city 1, CBOs are involved in the awareness campaigns to promote citizen participation in source segregation and the NGOs are involved in sorting wet waste in the dumping yard to produce manure. However, the role of NGOs in city 3 is observed to conduct awareness programs to citizens. The value chain of waste in city 2 appears complex compared to cities 1 and 3. This is due to the presence of PPP along with formal and informal sectors resulting in greater number of stakeholders and interactions among them.

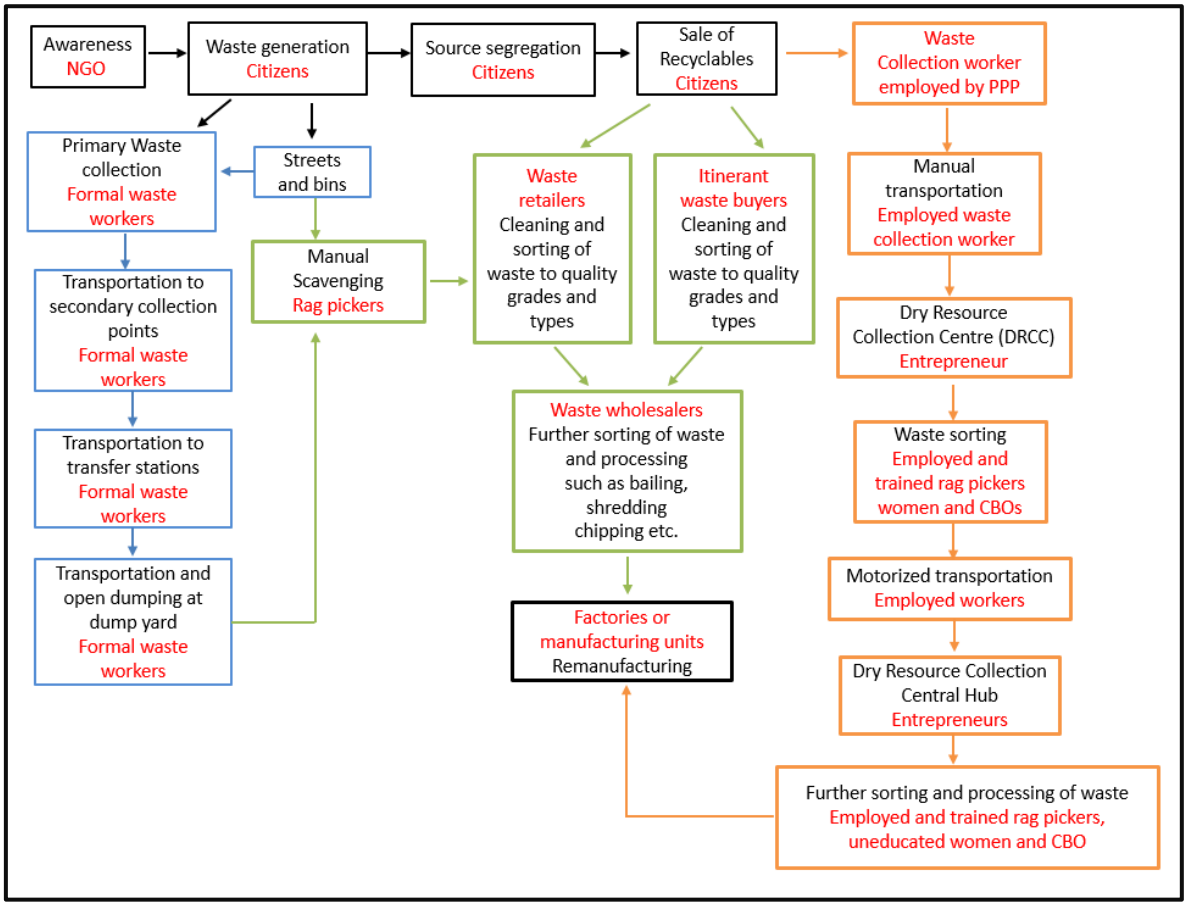


Figure 6.16: Waste value chain in city 2 (blue indicates flow of materials through formal sector; green indicates flow of materials through informal sector and registered waste traders; orange indicates flow of materials through PPP; black indicates other routes; red indicates participating stakeholders) (Source: Author)

As shown in figure 6.16, the upstream activities in waste value chain consist of waste generation and collection like in cities 1 and 3. In addition to waste collection by formal waste collection workers, rag pickers, itinerant waste buyers and waste retailers, a separate waste collection of dry recyclables is performed by waste workers employed by the PPP. Besides collection, the employed waste workers weigh the waste and pay citizens for

appropriately separated dry waste. The waste then reaches intermediate stage, where the waste wholesalers in the informal waste sector and the employed staff of the PPP clean and sort the waste further and process it according to the quality requirements. The waste in the PPP is then transported to a larger central hub from 18 different small Dry Recyclables Collection Centres (DRCC), where it is further processed and sent downstream for remanufacturing to factories or manufacturing units. The DRCC and central hub are run by small entrepreneurs who are supported by the PPP with infrastructure, space and training. They employ rag pickers, unemployed women and CBOs to sort and process the waste. The sorting and processing of waste is also performed by the waste wholesalers in the informal sector and are sent downstream to factories or manufacturing units.

6.3.1.2 Value adding activities and role of stakeholders

From the value chains mapped, the participating stakeholder and their activities are identified and are shown in the form of tables 6.2, 6.6 and 6.7. The participating stakeholder for each city, their activity, contribution for value addition and the average monetary gain obtained by each stakeholder group is indicated in each column of the table. Although value addition can be indicated in several ways such as social benefit, environmental protection, operational and economic benefits, it is indicated as the average income generated to the participating stakeholders following the methods of Zia *et al.,* (2008) and Agarwal *et al.,* (2005). The value addition is calculated in the monetary forms using the data collected through the interviews of stakeholders from the three cities and where possible, the other value-added benefits due to the process are indicated.

Table 6.2 shows the value addition to waste by different stakeholders in city 1. It can be observed that the monetary gain to stakeholder's ranges from £ 0.93 per kg to citizens and £3543 per month to wholesalers. Value added to the waste increases as the waste moves downstream and is also coupled with increase in waste volumes. Source segregation is observed in the city by citizens, but the segregated waste is sold to the informal waste buyers. The same source segregation is not observed when the waste is left for collection by the formal waste workers employed by the local authority (according to the interviews with local authorities). Source segregation is an important value adding step that should be performed by the waste generator (citizens) as the contamination of waste can be avoided, thus maximising the recovery of resources from waste and minimises the sorting costs (Aphale *et al.,* 2015). Although there are formal and informal waste collection routes, this

value adding step (source segregation) is only present when the waste is collected by the informal sector.

The formal waste workers sort the collected waste and sell the dry recyclables to the informal sector for personal benefit, but there is no data available on the quantity or monetary gain obtained. This leaves all the source segregated waste to reach only the informal sector in city 1. There are different levels observed in the informal sector which is similar to the informal waste hierarchy mentioned by Agarwal *et al.,* (2005). The lowest is the rag picker who performs a manual scavenging on streets, communal bins and dump yard to identify and collect the recyclables. The collected recyclables are cleaned and sold to the waste retailers. As the waste moves down stream, the waste retailers and itinerant waste buyers, manually sort the waste according to the categories such as paper, cardboard (according to the thickness) and plastics into types (such as coloured, black and transparent or their quality grades). The waste is then bought by waste wholesalers. It can be observed that the amount of waste traded is higher as the waste moves downstream. Similarly, the value and gain for the stakeholders in the downstream is higher. As the waste moves downstream it gets transformed to resource due to the value adding activities such as collection, sorting, processing and accumulation of waste (Scheinberg, 2011). Collection of waste adds value by maximising the amount of waste that can be transformed to resource. Similarly, cleaning and sorting of waste lead to separation of recyclables to the quality requirement of buyer, thus affecting its price for sale (Iskandar, 2003). Processing improves its quality and changes the physical form of waste and enables easy storage and transportation resulting in lower variable costs. Since such activities increase in the downstream, it adds more value to the waste. After the processing, waste is seen as a resource and competes with virgin raw materials for its price (Agarwal *et al.,* 2005). Interestingly, the value gained in much higher downstream but the difference between the cost price and selling price at every level is not very different. So, it is clear that the significant factor that contributes to the value addition is not the price of its trade, but the amount of waste traded and the collaborations or partnerships between the waste traders. In addition to the sorting and processing activities, Wilson *et al.,* (2006), Agarwal *et al.,* (2005) and Scheinberg *et al.,* (2010) also indicated that higher amount of waste trade would result in higher value addition as it increases the bargaining power for the waste trader. In city 1, it is also observed that the supplier who buys waste from wholesalers and stocks the processed waste has higher bargaining power.

Table 6.2: Value addition to waste by stakeholders in city 1 (Source: Field study conducted by Author)

Stakeholder group	Activity performed in waste value chain	Value addition	Average monetary gain
Citizens	• Source segregation • Sale of recyclables to informal sector	• Minimise waste contamination • Maximise collection potential	£0.93/kg of recyclable
Formal waste worker (local authority)	• Waste collection	• Minimise loss of waste	Not quantified
Formal waste worker (local authority)	• Segregation of waste after waste collection (voluntary)	• Identify potential recyclables and sell for personal benefit	No data
Rag pickers	• Manual scavenging on streets and dumping yards • Waste collection	• Valorisation of waste • Recovery and cleaning of recyclables	£23/month
Itinerant waste buyers	• Waste trade • Cleaning and manual sorting	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades	£51/month
Waste retailers	• Waste trade • Cleaning and manual sorting • Manual sorting of dry recyclables into categories and quality grades	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades Entrepreneurship	£100/month
Waste wholesalers	• Waste trade • Further sorting of waste • Processing of waste depending on categories such as compaction and chipping plastic, shredding and bailing paper and cardboards, etc.	• Sorting and processing of waste • Entrepreneurship and employment generation • Improves quality of recyclables by separating into categorises and quality grades • Changes the form of waste to secondary raw material	£3543/month
Waste suppliers	• Waste trade • Stocking of sorted and processed recyclables	• Entrepreneurship and employment generation • Commercialisation and supply secondary raw materials	No data
NGO	• Manual sorting of wet waste	• Composting	No data
CBO	• Awareness campaigns	• Mobilise citizen for source separation	Not quantified

Table 6.3: Waste quantity collected by informal sector in cities 1, 2 and 3 (Source: Field study conducted by Author)

Informal waste sector	Average Waste collected per month (Tonnes/month)		
	City 1	City 2	City 3
Waste pickers or Rag pickers	0.24	0.27	0.28
Itinerant waste buyers	2.57	2.23	2.3
Waste Retailer	3.78	5.53	4
Waste wholesalers	285	149	195

Table 6.4: Average value addition (in %) at every level of existing stakeholders. Calculated using the price per kg of waste traded by adopting the method of Agarwal et al (2005)

Stakeholders	Value addition in % per kg of waste traded		
	City 1	City 2	City 3
Itinerant waste buyers	21%	23%	26.5%
Retailers	38%	28%	24.4%
Wholesalers	16.5%	49%	40%
Suppliers	19%	N/A	N/A
PPP	N/A	241%	N/A

Similar findings are seen in city 3. Table 6.6 shows the value addition to waste by stakeholders in city 3. In addition to the formal waste collection by waste workers, the trade by informal sector is significant. The rag pickers collect the recyclables from streets, bins and dump yards and sell them to the retailers. The source segregation is found to be practiced by citizens to sell to the informal sector and not for the collection of waste by the formal waste workers. The households sell the waste to retailers or itinerant waste buyers who perform similar value adding activities like cleaning, sorting of waste into categories and quality grades and sell to waste wholesalers as in the case of city 1. However, the difference between the city 1 and city 3 is the existence of suppliers. Table 6.5 shows the wholesalers interviewed (KW2 and KW3) have reported a direct trade with the factories to sell their processed waste. The same was found from the interview with paper industry (KF1) in city 3 that there was no evidence of suppliers and the raw material is bought from the wholesalers. In line to the findings of city 1, the city 3 also shows the amount of waste traded is highest along the downstream of its value chain as shown in table 6.3 and there is a no significant difference between the value adding activities performed by the stakeholders from the upstream to downstream of the waste value chain.

Table 6.5: Excerpts from interviews for waste trade channels (Source: Author)

Stakeholder interviewees	**Excerpts from interviews**
Wholesaler 2 (City 3)	*"…I sell my paper waste to 2 pulping factoring nearby…Plastic is sent to factories in different places" (KW 2)*
Wholesaler 3 (City 3)	*"…There is no supplier, factories buy from me…" (KW3)*
Manufacturing unit (City 3)	*"…We do not have any suppliers for buying paper locally. We need different qualities of paper for different units. We buy some from other cities and we have suppliers for that." (KF1)*

Stakeholder group	Activity performed in waste value chain	Value addition	Average monetary gain to stakeholder group
Citizens	• Source segregation • Sale of recyclables to informal sector	• Minimise waste contamination • Maximise collection potential	£0.116/kg of recyclables
Formal waste worker (local authority)	• Waste collection	• Minimise loss of waste	Not quantified
Formal waste worker (local authority)	• Segregation of waste after waste collection (voluntary)	• Identify potential recyclables and sell for personal benefit	No data
Rag pickers	• Manual scavenging on streets and dumping yards • Waste collection	• Valorisation of waste • Recovery and cleaning of recyclables	£28/month
Itinerant waste buyers	• Waste trade • Cleaning and manual sorting	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades	£54/month
Waste retailers	• Waste trade • Cleaning and manual sorting • Manual sorting of dry recyclables into categories and quality grades	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades Entrepreneurship	£86/month
Waste wholesalers	• Waste trade • Further sorting of waste • Processing of waste depending on categories such as compaction and chipping plastic, shredding and bailing paper and cardboards, etc.	• Sorting and processing of waste • Entrepreneurship and employment generation • Improves quality of recyclables by separating into categorises and quality grades • Changes the form of waste to secondary raw material	£2324/month
NGO	• Awareness campaigns	• Mobilise citizen for source separation	Not quantified

Table 6.6: Value adding activities performed by different stakeholder groups in the value chain of waste in city 3 (Source: Field study conducted by Author)

The value adding activities in city 2 are different from cities 1 and 3 and are shown in table 6.7. There are higher number of stakeholders who benefitted with income generation due to the presence of a PPP in addition to the formal and informal sectors. As in the cases of cities 1 and 3, there is no formal waste recycling in city 2. The value addition ranges from £0.033/kg to citizens and is as high as £88,452/annum for local authorities. The citizens have two options to sell their waste. The PPP employs the staff to collect the dry recyclables from the citizens and pays money for their participation. The amount paid is determined according to the waste type and quantity which is similar to selling the dry waste to informal sector. This also increases the source segregation by citizens due to the extra income that can be brought. This is in line to Joseph (2006) who states economic incentives increase citizen participation. Due to presence of more waste collection channels such as formal, informal sectors and PPP, this adds value as it minimises loss of waste (Scheinberg, 2011). However, as shown in table 6.7, the price paid by the PPP is much lower than the price paid by informal waste traders. This could be attributed to the operational expenses incurred to the PPP resulting in the low price. But due to the price differences, the citizens find it more profitable to sell the waste to informal sectors. Irrespective of who is buying the waste, there is an overall increase in source segregation by the citizens which is a value adding activity (Aphale *et al.*, 2015).

Like cities 1 and 3, sources segregation is not followed by citizens when waste is left for formal waste collection by local authorities. The trend in the waste volumes and the income generated in the informal sector is similar to cities 1 and 3 and the value is higher as the waste moves downstream as observed in the studies of Zia *et al.*, (2008) and Agrawal *et al.,* (2005). There is no difference between the activities performed by the informal sector in city 2 compared to cities 1 and 3. There are additional roles performed by some of the stakeholders. The waste collection staff are paid by PPP to collect source segregated dry waste in addition to their regular door to door collection. This serves as an extra source of income and improves the collection efficiency of dry waste which is a value addition to the staff and to waste. Several authors have emphasised that higher recycling rate can be achieved by providing economic incentives to citizens and enterprises (Yuan-Young *et al.,* 2010; Contreras *et al.,* 2008; Dahlen *et al.,* 2007 and Joseph, 2006). In city 2, it is found that such extra pay to collection staff also drives the recycling rates. According to the interview with PPP operators (WPPP 2), it provides operational

advantage as the waste workers are familiar with the collection routes, number of households and time taken to collect.

"The collection staff usually work for municipality and know all the routes. They can plan the collection times. We don't train them for that. We only train to check quality for collection. It saves lot of time and money. In the same way, we employ rag pickers for sorting. This also saves money as they have the skill to sort waste" (WPPP2)

In addition, they use the same transport vehicles used for the formal waste collection. This results in sharing of resources and minimising the additional costs. According to The World Bank (2001), it is also clear that sharing facilities helps in developing financially viable solutions and improves waste services. The same operational benefits are observed in this case. For waste sorting at the dry resource collection centres and central hubs, the rag pickers, uneducated women and members of CBOs are employed by providing additional training. According to Haan *et al.,* (1998), providing training and organising informal sector contribute positively for value addition. This also increases the operational efficiency as the rag pickers are skilled in identifying the valuables from waste and perform the sorting activity faster (WPPP2). This form of manual sorting with expertise in extracting waste with value is an important step (Iskandar, 2003).

This also provides them with fixed income and better working conditions unlike manual scavenging. The PPP also provides entrepreneurial opportunities for operating the dry resource recycling centres and provides infrastructural and training needs. As a part of the PPP, NGOs are involved in providing awareness to citizens and training to staff and entrepreneurs. There are a greater number of stakeholders such as NGOs, entrepreneurs, employed staff, private sector participation local authorities' support and citizens. According to Zia *et al.,* (2008) and Baud *et al.,* (2001), the stronger the alliances and higher number of connections between the stakeholders, the higher is the recycling rates. Though there is no significant difference between the recycling rates of the three cities, City 2 still has a better performance than the other two which can be related to the greater number of stakeholders and their interactions existing in the city. City 2 also offers an opportunity to all the stakeholders to create a source of income through the value chain of waste by recycling. The significant difference is brought to the formal sector in city 2. As a part of the PPP, the formal sector (local authorities) have provided infrastructure and space for the recycling operations. In return, the formal sector saves an annual operational

expenditure of £88,452. This is possible due to the operations of PPP which diverts approximately 1,260 tonnes of waste from collection, transportation and disposal by local authorities and offers an operational advantage. Hence, the associated operational costs for the formal sector is reduced and saved which is a form of value addition (Scheinberg *et al.*, 2010). By studying the value chain for waste and stakeholder activities of the three cities, it is clear that value addition for waste is primarily determined by the volume of waste traded. Secondly, the volume of trade is affected by the participating stakeholders and their interactions. City 2 has greater number of stakeholders and higher level of collaboration between them resulting in the higher amounts of waste traded in the overall city. So, it is important to understand what kinds of interactions are taking place among the stakeholders and how these are affecting the value addition to waste.

Table 6.7: Value adding activities performed by different stakeholder groups in the value chain of waste in city 2 (Source: Field study conducted by Author)

Stakeholder group	Activity performed in waste value chain	Value addition	Average monetary gain to stakeholder group
Citizens	• Source segregation • Sale of recyclables to informal sector	• Minimise waste contamination • Maximise collection potential	£0.116/kg of recyclables
Citizens	• Source segregation • Sale of recyclables to PPP	• Minimise waste contamination • Maximise collection potential	£0.033/kg of recyclables
Formal waste worker (local authority)	• Waste collection	• Minimise loss of waste	Not quantified
Formal waste worker employed by PPP	• Purchase and collection of dry recyclables	• Maximise collection potential • Minimise waste contamination • Valorisation of waste	£1.1/collection trip of dry recyclables (in addition to salaries given by local authorities)
Dry resource collection centre (PPP) employed rag pickers, women and CBOs	• Cleaning and manual sorting	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades	£2.8/day (daily wages)
Dry resource collection centres and hub (PPP)	• Waste trade • Further sorting • Processing of waste depending on categories such as compaction and chipping plastic, shredding and bailing paper and cardboards, etc.	• Valorisation of waste • Entrepreneurship and employment generation • Improves quality of recyclables by separating into categorises and quality grades • Changes the form of waste to secondary raw material	£1166/month
Rag pickers	• Manual scavenging on streets and dumping yards • Waste collection	• Valorisation of waste • Recovery and cleaning of recyclables	£24/month
Itinerant waste buyers	• Waste trade • Cleaning and manual sorting	• Valorisation of waste • Improves quality of recyclables by separating into categorises and quality grades	£56/month
Waste retailers	• Waste trade • Cleaning and manual sorting	• Valorisation of waste • Improves quality of recyclables by separating	£116/month

	• Manual sorting of dry recyclables into categories and quality grades	into categorises and quality grades Entrepreneurship	
Waste wholesalers	• Waste trade • Further sorting of waste • Processing of waste depending on categories such as compaction and chipping plastic, shredding and bailing paper and cardboards, etc.	• Sorting and processing of waste • Entrepreneurship and employment generation • Improves quality of recyclables by separating into categorises and quality grades • Changes the form of waste to secondary raw material	£2004/month
Factories/ manufacturing units	• Remanufacturing • Purchase of raw material from PPP	• Use of secondary raw material obtained from processing waste- sustainable resource utilisation • Advantage of competitive pricing	£11.1 saved per tonne of raw material purchased from PPP compared to other suppliers
NGO	• Awareness campaigns	• Mobilise citizen for source separation	Not quantified
Local authorities (municipal authorities)	• Infrastructure for PPP	• Facilitate recycling • Benefit from reducing operational expenses due to operations of PPP	£88,452/annum avoided expenses for formal waste collection

6.3.1.3 Stakeholder interactions in value addition to waste

Understanding the interactions among the stakeholders is important as it provides insights on how each interaction affects the value addition to waste. By studying the value chain of waste and stakeholders in it, the stakeholder groups are classified by the researcher for the context of current study as follows.

- **Local authorities:** They are the local governing authorities of the cities and are commonly the municipalities and their employed staff.
- **Private sector:** This includes micro and small enterprises (MSEs), small and medium enterprises (SMEs) and large enterprises including the remanufacturing units. This also includes the waste traders such as itinerant waste buyers, waste retailers and waste wholesalers.
- **Informal sector:** This includes the rag pickers who perform manual scavenging and trade the collected waste. They are not considered as private sector as their trade is not formally registered or recognised.
- **Community Organisations:** This includes the organisations that represent local communities or work for a cause and consists of Non-governmental Organisations (NGOs), Community Based Organisations (CBOs), Resident Welfare Associations (RWA), etc.
- **Citizens:** This group includes the inhabitants of the cities and are also generalised as households.

a) Local Authority - Informal sector

In all the three cities, according to the interviews with local authorities and rag pickers there is an evidence of interaction between them as shown in table 6.8. This interaction is to identify the rag pickers and associate them with the formal waste collection performed by local authorities' staff. This form of an interaction appears to be a failure due to its ineffectiveness in providing financially viable solution for the two stakeholder groups. During the effort of formalising the informal sector, the local authorities are unable to pay regular salaries to them. Similarly, waste collection through formal route is time consuming while waste mining from bins and dump yards is quicker and profitable for rag pickers. The scenarios in all the three studied cities do not prove to support formalising informal sector. Agarwal *et al.,* (2005) tested different financial models in formalising the informal sector in Delhi, India. According to the authors, due to high number of rag

pickers, the local authorities would suffer financially as their salaries are higher than the operational benefits the rag pickers can bring to the local authorities due to their recycling activity. A similar problem is reported by the interviewed local authorities (table 6.8). Though the interaction exists to build collaborations between local authorities and rag pickers, they failed due to a lack of a win-win strategy. Therefore, a clear approach to formalising informal sector is needed to improve this interaction.

Table 6.8: Excerpts from interviews for local authorities and informal sectors interaction (Source: Field study conducted by Author)

Stakeholder group of interviewees	Excerpts from interviews
Local authority (city 1)	*"…we are making efforts to formalise the informal sector, but they are not interested… we ask them to go for waste collection along with our staff, and we allow them to take whatever they want from the waste…" (VLA 1)*
Local authority (city 1)	*"… The government is trying their best to identify the rag pickers, but they are so many, and we cannot identify all of them… The identified rag pickers were given identify cards, but they expect salary from us. How can the government give salaries to all…" (VLA 3)*
Local authority (city 1)	*"…Out of hundreds of rag pickers we identified, only 10-20 people are now in contact. They are never seen and do not want to participate in what we ask them to do… The government is unable to do anything as we do not have their information in government records…" (VLA 6)*
Local authority (city 2)	*"The waste pickers always create problems. They want money from us… We do not pay them any salaries, but the problem is if they collect more recyclables today, they sell them tomorrow and we will not find them day after because they are getting money for next few days. So, they will not work regularly if they are getting paid" (WLA 2)*
Local authority (city 2)	*"The urban local bodies are given targets by central government to identify the rag pickers…the municipality has given them identity cards to them so that they can collect the waste regularly, but they are not seen" (WLA 3)*
Local authority (city 3)	*"Already government identified 100 rag pickers and issued identity cards to them. But most of them are hardly in contact with us now. So, we are trying to identify, and they keep disappearing. So, this process looks like it will never end…it is a waste of our time and resource" (KLA 2)*
Rag pickers (city 1)	*"The government asks us to collect the waste by going all with their staff… We do not get any money… I can do this work quickly if I go to every street myself." (VWP 3)*
Rag pickers (city 1)	*"There is no use of listening to the officers. They will not give us any money. If they give money, why will I not go" (VWP 15)*
Rag pickers (city 2)	*"They are not supporting us… They will not pay for the work*

	I do…" (WWP 3)
Rag pickers (city 3)	*"if I should do the same work, why should I go with them? I can do the work whenever I want to do…" (KWP 2)*
Rag pickers (city 3)	*"I went few times for with their staff to collect waste. They argue with us as they want to take the things, I am taking… They get salary for doing their work, but I do not get any money. If I cannot get waste that I need, how can I survive?" (KWP 4)*

b) Local authorities - Community Organisations-Citizens

In cities 1 and 3, the local authorities have collaborated with the CBOs to spread awareness to the citizens about source segregation and community participation. In city 2, the local authorities have collaborated with NGOs for the same purpose. According to the surveyed citizens, 51%, 20% and 29% of the citizens in cities 1, 2 and 3 have reported to be aware of awareness programmes through community organisations. Several authors have found that awareness campaigns have a positive effect on citizen participation and recycling (Grazhdani 2016; Caniato *et al.,* 2015; Starr and Nicolson 2015, Shaw, 2008) and community organisations have an important role in creating awareness (Joseph, 2006). So, success or failure of this interaction is not clear, but from the responses of the citizens, it is understood that a wider target of citizens should be considered as the majority in cities 2 and 3 are not aware of these awareness campaigns.

c) Local Authorities - Private sector

Among the cities 1, 2 and 3, this type of interaction is strong in city 2. As shown below, according to the interviews with local authorities, this interaction existed in city 1, but the private sector suffered from financial sustainability and was therefore suspended.

"A part of the collection is outsourced to the private sector, but they did not get profit and ran into loss. So, the private company did not continue to work. The main reason is because the waste is not segregated by citizens, the company cannot get any money from the waste and they should send it for disposal. Citizens are not paying for the collection also. So, there is no income for the company (VLA5)"

There is no evidence for the existence of this form of interaction in city 3. In city 2, there is presence of public private partnership where the local authorities have provided land and infrastructural facilities and the private sector has provided the technical support and training to improve recycling rates (as explained in chapter 5). This interaction appears to

be a success due to the entrepreneurship and employment opportunities provided because of the interaction. From the studies of Troschinetz and Mihelcic (2009), incentivising land availability promotes recycling facility. The same is observed in city 2 as the local authorities have supported the recycling units by providing land. Srivastava *et al.*, (2005), has indicated that unemployed should be considered as an opportunity to improve waste management scenario. Similarly, the author has also indicated the absence of public private partnerships is a threat to waste managing system in India. In city 2, from this interaction it is observed that threats are overcome, and opportunities are utilised. The interaction not only improved recycling rates as shown in table 6.9, but also created a social impact due to the entrepreneurship and employment generation. From the interview with the PPP operator in city 2 (WPPP1), there are approximately 500 employees and more than 20 entrepreneurs including the micro and small enterprises. According to the studies of Yuan-Young *et al.*, (2010) a similar finding was observed in Taiwan, where financial incentives and technical support helped in success of entrepreneurs which resulted in increasing the recycling rates and a similar success trend is seen in city 2.

Table 6.9: Stakeholder group contributions towards recycling rates of cities 1, 2 and 3 (Source: Field study conducted by Author)

	Contribution to recycling rate by formal sector (%)	**Contribution to recycling rate by informal sector (%)**	**Contribution to recycling rate by PPP (%)**	**Contribution to recycling rate by others (%)**	**Total recycling rate (%)**
City 1	0	1.06	0	0.1	1.16
City 2	0.4	2.3	1.7	0	4.4
City 3	0	3.7	0	0	3.7

d) Private Sector - Community organisations

The interaction between private sector and community organisations exist only in city 2. These include two types. One is the interaction with NGOs to whom training is provided to propagate awareness to citizens. Though there is no clear measurement to assess the success of this, according to the PPP model, the NGOs mark the houses to whom awareness is conducted and are expected to participate in source segregation. This is followed up by the waste collection staff to monitor the participation in source segregation. Aphale *et al.*, (2015) cited that social pressure promotes recycling by citizens. The model in city 2 is also creating social pressure among the citizens by marking the houses and following up on their participation. This is also reflected on the recycling rates of the city

and therefore this type of interaction can be considered successful. The second type is the interaction between the private sector and the CBOs who gain employment. This facilitates in livelihood creation for the unemployed and promotes sorting of waste with low capital costs, which is an important value adding step as it drives economic growth.

e) Private sector - Informal sector

This type of interaction is present in all the three cities. They lead to different types of collaborations. One type is employing the rag pickers for waste sorting in the small enterprises formed by the PPP in city 2. This type of interaction improves the working conditions of the rag pickers, creates livelihood besides increasing the recycling rates, but it is absent in cities 1 and 3. The other type is maintaining mutual contracts between waste retailers and rag pickers. This has a positive affect to both the stakeholder groups as the sale of collected recyclables is guaranteed for the rag pickers and the amount of waste traded is increased for waste retailer which leads to higher income generation. This form of interaction is present in all the three cities. In all the cases this interaction has a significant effect on the value addition. This is higher in city 2, due to a greater number of interactions which are caused due to the existence of micro and small enterprises supported by PPP. According to Scheinberg (2011), an NGO in Bangalore city (India), facilitates the employment of informal rag pickers with large waste generating commercial units. So, the commercial units get their waste cleared without modernising their waste equipment and this guarantees a regular amount of waste collection to the waste pickers which lead to higher income for them. According to the study of Baud *et al.,* (2001), Chennai city (India), worked using a similar model where NGOs and CBOs employed the rag pickers. This not only benefits the environment but also the socio-economic aspects of the rag pickers. The CBO-rag picker collaboration did not last for long due to the lack of coordination. External factors like market fluctuations for price of raw materials also affected the income for rag pickers. In city 2, due to the involvement of large private enterprise in the PPP who is also a buyer of the raw materials without intermediaries, the effect of such external factors can be expected to be minimal. Therefore, this interaction between private sector and informal sector maximises income generation and adds value to the waste besides contributing to recycling rates.

f) Private Sector-Private sector- Citizens

This interaction is common in all the three cities. This includes the coordination between citizens and itinerant waste buyers/retailers and large-scale suppliers/private manufacturing units or factories. According to the interviews with itinerant waste buyers in all the three cities, it is observed that they maintain a regular contact with the households. As a result, the households sell their waste only to the itinerant waste buyer which increases the amount of waste trade. According to the waste buyers, though people from all income levels sell waste, the middle-income group households sell waste more often (as shown in table 6.10). According to a study in Dehradun conducted by Suthar and Singh (2015), middle-income families tend to sell waste due to the extra income they can obtain from it. Therefore, financial benefit can be considered as a driver for citizen participation in separating the waste at source and to sell it.

Similar co-ordination is observed among the private waste traders such as itinerant waste buyers with wholesalers or waste retailers with wholesalers resulting in a private sector-private sector interaction according to the classified stakeholder groups in beginning of this section 6.3.1.3. This also leads to a win-win situation as there is guaranteed sale of waste at the upstream such as retailers and itinerant waste buyers. It also provides higher amount of waste at the intermediate and downstream levels of waste value chain such as wholesalers, suppliers and factories. There is evidence of private-private interaction at every level of the waste trade in all the three cities to increase the amount of waste traded.

Similar types of interactions are also seen in the city 2 as the entrepreneurs of the PPP maintain contracts with factories to supply raw materials regularly for paper and plastic manufacturing. Interactions between the waste traders are reported by Baud *et al.,* (2001) in Chennai, Zia *et al.,* (2008) in Kanpur and Agarwal *et al.,* (2005) in Delhi. According to these three studies, such interactions lead to high resource recovery which can help in commercialisation of secondary raw materials and higher value addition to waste. According to Baud *et al.,* (2001), this results in low bargaining power to the stakeholders at the upstream of value chain. This is also observed to be the same in all the three cities. According to the interviews with the waste retailers (VR1) and itinerant waste buyers (KIWB2) shown in table 6.10, the price is predetermined by the wholesalers and suppliers whereas they do not have room for negotiation either. The only choice left for them is to either sell or not sell the already bought waste. Though this interaction suffers from the social problems, it positively affects the value addition to waste.

Table 6.10: Excerpts from interviews for private sector-private sector interactions (Source: Field study conducted by Author)

Stakeholder group of interviewees	Excerpts from interviews
Private sector (itinerant waste buyer, city 1)	*"I generally go to same houses every two months to buy waste…" (VIWB2)*
Private sector (itinerant waste buyer, city 2)	*"All kinds of people sell waste like commissioners, teachers… but mostly middle-class people sell and bargain with us to pay more for their waste and force us to buy even if I say I will not get profit from it" (WIWB1)*
Private sector (itinerant waste buyer, city 3)	*"so many people sell waste. I give my number to them and they will call me when they have waste ready to sell" (KIWB2)*
Private sector (itinerant waste buyer, city 3)	*"I buy from many houses, but mostly we have regular customers…We also sell to same wholesalers generally" (KIWB5)*
Private sector (Wholesaler, city 1)	*"We maintain contact with the retailer and waste buyers. We collect waste from them on monthly basis and do it for free. We plan the schedule and route depending on the amount of waste the retailers and other traders have in stock. Similarly, we also sell the waste to same supplier all the time" (VW2)*
Private sector (Wholesaler, city 3)	*"I always buy from same people. Sometimes new people come to sell us by themselves. We have an understanding generally. We do not sign any contracts, but it is like a contract between us" (KW1)*
Private sector (Retailer, city 1)	*"the price is already fixed by wholesalers, and we cannot bargain with them" (VR1)*
Private sector (itinerant waste buyer, city 2)	*"Our wholesalers inform what the price is before we buy waste. Depending on that, we pay to the sellers. Sometimes, if we have more waste, we can ask for higher price" (KIWB1)*

g) Local Authorities-Citizens

This is a very important type of interaction as it is between the service providers and service receivers who are also waste generators. This form of interaction appears to be weak in all the three cities as the local authorities do not interact with citizens directly due to the absence of inclusive governance. The only form of this interaction identified is using social media or mobile applications. It is also seen that this service is not successful in engaging citizens through these channels. The local authorities (VLA1), in city 1 have reported use of social media to promote awareness and citizens interact with local authorities to complain about the problem in waste collection.

"Our page always posts many things for awareness…If people are using our apps, they can contact us directly for any complaints and we can access their location. According to that we redirect the complaint to a local in charge…We send messages for awareness through app also. But people are not very active as we expected in using these." (VLA1)

Hence, this is a bidirectional interaction, but there is no significant effect on value addition in all the three cities.

From the three cities, the following types of interactions among the stakeholder groups are identified and their effect on value addition is summarised in table 6.11.

Table 6.11: Comparisons of interactions between the cities 1, 2 and 3 (Source: Field study conducted by Author)

Stakeholder Interaction	City 1	City 2	City 3
Local authority-Informal sector	+0	+0	+0
Local authority-Community Organisation-Citizens	+?	+?	+?
Local authority-Private sector	+0	++	-
Private sector-Community organisations	-	++	-
Private sector-Informal sector	+	++	+
Private sector-Private sector	+	+	+
Local authorities-Citizens	+	+	+
++ indicates present with high significance on value addition; **+** indicates present; **+0** indicates present but unsuccessful; **+?** indicates present but success or failure not clear; **-** indicates absent			

Mapping the value chain and the value adding activities in three cities showed the different forms of possible stakeholder interactions. The interactions studied show the most connected stakeholder and it not only adds value to waste, but also benefits either through income generation or operational effectiveness. There are several other forms of interactions possible among the stakeholders. Since waste management problem should look for more local solutions, this allows the governing authorities to identify the best applicable stakeholder collaboration and work for its formation or improvement. It is also observed that some of the stakeholder interactions that can increase value addition and play significant role in waste free cities concept are either weak or unsuccessful (as shown in table 6.11). Therefore, it is important to identify the barriers and challenges for strengthening such interactions and improve the waste management scenario for the successful transformation towards waste free cities.

6.4 Stakeholder interaction and its impact on valorisation of waste

The application of waste free cities framework and studying the value chain of waste in three cities, have provided an overview of waste management. It refers specifically to fast urbanising cities that are attempting to transform into smart cities but struggling to design waste management solutions. From the three cities taken as case studies, the challenges and problems faced by them to achieve waste free cities and recover value from waste are identified. In addition to the application of framework and studying their interactions, the primary data sources such as interviews with different stakeholders are used. The aim of this section is to identify possible solutions for the problems. Benchmarking methodology is adopted to identify the best practices. A comparison is made within the three cities and various other cities that are successful in overcoming such problems. Developed countries are ahead in tackling similar problems, but, their waste compositions, legal enforcement and budgets for waste management are different from the developing countries and transfer of solution may not be applicable. Hence, several cases in developing countries and particularly in India are reviewed to identify the best solution that is more feasible to the current problems. This can help in corrective measures and improve the state of waste management in the studied cities.

6.4.1 Results and discussions

Based on the overall picture of waste management in all the three cities, the problems are identified. The problems are mostly related to governance, operations and stakeholders. They often have a relation between each other. In this study, the best practices that are suitable and feasible as local solutions are only considered and proposed. For some of the problems, suitable practices were not identified, but suggestions are given based on the researcher's understanding of the problem. The problems and proposed best practices are discussed below.

6.4.1.1 Problem 1-Poor means of integrating stakeholders

a) Citizens: Citizens are ignored in decision making process as they are not consulted in any from. They play the most important role in value chain as they are the waste generators. Poor citizen participation in source segregation is a hinderance in all the three cities when waste is collected by formal waste workers. According to the interviewed waste buyers as shown in table 6.12, there is no problem with source segregation when waste is sold by citizens. This participation in source segregation can be attributed to the economic gain to the households from selling waste. Therefore, the local authorities have

failed in identifying the drivers or motivators for their participation in source segregation and behavioural change.

Table 6.12: Excerpts from interviews for citizen participation in source segregation to sell waste (Source: Field study conducted by Author)

Stakeholder group of interviewees	Excerpts from interviews
Private sector (itinerant waste buyer, city 1)	*"There is no problem with separation. The residents already separate and then sell…" (VIWB2)*
Private sector (itinerant waste buyer, city 2)	*"They (citizens) usually separate different types like paper, cardboard and plastic. I check again and see if they are correct… Some things like oil printed paper are not bought from us by wholesalers. So even I don't buy as I can't sell them, but people try to sell them like normal paper" (WIWB2)*
Private sector (PPP, city 2)	*"Households are already trained on how to segregate waste into different types. The collection staff are also trained, and they check before buying and inform the households that it is wrong separation. So, we generally do not have any problem…If the separation is wrong repeatedly, the staff make a note of the house and we will follow up on educating them again." (WPPP1)*
Private sector (Retailer, city 3)	*"Usually because same people sell waste to me, they know how I buy. They are used to separation and I generally do not have problem. Sometimes, new people fight with us if I say it is not correct and I have to separate. This happens rarely. Mostly people who want to sell separate well because they know they can get more money if it is proper" (KR1)*

Source segregation is an important value adding activity and several studies (Starr and Nicolson, 2015; Dahlen *et al.,* 2006 and Linderholf *et al.,* 2001) have shown that collection of user charges based on volume or weight of waste have successfully reduced waste generation and increased source segregation. Contrastingly, Linderholf *et al.,* (2001) and Fullerton and Kinnaman (1996) have also reported that such user fee collection system could pose an increased risk of illegal dumping or burning. These also harm the environment and increase the collection complexity. According to the interviews with local authorities of all the three cities as shown in table 6.13, the citizens are less willing to pay user charges. From the citizens' participation in source segregation to sell waste, it indicates the role of economic incentives as a motivation for improved participation. It is

also observed in Wudang district of southwest China that the incentive-based model was successful in increasing community participation in source segregation. The model is a multi-stakeholder collaboration and provides different incentives to stakeholders. Citizens receive credits for supermarkets as an incentive for source segregation. This form of incentives did not affect the financing ability of the local authority but reduced the operating costs. It is considered as a success as the waste reduction rate has increased from 25.4% to 87.3%. (Xu *et al.,* 2015). A similar practice is seen in Taiwan where people were rewarded for source segregation (Yuan-Young *et al.,* 2010). Incentivising home composting has been practiced in Hernani, Spain. The households are trained on how to carry out composting at home and are provided with detailed manuals and bins. The municipalities offer 40 percent discount on waste collection fees for the participating households (Connett, 2013). This is also applicable to the three case study cities with certain modifications as the households are not currently paying user charges for waste management. Particularly, as the organic content in developing countries is higher than in developed countries (Shekdar, 2009), if home composting is practiced, it reduces the waste generated and the overall operational costs. It is also likely to reduce the contamination of dry waste and increase their value. If the local authority can find means of purchasing the compost or incentivising it, it will be an additional income source particularly for middle income group households and can increase their participation. It can be understood that rewarding or providing incentives through economic means to the citizens can improve source segregation. Hence, these are considered applicable in all the three case study cities.

Table 6.13: Excerpts from interviews on user fees for waste collection (Source: Author)

Stakeholder group of interviewees	Excerpts from interviews
Local authority (city 1)	*"People are already struggling with education and health being very expensive and the city mostly has middle class people. So, it is very difficult for them to pay extra money for waste. They cannot pay, and we are not forcing them to pay." (VLA4)*
Local authority (city 2)	*"Generally, people don't pay money to us. If we don't collect waiting for money, they will throw their waste on the roads. That will only make the city dirty and there will not be any other use" (WLA2)*
Local authority (city 3)	*"…We are not taking the collection fees as the people are not ready to pay. If it is for water or electricity, then they will pay. For waste they are not ready to pay" (KLA 1)*

b) Small and Medium Enterprises: There are several registered waste traders such as waste retailers and wholesalers who pay tax to the government and contribute to economic growth. They create employment to an average of 2-25 people per enterprise. They also play a role in commercialising waste as raw materials and improve recycling rates. However, these enterprises suffer from several challenges and are often categorised as informal sector. They also suffer from capacity building. It is clear from the value chain that higher amounts of waste trade result in higher income generation. According to the interviews with waste traders in all the three cities, space is a major investment and poses a challenge. Lack of adequate for sorting hinders their ability to trade higher amounts of waste. The smaller traders also suffer with lack of storage space. Their current storage facilities do not ensure quality of waste due to greater chances of getting wet in rain, or theft (as mentioned in table 6.14). Hence, they are bound to trade smaller amounts resulting in lower profit margins. In addition to the space, these enterprises or waste traders do not obtain any form of subsidies, incentives or tax concessions though they benefit the local authority by decreasing the amount of waste that has to be collected and managed by the formal sector (as explained in section 6.3.1.2).

Table 6.14: Excerpts from interviews about storage space as a problem Source: Field study conducted by Author)

Stakeholder group of interviewees	Excerpts from interviews
Private sector (itinerant waste buyer, city 1)	*"If I have space to store waste, then I will get profit as I can sell everything at once and get more money. But I am not able to pay rent for that…" (VIWB6)*
Private sector (itinerant waste buyer, city 3)	*"Government does not do anything for people like us… I buy waste and if it rains heavily, paper gets wet. Even if we dry it, as its weight changes, wholesalers will not buy, and I lose money. To store such things, we need small godowns (warehouses) One more problem is with termites... Again, for plastic the problem is different. Rats will eat and spoil, but that is not a big problem." (KIWB2)*

This problem has been identified in the studies of Agarwal *et al.,* (2005) and Zia *et al.,* (2008). In Taiwan, zero waste is considered, and strategies were implemented to achieve them. As recycling is heavily relied on small and medium enterprises, they are supported with financial incentives and technical trainings. Subsidies were also provided for industry development for recycling as a priority to sustainability and zero waste. Such support extended by local authorities showed positive results for recycling and waste disposal was

minimised (Yuan-Young *et al.*, 2010). In Philippines, the role of itinerant waste buyers and their contribution to recycling rates of Manila are recognised and support was offered by NGO to waste dealers or middle men through a programme called 'Linis Ganda'. This organised the middle men into cooperatives which helped in gaining recognition and increasing their bargaining power. As a cooperative, their interaction with waste generators and recyclable buyers has increased. The NGO also helped in capacity building by facilitating credits from financial institutions at a lower interest to improve their infrastructure (Wilson *et al.*, 2009). Due to the similarity in the problems faced by the waste traders in all the three cities, these practices are appropriate and can be replicated.

c) Rag pickers: Rag pickers work in unhealthy conditions and do not receive any form of support. The efforts to formalise them have failed in all the three cities as it does not benefit the rag pickers. Though formation of cooperatives in several places in India is proven to be successful through NGOs and CBOs, it had not been planned in these studied cities. Formation of micro enterprises by the identified informal sector is not seen or reported. So, the approaches to formalise the rag pickers is a problem in all the three cities. One of the successful models to formalise the rag pickers is seen in Pune, India. With a collaboration between NGO and local authorities, rag pickers were organised into cooperatives called 'SWaCH' (Solid Waste Collection and Handling). The local authority helped by providing equipment and infrastructure. The SWaCH provided the managerial support to the rag pickers. The rag pickers were employed for door to door collection of waste for a user fees in the areas where the local authorities were not operating. This also helped the residents as a waste collection service is provided by rag pickers. Source segregation was made mandatory and the user charges and sale of recyclables were finance sources for operations of SWaCH and income sources for rag pickers. The local authorities also offered social benefits to the involved rag pickers (UMC, 2015; Gupta, 2012). Similar model is used in Mumbai, India. An NGO that works for gender equality and environment (Stree Mukti Sangathan) collaborated with the local authorities and trained the women rag pickers. They were them employed in residential and commercial societies on monthly salary basis. The employed rag pickers provided waste collection to the societies and composted the wet waste. They were also allowed to sell the recyclables in addition to their work (UMC, 2015). These two practices followed are possible models that can be used in the three studied cities as they help in service expansion as well as in organising the informal sector by creating self-employment opportunities. However, in both the best

practices identified, a strong collaboration between NGO and local authority is seen and is the reason for success. Hence, strong interaction between these stakeholders is needed to adopt the identified best practices in all the three cities.

d) Research and academic institutions: The research and academic institutions play an important role in smart cities (Lombardi *et al.,* 2012) and waste management (Joseph, 2006). Their presence or engagement is not seen in any of the three studied cities. There is a need to design and assess feasibility of models and technology at local level (Borghi *et al.,* 2014) for waste prevention and management which can be performed through research. It is observed in Flanders, a region in Belgium that students and professionals were involved for designing innovative ways to prevent waste. This is also encouraged through cash prizes as competition (Connett, 2013). This is possible to replicate in all the three cities although it is practiced in a developed country. A similar programme was conducted among schools in Gangtok, an Indian city which encouraged poster presentations, essay writings on urban waste management. It was also successful in drawing few ideas. It is already seen in city 2 that a 7-day challenge which involved students was successful. Involving educational institutions such as schools is beneficial and can be seen as an enhanced communication channel. Hence, researchers and research projects should also be included like in the case of Belgium.

6.4.1.2 Problem 2 - Lack of advanced or appropriate use of technology and infrastructure

a) Transport type: The three studied cities use open transportation vehicles for waste transportation which also results in further littering of waste. Accumulation of waste around the bins or collection points is also a common problem. Added to this, door to door service is not provided in all the areas due to the accessibility issues for waste transport vehicles. In cities 1 and 3, the use of advanced technology for waste collection and transportation is not present except for the use of GPS fitted vehicles and city 2 is in a stage to pilot underground bins but not fully operational. Modern technology in waste management is believed to improve and provide more integrated approaches to value addition (Borghi *et al.,* 2014). The same practices of using smart technologies are observed in several cities in developed countries such as Stockholm in Sweden (Navigant research, 2014) and London in UK (DBIS, 2013). This was tried in Gujarat International Finance Tech (GIFT) City for a length of 2km with the controlled speed of 110-140 km/hour. It also facilitates segregation of wet and dry wastes for further treatment or recovery. It is

also a smart city initiative (Shukla, 2016). Since this is successful in Indian city, and the three studied cities suffer from transportation issues and are trying to transform into smart cities, it can be suggested as a best practice. It can be replicated but a further cost- benefit analysis is required to make it operational.

b) Storage: In all the three cities, there are no appropriate storage facilities for waste. The waste is accumulated in open at the secondary collection points and transfer stations which can pose health and environmental hazards. So, there is need to upgrade the existing infrastructure and use applicable technology. There are several best practices that are identified for improving such facilities. One of the most successful practice is to create recycling warehouses. Belo Horizonte City in Brazil was successful in regenerating the waste storage spaces into recycling warehouses. There were agreements between the rag pickers associations and local authorities where the rag pickers were given access to the storage sites to sort the waste and were paid accordingly. They also estimated the value of recyclables obtained which helped in maintaining data (Dias, 2011). In the UK, the collected waste is taken to Material Recovery Facility (MRF), which is similar to the transfer station in the studied cities. However, sorting of recyclables in MRFs occurs through smart technologies and mechanical sorting equipment (DBIS, 2013). In Hyderabad, an Indian city, an NGO called civic EXNORA employed rag pickers to sort waste. It was observed that providing space for sorting improved their efficiency (Colon and Fawcett, 2006). From these best practices, it can be understood that converting transfer station to sorting spaces can be a best practice. In short term, employing or providing access to the informal sector to such converted sorting spaces can benefit them by giving access to collected waste. It also helps in diverting the waste from landfill as the informal sector recover valuables from the accumulated waste at transfer station which would otherwise reach the dumping yard for open dumping. Since city 2 already provides dedicated space for sorting waste through PPP, in long term, installing mechanical separation units at transfer stations and composting on site can be suggested as best practices.

c) Choice of technology: To adopt smart waste management techniques, transfer of technology from other countries is seen, without considering its feasibility to local problems and waste compositions. Compacter trucks or bins are in use or planned for implementation and are seen as ways of upgrading existing infrastructure. The compaction is more suitable for waste with less organic content unlike the composition of waste in

developing countries (Shekdar, 2009) including the three cities studied. Hence, they can be considered as unsuitable or less suitable technological adaptation which is a problem as it adds investment to already budget constrained local authorities without gaining return on it. In order to select any type of equipment or technology from collection bin to processing unit, the exact data on waste composition, densities, volumes and quantity are required (Wilson et al., 2015b). There is no best practice identified, but feasibility studies for appropriate technology is recommended. Linking research and academic institutions may help in identifying the best possible solution that is more suitable for local conditions.

6.4.1.3 Problem 3 - Lack of awareness and appropriate communication strategy

The lack of awareness is a major problem in all the three cities. Source segregation is not followed by citizens. The street sweepings also include behavioural waste of the citizens that is caused due to littering, in addition to the waste accumulation around the collection points. These not only contaminate the waste and affect their recovery, but also have adverse effects on environment and health issues. One of the interviewed local authority stated as below.

> "*the citizens are not realising we are asking them to dispose the waste properly for their wellbeing. They feel they are doing a favour to the government…We are trying to explain them in many ways, but they do not understand and are not showing any interest (VLA2).*"

This indicates that lack of awareness among citizens is a problem. There is a need to educate the citizens on the adverse effects caused by waste on health and the associated benefits. The communication strategy has to be redesigned in all the three cities, though city 2 is doing relatively better. It is seen that local authorities are trying to communicate with the citizens to create awareness, but this communication is not reaching to all types of people.

Social media is seen as a successful strategy to promote environmental awareness in Iraq (Rahim and Jalaladeen, 2016). Scotland has successfully used social media to spread awareness on littering and fly tipping by posting images and visuals to show the scale of problem and used tag lines like 'ugly glory'. It also rewarded cities with better cleanliness. This led to the creation of awareness as well as social cohesion as people had a belongingness to a place or city and did not like it being called ugly. This helped in bringing behavioural change (Zerowaste Scotland, 2018). This type of communication is

also a characteristic of smart city. However, this may result in digital divide particularly in the developing countries due to the demographic differences in education, age, access to technology, etc. Therefore, additional communication channels are required to reach a variety of people.

In Taiwan, awareness for citizen participation is brought by using numerous means like communicating through NGOs, primary schools, rewarding participation, etc. which showed a change in people towards the sustainable behaviour (Yuan-Young *et al.*, 2010). Similarly, Bangalore (an Indian city), has also adopted number of ways like hoardings, posters, leaflets, educational booklets, communication through mass media such as advertisements on television, newspaper and radio. This was also considered as a success as the source segregation in Bangalore doubled after the launch of awareness campaigns (UMC, 2015). Therefore, a mix of such awareness campaigns along with social media can be adopted as best practice in all the three case studies.

6.4.1.4 Problem 4 - Lack of infrastructural capacity and bargaining power

The small-scale recyclers also contribute to city's recycling rates and play a crucial role in waste value chain. They gather waste from various sources and improve the collection efficiency. They often suffer with low margins of profit due to lower volumes traded. From the interviews of itinerant waste buyers and retailers in all the three cities, it is evident that though they have interest in trading greater amount of waste, they are unable to do so due to the financial and space constraints (shown in table 6.13 previously). Storage space is important but at this level with lower amounts of waste traded, it is expensive for such traders. Since waste processing does not start at this level, the waste is not chipped or bailed resulting in larger volumes. Furthermore, due to the lack of such storage spaces, they are compelled to trade smaller amounts of waste. This is due to inadequate storage facility which leads to poor quality of waste caused by pests or rain. Since, the quantity of waste is lower, they do not have bargaining power resulting in lower selling prices. The earlier mentioned best practices such as organising recyclers like in the case of Manila, Philippines (Wilson *et al.*, 2009) is applicable to build capacity which can further increase bargaining power. The same is also seen in Iloilo city in Philippines where municipalities facilitated the formation of associations for recyclers (Paul *et al.*, 2012 in Aparcana, 2017). Same is seen in the cases of Cairo (Egypt) and Bogota (Colombia) and all have shown positive results in building capacities coupled with higher bargaining power (Terraza and Sturzenegger, 2010 in Aparcana, 2017). Therefore, formation of associations of recyclers

either through the support of local authorities or NGOs can be considered as a best practice to overcome this problem.

6.4.1.5 Problem 5 - Lack of connection between the local and national secondary raw material markets

Waste is converted to secondary raw material and competes with virgin raw materials. Although the paper waste is bought by the paper manufacturing units locally in cities 1 and 3, most of the waste such as plastic and metals are traded out of the city. There is presence of local and national markets. Such trades in the markets are held by wholesalers or suppliers. The retailers or itinerant waste buyers do not have any form of contacts or connections with such markets resulting in a single channel of trade as seen in the value chains (in section 6.3.1). However, linking the local and national markets is required to drive smart economy (Giffinger *et al.*, 2007). This is also evidenced from the interview with local authorities in City 3.

"As a smart city, we laid roads from recycled plastic… Waste is not brought from here. It was contracted to outsiders and I do not know from where it comes exactly…" (KLA2)

The city 3 has laid plastic road from recycled plastic as a smart initiative and the plastic used is imported from other cities. This also makes it clear that the government is not taking any initiatives to help in connecting such markets or buyers with the local recycling traders.

In Cairo, the *Zabaleen* community who are primarily rag pickers and small-scale traders have formed into micro enterprisers and carry out plastic remanufacturing and transforming it into household items such as clothes hangers, etc. They also make fresh paper from recycled paper. This was seen successful as they directly market their finished products (Connett, 2013). Similarly, in Kovalam, which is located in the state of Kerala in India, as a part of zero waste programme, cottage industries were formed which created employment to a number of people. They produce useful items from waste such as paper bags from recycled papers, bags from used clothes, etc using their craftsmanship (Connett, 2013). Therefore, connecting the small-scale waste dealers with such industries can be observed beneficial to both the parties and this can be considered as best practice. In addition, previously proposed best practices for financial incentives and capacity building can help in gaining bargaining power. This can also facilitate an easy trade in different

markets. Although best practices are not found, it is also suggested by the researcher that policy designs for use of locally recycled products in government projects should be considered.

6.4.1.6 Problem 6 - Weak stakeholder interactions

By studying the stakeholder interactions, it is clear that some of the interactions that can significantly affect the value addition with other social benefits are observed to be weak in all the three cities with few exceptions to city 2. The interactions between 'local authority and informal sector' and 'local authority and citizens' are weak in all the three cities. The interaction between local authority and private sector though existed in city 1, resulted in failures. Similar interactions were successful in other Indian cities. Interaction among the private sectors is present in all the three cities and such interactions within the waste traders are observed to be successful. This also showed a better citizen participation in source segregation which is otherwise absent during the interaction with local authority staff. Hence, these weak interactions negatively affect the waste management and value generation to waste. As already discussed, formation of rag pickers associations in Pune or financial incentives to small-scale dealers in the case of Manila will help in strengthening the stakeholder interactions. The improved communication strategy like Bangalore and Scotland can also improve the interaction between local authorities and citizens.

6.4.1.7 Problem 7 - Weak legal enforcement

According to the MSW rules, 2016, the waste generators should segregate their waste at source, not litter and pay user fees for the collection service offered. However, in all the three cities, the enforcement of such laws is very weak and is not fully implemented. According to the interviews with local authorities, the citizens feel it as a burden to pay the user fees and is not being collected.

"People are already struggling with education and health being very expensive and the city mostly has middle class people. So, it is very difficult for them to pay extra money for waste. They cannot pay, and we are not forcing them to pay." (VLA4)

In city 1, the collection of user fee is piloted in few areas. In addition, the environmental monitoring is not clearly indicated for current waste practices in the three cities. However, the overall enforcement of legal framework is a problem to achieve cleaner cities. In Ahmedabad, an Indian city, legal enforcement for waste related activities is strengthened

through mobile courts. The mobile courts visit different places of various types of waste generators, particularly commercial establishments to check their waste disposal activity. If they are found to violate the rules, it would affect their license or result in charges against them instantly. Such mobile courts are considered successful and are planned to replicate in other cities due to their effectiveness. Due to this form of legal enforcement, collection efficiency from commercial establishments is found to increase in Ahmedabad city (UMC, 2015). This can be seen as best practice and be applied in the studied cities. Particularly in city 1 due to high population and waste generations, the additional expenses incurred due to mobile courts can be recovered from the operational costs of waste management services. If the mobile courts randomly inspect the source segregation as well as the collection efficiency of collection staff, it can promote citizen participation. Before such practice, local policies or acts should be designed by making source segregation mandatory and should mention the charges for non-participation. It should also be communicated to citizens before implementation. Such an enforcement is likely to be successful as it brings social pressure to participate in appropriate source segregation.

6.4.1.8 Problem 8 - Lack of data

The absence of database for waste related data is also a problem. Lack of relevant data is a limiting factor for building suitable models to improve the waste management system. According to Burnley (2007), it is important to understand the waste composition data to frame appropriate strategies to meet the local needs. The presence of such data will help in monitoring the waste managing activities and meeting the national targets. It is generally a problem in most developing countries. Without the material flow of recyclables, it is not possible to understand the recycling sector (Mutz, 2015). One of the ways to understand such material flows is implemented in Taiwan using GPS and RFID technology to record the quantities of collection, disposal and end of life products. This has successfully helped in developing a reporting system though not a complete database for waste (Yuan-Young *et al.,* 2010). Since, some of the vehicles in cities 1 and 2 are GPS tracked, it can be replicated to build data on waste flows. In addition, Wilson *et al.,* (2015a) has developed 'wasteaware indicators' to maintain a standard set of data related to waste throughout the world. It is suitable to most cities in developing and developed countries and few Indian cities have used it to build their data set. However, the three studied cities can use the indicators and update their relevant data.

Studying the different aspects of waste management and smart city initiatives, it can be understood that there are no significant efforts to improve the value addition to waste either for the smart city transformation or for environmental protection particularly in cities 1 and 3. It is also clear that the role of local authorities is very crucial in not only interacting with stakeholders but also to strengthen the other interactions between different stakeholders. There are certain problems that hinder the development of current waste management status. The problems are identified and recommended best practices are shown in table 6.15. Though citizen participation is most important, it has been a problem not only in developing countries but also developed countries. However, developed countries have found measures to improve their participation. As suggested as a best practice, the motivating factors for citizen participation should be identified as an improved strategy. The role of private sector has to be identified carefully by dividing the sector based on their scale of business and meeting their challenges thereby tremendously increasing the recycling rates. The economic, social and environment benefits offered by such sectors should be recognised and appropriate policy design should be made to integrate them and support them. The policies on cleaner production and extended producer responsibility are not evident and should also be considered. However, linking the industries with private sector could be a means of cleaner production for a country like India and more appropriate ways of dealing local problems should be carried out unlike the transfer of technology or directly replicating a successful model elsewhere.

Table 6.15: Problems identified with stakeholders, processes involved, recommended best practices from other cities and countries with their relevance to smart categories in waste free cities framework (Source: Field study conducted by Author)

Problem	Stakeholders involved	Process involved	Best practices	Effect of best practices on smart categories of waste free cities framework
Poor means of integrating stakeholders	Citizens	Participation in source segregation	Wudang (China), Taiwan and Hernani (Spain)	Smart Governance Smart People
	Small and Medium enterprises	Financial support, capacity building, employment and entrepreneurship	Manila (Philippines) Taiwan	Smart Economy Smart Governance
	Rag pickers	Support and formalisation process	Pune (India) Mumbai (India)	Smart Governance
	Research and academic institutions	Research and development	Flanders (Belgium) Gangtok (India)	Smart Governance
Lack of advanced or appropriate use of technology and infrastructure	Local authorities	Transportation and infrastructure	Stockholm (Sweden) GIFT City (India)	Smart Mobility Smart Living
	Local authorities Rag pickers	Storage	Bele Horizonte City (Brazil), UK, Hyderabad (India)	Smart Environment Smart Economy Smart Living
	Local authorities	Technology choice	Not identified	-
Lack of awareness and appropriate communication strategy	Citizens Local authorities Community organisations	Communication	Scotland (UK), Taiwan, Bangalore (India)	Smart People
Lack of infrastructural capacity and bargaining power	Private sector waste dealers (Small and medium enterprises)	waste volumes, storage and infrastructure	Manila (Philippines) Cairo (Egypt) and Bogota (Colombia)	Smart Economy
Lack of connection between the local and national secondary raw material markets	Private sector Local authorities	Channels for waste trade, access to markets	Cairo (Egypt) Kovalam (India)	Smart Economy
Weak stakeholder interactions	All	Information exchange, waste trade or material flow	Manila (Philippines) Scotland (UK), Bangalore and Pune (India)	Smart Government
Weak legal enforcement	Local authorities	Policy implementation and source segregation	Ahmedabad (India)	Smart Government
Lack of data	Local authorities	Data availability	Not identified	-

Chapter 7: Conclusion

7.1 Introduction to chapter

The thesis contributed in drawing a relationship between three important concepts namely smart cities, sustainability and waste management. There is a gap in literature as these concepts are not seen from a common view point though they have common objectives (Bibri and Krogstei, 2017) and each one complements the other. Waste management from smart cities perspective is mostly viewed from application of advanced technology. This thesis draws a link between waste management and smart cities from all smart categories' perspectives proposed by Giffinger *et al.*, (2007) and from the dimensions of sustainability in triple bottom line proposed by Elkington (1998 in Gimenez *et al.*, 2012). Moreover, smart cities and sustainability are seen to be limited to western countries. This thesis not only links these concepts but also applies them to the cities in developing countries that are attempting to transform to smart cities, where there is no research so far. This chapter reiterates on the key findings, the contributions of the research with its limitations and future work.

7.2 Key findings

The key findings of the research are mentioned below. Relevant section numbers from the thesis that support the findings are mentioned in brackets.

7.2.1 Factors promoting smart transformation

The application of waste free cities framework shows the relationship between smart cities, sustainability and waste management. The research found that improving waste management services plays a significant role towards smart transformation of city as each activity is found to have effects on more than one smart categories.

Improving waste service facility contributes to smart living as it affects public satisfaction (section 6.2.2.1). Similarly, providing education on waste management increases awareness and participation of citizens in source segregation and waste minimisation (section d in 6.2.2.1). While improving the services to improve smart living, it not only improves the social sustainability, but all has a positive effect on smart environment and smart economy (as shown in figure 7.1)

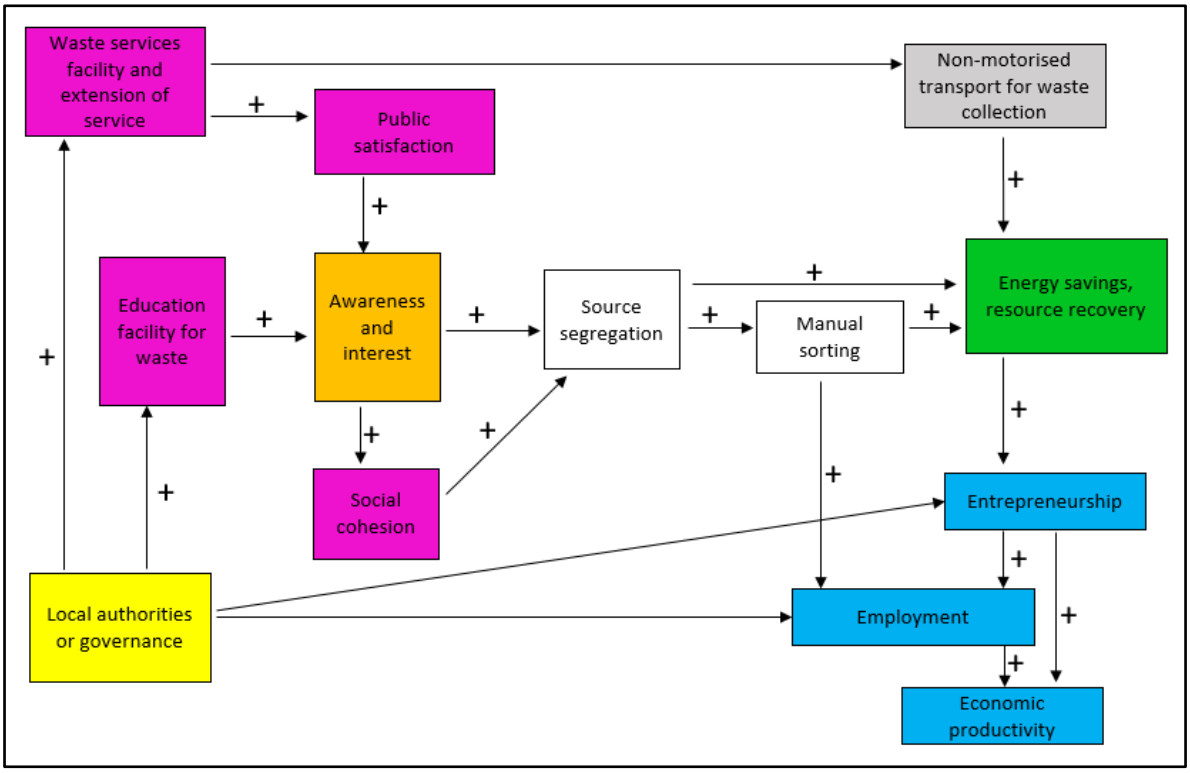


Figure: 7.1 Diagram showing the role of waste management in smart transformation and the effect of each smart category on the others due to waste managing activities (Source: Author) (Each factor in the diagram is colour coded according to their smart categories in waste free cities framework explained in chapter 3).

Awareness campaigns through activities such as clean cities championship in city 2 improved citizen participation and increased source segregation in the city. It also brought social cohesion during the process as the activity created a competitive spirit for managing waste between communities (section c in 6.2.2.1). Since social cohesion improves quality of life, the waste management awareness campaign in city 2 which is to create smart people, has also impacted on smart living.

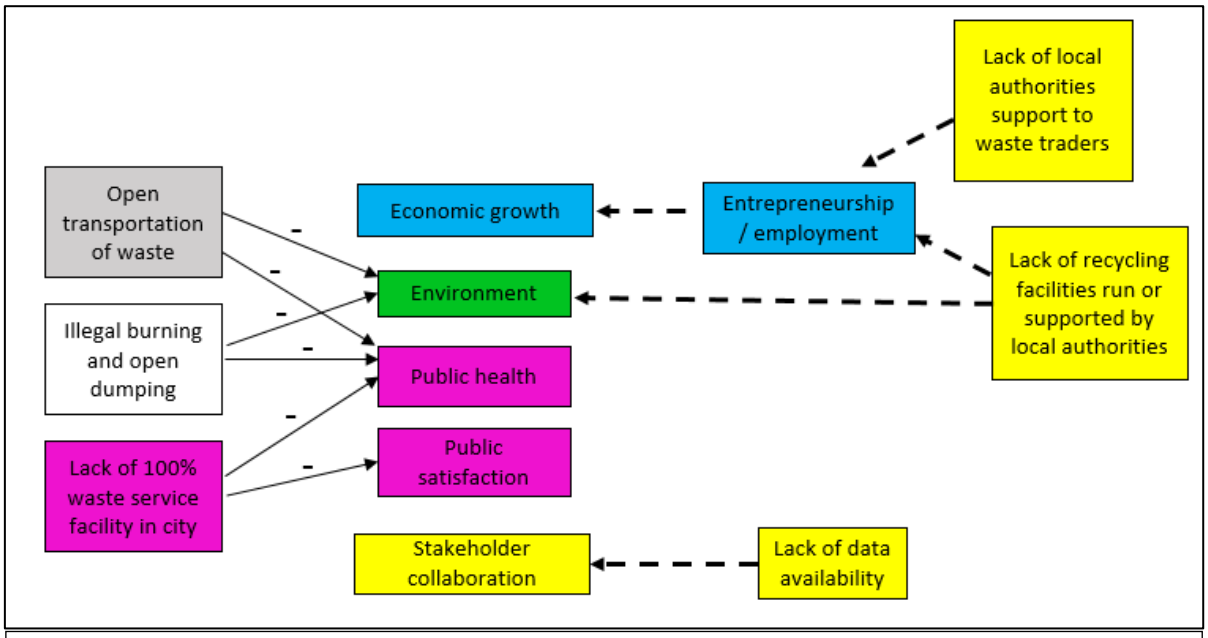
In the three cities, it is found that source segregation and resource recovery have led to significant energy savings, natural resource substitution and recycling rates (Section b in 6.2.2.1). The primary waste collection depends on non-motorised transportation (section a in 6.2.2.1) and waste processing involves manual sorting activities (6.3.1.1). Hence, they meet smart environment indicators due to the sustainable resource management.

The waste managing sector offers a great potential to generate employment and provides entrepreneurship opportunities as seen in the case or PPP in city 2 and informal sectors in all three cities (section e in 6.2.2.1). Resource recovery from waste generates income and is

found to be a profitable business at large scale (6.3.1.2). There are many registered waste dealers in all the cities who commercialise the secondary raw material extracted from waste and are also taxpayers. They add to the productivity and play a role in economic growth in addition to the supply of substitutable resources. Hence, effective waste management with greater resource recovery is fuelling a smart economy that is essential for smart transformation of city.

7.2.2 Factors limiting smart transformation

The research has identified that some of the operations in current waste management of the cities limit or negatively affect the smart transformation process as shown in figure 7.2.



Legend: *smart governance smart economy smart mobility smart living smart environment dashed line indicates restricting smart transformation and solid line with – indicates the negative effect on smart transformation).*

Figure: 7.2 Diagram showing the effect of current waste management status on smart transformation and the effect of each smart category on the others due to waste managing activities (Source: Author) (Each factor in the diagram is colour coded according to their smart categories in waste free cities framework explained in chapter 3)

Waste transport system in all the three cities is generally performed using open vehicles leading to spreading of waste and further contamination during the transportation process. So, the current system is not environmentally friendly and creates social problems such as public health and cleanliness. The waste collection service is not offered to all the households in the city due to the difficulty to access the households leading to lower public

satisfaction (section c in 6.2.2.1). Hence, the current transportation type has a negative effect on environment and living.

Environmental protection is not prioritised in any of the cities and their stakeholders. The environmental benefits obtained are only by-products of the main operations and revenue generating processes. In addition, less concern on environment is seen due to activities such as open dumping, illegal burning and littering which cause environmental burdens.

Lack of source segregation is not due to lack of awareness about its benefits. The reason for non-participation is due to the lack of short-term gain to the participants. This is evident in all the three cities as source segregation is practiced on a voluntary basis when there is an economic benefit from it (through informal sector or PPP).

Lack of inclusive governance and data availability are observed as hinderances for smart transformation. Due to lack of data, it poses difficulty to include stakeholders such as academics and research institutions.

Private waste traders and informal sector contribute significantly to economic growth through greater value addition to waste. The formal sector is not active in such activities and is restricted to collection and open dumping. The current scenario is neither promoting recycling and environmental protection nor supporting other existing services particularly in cities 1 and 3 (6.3.1.2). The city 2 shows the role of local authority is crucial to improve recycling rates or to support other organisations and workers involved in such activities (section f in 6.2.2.1). Therefore, such non-participation or service expansion retards smart transformation.

Stakeholder collaborations are different in the three cities and the differences in the collaborations are due to varied roles of local authorities in the three cities. Stronger collaborations between stakeholders and greater interactions between them significantly drives transformation (section f in 6.2.2.1 and 6.3.1.3). So, if local authorities do not prioritise such collaborations throughout the waste value chain, it restricts the transformation process.

7.2.3 Role of stakeholder collaboration and interactions

The research found that stakeholder collaboration and greater level of interactions among them play significant role in value addition to waste and there is a need to strengthen such interactions.

The interactions between stakeholder are strengthened by creating a benefit to the participating stakeholder (money, incentive, etc.) including citizens and waste traders (6.3.1.2). A competitive spirit among the communities or bringing social cohesion helps in strengthening the interaction (section c in 6.2.2.1). Moreover, stakeholder interaction for flow of information can be strengthened through use of preferred choice of communication channel (such as face to face or social media, 6.4.1.3).

7.2.4 Role of technology

The research found the role of technology in improving waste services is not the sole source in smart transformation but is an enabler. In a developing countries scenario, it has a greater role in communications than in operations.

From the operations of waste management, it is found that current activities are not relying on advanced technology or commonly called smart waste management. Since, waste management is mainly based on manual labour and their mechanical energy, it relies less on other natural resources, reduces environmental burden and also provides social benefit. However, upgrading the current infrastructure is needed to improve services and capacity.

Use of advanced technology (smart waste management) offers operational advantages particularly to improve collection efficiency, to monitor and communicate with collection staff and citizens. GPS technology for tracking operations of collection staff and RFID tagging of communal bins are successful in the cities that have used them (section a in 6.2.2.1). Hence, it is a useful technology to improve the operations of waste management in developing countries. Such technological upgrade is financially viable due to the operational benefit it offers and does not involve replacing the current infrastructure. Therefore, specific areas where such application of technology can improve services should be identified and selectively used. Applying or upgrading overall system with advanced technology is not only a financial burden but will also cause threat to thousands of people's livelihood. Hence, the direct transfer of technology cannot be a solution to developing countries' waste problem. While technology is important in improving poorly managed areas or unexplored activities of the value chain, for technology to become an enabler there is a need for adopting to locally contextual issues.

Adaptability of people to use advanced technology in waste services and willingness to change behaviour is generally present in all the three cities. It is also found that there is a changing preference of citizens for flow of information and communication purposes

including awareness campaigns. They started to choose digital communication channels such as social media and mobile applications. Therefore, use of technology is prioritised for such communication purposes (section c in 6.2.2.1 and 6.4.1.3).

7.2.5 Practical applicability

The findings show that the research has practical applicability and can be related to strategic, tactical and operational levels of planning.

7.2.5.1 Strategic level

There is a gap in policy design for waste services in line to smart city objectives such as sanitation and sustainable resource management.

There is gap in existing policies in theory and practice such as SWM rules, 2016 ad Swachh Bharat Mission pertaining to resource recovery, formalising informal sector and user fee collection are not implemented.

7.2.5.2 Tactical level

The local authorities (formal waste services) are limited to waste collection and disposal. The value recovery and disposal procedures are not prioritised. Therefore, the local authorities do not have control on the downstream activities of the waste value chain.

The policy enforcement is weak in the existing systems and does not meet the strategic plan. The environmental monitoring or assessment activities do not indicate a standard procedure or criteria making it unclear on the environmental protection measures.

7.2.5.3 Operational level

The research has identified waste management operations that have positive and negative effects on smart transformation.

The operational planning requirements include economic incentives to stakeholders, capacity building, linking secondary markets with traders and tailoring communication methods.

7.3 Contributions

The research identifies gap in literature where sustainability, smart cities and waste management are not studied together although literature is available on the concepts separately. In addition to findings mentioned in previous section, the research has theoretical and practical contributions that are summarised below.

7.3.1 Theoretical contributions

The research introduces a new concept called waste free cities. It provides a definition and framework for the concept. The concept of smart cities or their transformation process in developing countries is not studied. Moreover, the concept of waste management is not related to the smart transformation generally as well as from the context of developing countries. Hence, to fill this gap, theoretical framework for waste free cities is introduced for developing countries which considers the characteristics of smart cities, its factors and indicators that can improve waste management processes from circular economy point of view. The literature considers sustainability and smart cities as western concepts and have not been applied on developing countries leaving a gap in literature. This research includes factors relevant to cities in developing countries that are transforming or aiming to transform into smart cities. Hence, this framework proposes a new pathway enabling the application of supposedly western concepts of "sustainability" and "smart cities" to developing countries. This provides foundation for other researchers in the research area and facilitates further research on transforming smart cities in developing countries.

Waste management, smart cities and sustainability depend on multiple factors which are common. The framework, therefore, categorises such factors into smart city and sustainability dimensions. Application of framework shows how each of those categories is performing with current waste management operations. It helps in identifying the problem based on the performances and allows comparison with other cities to understand what is being done better. The three concepts in the study are driven by collaborative effort of stakeholders. Though the framework includes the stakeholder collaboration and participation, the research has also contributed by studying the different types of stakeholders, their roles and possible interactions between them. This achieves greater value addition to waste and effects smart transformation due to the effect it has on the other smart categories.

7.3.2 Practical Contributions

In answering the research objectives 1 and 2, along with framework application, the waste value chain, stakeholder' role and their interactions are studied. They have practical contribution as they can help in tactical and operational issues which have role in achieving waste free cities.

7.3.2.1 Tactical contribution

Application of the waste free cities framework helped in identifying the performance of each smart category. It also aids in detecting the factor or indicator that is causing an impact on the performance. Therefore, it helps in problem detection when any category is not performing well. It makes it evident which indicator needs improvement. Using this framework for comparison between cities helps in identifying how or in what categories the other cities are exceeding in performance. This facilitates in identifying better performing indicators which can be adopted by others.

7.3.2.2 Strategic contributions or policy implications

The research has identified several aspects of the current waste management that have positive and negative effects on smart transformation. Therefore, this enables in framing strategies or planning to improve the factors that are restricting the transformation process.

The stakeholders and their participation plays an important role in waste free cities. The interaction between the stakeholders need to be strong to improve their participation. These interactions are of different types and each interaction is affected in different ways such as legal enforcement, incentives, support, etc. Identifying the possible interactions in cities for value addition to waste is an important contribution. The motivators that can strengthen the relationship is also an important contribution as it enables decision makers to design policies accordingly. Moreover, from the three cities, it is found that formalisation process of the informal sector is unsuccessful. It also provides best practices that can be considered to achieve better approaches to include the informal sector that can benefit them and also the local authorities. Additionally, public private partnerships should be built in waste managing sectors throughout the value chain. It is also important to strengthen the private-private partnerships between the waste traders and markets through policies.

The research also found that the policies that connect secondary raw material trade with markets are absent. The decision makers can use the research to consider the positive effects of linking waste or secondary raw material traders to markets due to the economic and environmental benefits associated with them. Introducing policies which can facilitate the use of such locally recycled raw materials can create market dynamics and increase the demand for them. This will also benefit the recycling market who are found to suffer with lack of profits. Moreover, policies such as cleaner production and extended producer

responsibility should be introduced and strengthened, and such practices are currently absent in all the three cities.

7.3.2.3 Operational contributions

The research identifies various processes in waste management operations and indicates the required changes. The value chains studied show the need for stakeholder involvement and need for technological upgrade for waste collection, transportation and storage facilities. Additionally, there is a need for improvement in managerial and organisational aspects such as improving infrastructure for waste transportation and sorting, integrating informal waste workers with sorting activities, facilitating capacity building for small and medium sized waste traders, providing financial support through subsidies to the micro and small enterprises that trade and recycle waste. The other important aspect that could help in improving the waste recycling is to integrate the local and national secondary raw material markets as this could increase the channels for waste trade and help in increasing the bargaining power for micro and small waste traders. Promoting awareness through improved communication strategy and effective legal enforcement are also identified as areas that need improvement and important for operational effectiveness. The best practices section (section 6.4) of the thesis can be used to improve the current operations.

7.4 Limitations of research

The theoretical framework is limited to developing countries. A comparison between the transforming cities and smart cities from developed countries could indicate evident differences between their transformation processes. However, this framework restricts the measurement scale of various factors according to the scenarios across developing countries. To apply the framework on cities of developed countries modification of factors and measurement scale are required to draw such comparisons.

The research follows a case study method and found the relevance between waste management, sustainability and smart cities is present. The findings however cannot be generalised as the problems and solutions are local to the cities. The research also limits the study to household waste. In practice, a boundary between household waste and other types of wastes can only be drawn in the initial stages of the waste collection, but not throughout the value chain.

The research identified different types of stakeholder interaction and identifies different factors that strengthen such interactions. However, the research does not measure the strength of the interactions. This is discussed further in the future research section.

7.5 Future work

An additional theoretical framework will be developed to apply on the cities of developed countries. Verification of the current status of a city with this framework and comparing it with a more advanced city can help in developing a road map towards waste free cities. Some of the factors in the waste free cities framework that are used in this research are applicable only to developing countries. Once, all such factors show the highest score in the current framework, it indicates, the city is performing well and is capable to be compared with cities in developed countries. Therefore, this new framework is planned as future work and can not only be used to compare between the transformed cities but also between the transforming cities across nations. This will make the transition to waste free cities a two-step process. The first step is using the existing framework and achieving the highest score for most factors. The second step will be the use of the future framework that can be applied for cities in both developing and developed countries.

As mentioned in the earlier sections the stakeholder interactions are studied. Measuring those interactions with social network analysis can indicate the strength of the interaction and how the stakeholders or actor involved in it affect such strengths. Then, the positive and negative effects can be measured precisely, leading to a more effective strategic and operational planning.

References

Abdoli, S. (2009) "RFID Application in Municipal Solid Waste Management System". *International Journal of Environment and Resources*, 3(3), 447–454.

Adinyira, E., Oteng-Seifah, S. and Adjei-Kumi, T. (2007) "A Review of Urban Sustainability Assessment Methodologies". *International Conference on Whole Life Urban Sustainability and its Assessment,* Glasgow.

Agarwal, A., Singhmar, A., Kulshrestha, M. and Mittal, A.K. (2005) "Municipal solid waste recycling and associated markets in Delhi, India". *Resources, Conservation and Recycling*, 44 (1),73–90.

Ahmed, S.A. and Ali, M. (2004) "Partnerships for solid waste management in developing countries: Linking theories to realities". *Habitat International*, 28(3), 467–479.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I. and Airaksinen M. (2017) "What are the differences between sustainable and smart cities?". *Cities*, 60, 234–245.

AIIPL (2016) "Public Private Partnerships in Municipal Solid Waste Management". *Athena Infonomics*, Available at: http://nswaienvis.nic.in/Waste_Portal/Case_Studies/cs_jul15/Public%20Private%20Partnerships%20in%20Municipal%20Solid%20Waste%20Management.pdf (Accessed on 02nd May 2017)

Alberti, M. (1996) "Measuring urban sustainability". *Environmental Impact Assessment Review*, 16, 381– 42.

Albino, V., Berardi, U. and Maria, R. (2015) "Smart Cities: Definitions, Dimensions, Performance, and Initiatives". *Journal of Urban Technology*, 22(1), 3-21.

Anagnostopoulos, T., Zaslavsky, A. and Medvedev, A. (2015) "Robust waste collection exploiting cost efficiency of IoT potentiality in Smart Cities". *International Conference on Recent Advances in Internet of Things (RIoT)*, Singapore, 1-6.

Anand, P.B. (1999) "Waste Management in Madras Revisited". *Environment and Urbanization*, 18(2), 161–177.

Annepu, R.K. (2012) *Sustainable Solid Waste Management in India*, Available at:

http://www.seas.columbia.edu/earth/wtert/newwtert/Research/sofos/Sustainable_SWM_India_Final.pdf (Accessed on 10th August 2017)

Anschütz, J., Scheinberg, A. and Ijgosse, J. (2004) *Putting Integrated Sustainable Waste Managment into Practice-Using the ISWM Assessment Methodology,* Netherlands: Waste.

Anthopoulos, L. G. and Fitsilis, P. (2010) "From Digital to Ubiquitous Cities: Defining a Common Architecture for Urban Development". *Sixth International Conference on Intelligent Environments, IEEE Xplore*, 301-306.

Aphale, O., Thyberg, K.L. and Tonjes, D.J. (2015) "Differences in waste generation, waste composition, and source separation across three waste districts in a New York suburb". *Resources, Conservation and Recycling*, 99, 19–28.

APUFID (2016) *Detailed project on solid waste management of Visakhapatnam*, Available at: http://sac.ap.gov.in/sac/UserInterface/Downlaods/MSWMReports/Vizag%20DPR_R13107.pdf (Accessed on 22nd March 2017).

Armijo, C., Puma, A. and Ojeda, S. (2011) "A set of indicators for waste management programs". *2nd International Conference on Environmental Engineering and Applications IPCBEE*, vol.17, IACSIT Press, Singapore.

Aruna, D., Reddy, T.B., Swamy, A.V.V.S. (2013) "Study of Municipal Solid Waste Management Scenario of Kakinada City". *International Journal of Engineering Research and Applications*, 3(1), 931-940.

Bakıcı, T., Almirall, E. and Wareham, J. (2012) "A Smart City Initiative: The Case of Barcelona". *Journal of the Knowledge Economy*, 2(1), 1–14.

Bandara, N.J., Hettiaratchi, J.P., Wirasinghe, S.C. and Pilapiiya, S., (2007) "Relation of waste generation and composition to socio-economic factors: a case study". *Environmental Monitoring and Assessment*, 135(1–3), 31–39.

Barr, S., Ford, N.J., and Gilg, A.W. (2003) "Attitudes towards recycling household waste in Exeter, Devon: quantitative and qualitative approaches". *Local Environment*, 8(4),407–421.

Barrionuevo, J.M., Berrone, P. and Ricart, J.E. (2012) "Smart Cities, Sustainable Progress". *IESE Insight*, 14, 50–57.

Baud, I., Grafakos, S., Hordijk, M. and Post, J. (2001) “Quality of Life and Alliances in Solid Waste Management: Contributions to Urban Sustainable Development”. *Cities*, 18 (1), 3–12.

Bautista, J. and Pereira, J. (2006) "Modeling the problem of locating collection areas for urban waste management. An application to the metropolitan area of Barcelona". *Omega Elsevier*, 34(6), 617-629.

Beigl, P., Wassermann, G., Schneider, F. and Salhofer, S. (2004) “Forecasting Municipal Solid Waste Generation in Major European Cities”, *9th International Congress on Environmental Modelling and Software.* .Available at: https://scholarsarchive.byu.edu/iemssconference/2004/all/83 (Accessed on 20th November, 2015)

Bibri, S. and Krogstie, J. (2017) “Smart sustainable cities of the future: An extensive interdisciplinary literature review". *Sustainable Cities and Society*, 31, 183–212.

Bibri, S. E. (2013) *ICT for sustainable urban development in the European Information Society: A discursive investigation of energy efficiency technology*, Master Thesis. School of Culture and Society, Malmö University. in Bibri, S. and Krogstie, J. (2017) “Smart sustainable cities of the future: An extensive interdisciplinary literature review". *Sustainable Cities and Society*, 31, 183–212.

Bibri, S. E. (2015b) *The shaping of Ambient Intelligence and the Internet of Things: Historico-epistemic, socio-cultural, politico-institutional and eco-environmental dimensions*, Berlin, Heidelberg: Springer-Verlag. In in Bibri, S. and Krogstie, J. (2017) “Smart sustainable cities of the future: An extensive interdisciplinary literature review". *Sustainable Cities and Society*, 31, 183–212.

Binder, C.R. et al., (2008) "Smart labels for waste and resource management: An integrated assessment". *Journal of Industrial Ecology*, 12 (2), 207-229

Binder, C.R., Quirici, R., Domnitcheva, S. and Staubli, B. (2008) "Smart Labels for Waste and Resource Management -An Integrated Assessment". *Journal of Industrial Ecology*, 12 (2), 207-228.

Bingham, S. (2018) *Chicago Climate Action Plan Advanced Transportation Technologies Initiative: Final Project Report*. United States.

Blackburn, W.R. (2007) *The Sustainability Handbook: The Complete Management Guide to Achieving Social, Economic and Environmental Responsibility*. London: Earthscan.

Block, T., Assche, JC., and Goeminne, G. (2013) “Unravelling urban sustainability. How the Flemish City Monitor acknowledges complexities” *Ecological Informatics*, 17, 104–110.

Borghi, A.D., Gallo, M. Strazza, C., Magrassi, F., Castagna, M. (2014) "Waste Management in Smart Cities: the application of circular economy in Genoa (Italy), *Impresa Progetto-Electronic Journal of Management*, n.4.

Boyatzis, R. (1998) *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.

Boyce, C. and Neale, P. (2006) *Conducting In-Depth Interviews: A Guide for Designing and Conducting In-Depth Interviews*, Watertown, USA: Pathfinder International.

Bradley, J. (1993) "Methodological issues and practices in qualitative research". *Library Quarterly*, 63(4), 431-449.

Braun, V. and Clarke, V. (2006) "Using thematic analysis in psychology" *Qualitative Research in Psychology*, 3(2), 77-101.

Bryman, A. and Bell, E. (2007) *Business Research Methods*, 2nd Edition. Oxford: Oxford University Press.

Burnley, S.J. (2007) "A review of municipal solid waste composition in the United Kingdom". *Waste Management*, 27(10), 1274–1285.

Caniato, M., Mentore, V., Visvanathan, C., and Zurbrugg C. (2014) “Using social network and stakeholder analysis to help evaluate infectious waste management: A step towards a holistic assessment” *Waste Management*, 34, 938–951.

Caniato, M., Tudor, T. and Vaccari, M. (2015) “Understanding the perceptions, roles and interactions of stakeholder networks managing health-care waste: A case study of the Gaza Strip”. *Waste Management*, 35, 255–264.

Caragliu, A., Del Bo, C. and Nijkamp, P. (2009) "Smart Cities in Europe". *Proceedings of the 3rd Central European Conference in Regional Science—CERS*, Kosice, 7-9 October 2009, 49-59.

Castells, M (2000), "Urban sustainability in information age", *City*, 4(1), 118-122.

Census (2011a) *Rural Urban Distribution* (Online) Available at: http://www.censusindia.gov.in/(S(rowyjkyvbddqva550hjwgc55))/Census_Data_2001/India_a t_Glance/rural.aspx (Accessed on 7th March 2017).

Census (2011b) *Government of India* (Online) Available at: http://www.censusindia.gov.in/2011census/PCA/A-2_Data_Tables/00%20A%202-India.pdf (Accessed on 12th March, 2017)

Central Intelligence Agency (CIA), (2017), *The World Factbook*, Available at: https://www.cia.gov/library/publications/resources/the-world-factbook/geos/in.html (Accessed on 20th September 2016).

Chatterjee, S. and Kar, A.K. (2015) "Smart Cities in Developing Economies: A Literature Review and Policy Insights". *International Conference on Advances in Computing, Communications and Informatics (ICACCI), IEEE*, 2335-2340.

Chen, T-M. (2010) "Smart Grids, Smart Cities Need Better Networks". *IEEE Network*, 24(2), 2-3.

Cheng, H. and Hu, Y. (2010) "Planning for sustainability in China's urban development: Status and challenges for Dongtan eco-city project". *Journal of Environmental Monitoring*, 12(1), 119–126.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J.R., Mellouli, S., Nahon, K., Pardo, T.A. (2011), "Understanding smart cities: An integrative framework", *Proceedings of the Annual Hawaii International Conference on System Sciences*, Available at: https://doi.org/10.1109/HICSS.2012.615 (Accessed on 20th December, 2016).

Chowdhury, B. and Chowdhury, M.U. (2007) "RFID-based real-time smart waste management system". *In Australasian Telecommunication Networks and Applications Conference, ATNAC* 2007.

CDP-City Development Plan, (2011). *Warangal City Development Plan*, Hyderabad: Urban Governance Area, Administrative Staff College of India (ASCI).

Cointreau-Levine, S. (1994) "Private sector participation in municipal solid waste management in developing countries In: The Formal Sector", *Urban Management Programme Policy Paper*, 13(1), Washington: World Bank.

Colon, M., Fawcett, B., (2006) "Community-based household waste management: lessons learnt from EXNOR's zero waste management scheme in two south Indian cities". *Journal of Habitat International*, 30, 916-931.

Connett, P. (2013) *The Zero Waste Solution*, Vermont: Chelsea Green Publishing.

Contento, I.R. (2011) "Using Research and Theory in Practice: A Stepwise Procedure for Designing Thory-Based Nutrition Education". In I.R. Contento (ed) *Nutrition Education: linking research, theory, and practice*, 2nd Edition. Sudbury: Jones and Barrlett Publishers.

Contreras, F., Hanaki, K., Aramaki, T. and Connors, S. (2008) "Application of analytical hierarchy process to analyze stakeholders' preferences for municipal solid waste management plans, Boston, USA". *Resources, Conservation and Recycling*, 52(7), 979–991.

CPHEEO (2017) *Central Public Health & Environmental Engineering Organisation*, Ministry of Urban Development, Government of India, http://cpheeo.nic.in/ (Accessed on 04th May 2017)

Cresswell, J.W. (2007) *Qualitative Inquiry and Research Design: Choosing among five approaches*. 2nd Edition, California: Sage Publications.

Creswell, J. W. (2003). *Research design: qualitative, quantitative, and mixed methods approaches*. 2nd Edition, London: SAGE Publications.

Creswell, J.W. (2009) "Mapping the field of mixed methods research", *Journal of Mixed Methods Research*, 3 (2), 95-108.

Dahlén, L., Vukicevic, S., Meijer, J.E., Lagerkvist, A. (2007) "Comparison of different collection systems for sorted household waste in Sweden". *Waste Management*, 27(10),1298–1305.

Denscombe, M. (2002) *Ground Rules for Good Research: A 10 Point Guide for Social Researchers*. Buckingham: Open University Press.

Denzin, N.K. (1978) *Sociological Methods*, New York: McGraw-Hill.

Denzin, N.K. and Lincoln, Y.S. (2003) *Strategies of qualitative inquiry*, 2nd Edition. California: Sage Publications.

Denzin, N.K., and Lincoln, Y.S. (2003) *The Landscape of Qualitative Research, Theories and Issues*, 2nd Edition, London: Sage Publications.

Department for Business Innovation and Skills (DBIS), (2013) *The Smart City Market: Opportunities for the UK,* Research paper number 136. United Kingdom: Ove Arup and Partners Ltd.

Desmond, M. (2006) "Municipal solid waste management in Ireland: Assessing for sustainability", *Irish Geography*, 39(1), 22-33.

Dias, S.M. (2011) "Integrating informal workers into selective waste collection: the case of Belo Horizonte, Brazil- WIEGO Policy Brief". *Urban Policies*, 4, 1-12.

Donaldson, T. and Preston, L. (1995) "The stakeholder theory of the corporation: Concepts, evidence and implications". *Academy of Management Review*, 20, 65-91.

Dowlatshahi, S. (2000) "Developing a theory of reverse logistics". *Interfaces*, 30(3): 143-55.

DPR. (2016a), *Detailed Project Report on Municipal Solid Waste Management for Visakhapatnam DPR on MSWM for Visakhapatnam*, available at: http://sac.ap.gov.in/sac/UserInterface/Downlaods/MSWMReports/Vizag DPR_R13107.pdf. (Accessed on 25th November, 2016).

DPR. (2016b) *Draft Detailed Project Report for Warangal Municipal Corporation, Cluster-III*, IPE Global Limited, New Delhi.

DPR. (2016c), *Draft Detailed Project Report for Implementation of Municipal Solid Waste Management in ULBs in Andhra Pradesh for Zone-II Under East and West Godavari*, Available at: http://sac.ap.gov.in/sac/UserInterface/Downlaods/MSWMReports/Kakinada%20Draft%20%20DPR.pdf (Accessed on 3rd January, 2017).

Dresner, S. (2002) *The Principles of Sustainability*, 2nd edition. London: Routledge.

Easterby-Smith, M., Thorpe, R. and Jackson, P. R. (2008) *Management research*, 3rd edition London, SAGE Publications

Ekere, W., Mugisha, J., Drake, L. (2009) “Factors influencing waste separation and utilization among households in the Lake Victoria crescent, Uganda”. *Journal of Waste Management*, 29, 3047–3051.

Elkington, J. (1998) “Cannibals with Forks: The Triple Bottom Line of the 21st Century”. New Society Publishers, Stoney Creek. In Gimenez, C., Sierra, V., and Rodon, J (2012) "Sustainable operations: Their impact on the triple bottom line", *Int. J.Production Economics*, 140, 149–159.

Elkjaer, B. and Simpson, B. (2011) “Pragmatism: A lived and living philosophy. What can offer to contemporary organization thoery?” in H. Tsoukas and R.Chia (eds) *Philosophy and Organization theory*. Bradford: Emerald publishing Ltd, pp. 55-84.

Elliot, J.A. (2006) *An Introduction To Sustainable Development*, 3rd edition. Oxon: Routledge.

Eltis (2017) “Gelsenkirchen tests EVs for waste collection (Germany)”, Eltis, *The Urban Mobility Observatory*, Available at: http://www.eltis.org/discover/news/gelsenkirchen-tests-evs-waste-collection-germany?utm_medium=email&utm_campaign=Eltis%20Mobility%20Update%20April%202017&utm_content=Eltis%20Mobility%20Update%20April%202017+CID_26a41b68491bb3b8cbe3951c26583c9b&utm_source=Email%20marketing%20software&utm_term=Gelsenkirchen%20tests%20EVs%20for%20waste%20collection (Accessed on 29th June, 2017).

EPA (2016) Waste reduction Model: Energy and the Environment, United States Environmental Protection Agency, Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (Accessed on 17th April, 2018)

Eremia, M., Toma, L. and Sanduleac M. (2017) “The Smart City Concept in the 21st Century”. *Procedia Engineering*, 181, 12-19.

Ezeah, C., Fazakerley, J.A. and Roberts, C.L. (2013) “Emerging trends in informal sector recycling in developing and transition countries”, *Waste Management*, 33, 2509-2519

FFMR-Fact Finding Mission Report (2016) *Smart City Kakinada*, India:Innovative Centre Denmark.

Falconer, G and Mitchell, S (2012) *Smart City Framework: A Systematic Process for Enabling, Smart+Connected Communities*. Available at https://www.cisco.com/c/dam/en_us/about/ac79/docs/ps/motm/Smart-City-Framework.pdf (Accessed on 23 May 2017)

Filho, WL., Brandli, L., Moora, H., Kruopien, J. and Stenmarck A. (2016) "Benchmarking approaches and methods in the field of urban waste Management", *Cleaner Production*, 112, 4377-4386.

Firestone, W. A. and Herriott, H.R. (1983) "The formalization of qualitative research", *Evaluation Review*, 7(4), 437-466

Fleematics, (2015) *Fleetmatics Helps Ireland's Leading Glass Recycling Firm Improve Customer Service,* Available at: https://www.fleetmatics.co.uk/ourcustomers/rehab-glassco (Accessed on 20th November 2015)

Flick, U. (2006), *An Introduction to Qualitative Research*, London: Sage Publishers

Fullerton, D. and Kinnaman, T.C. (1996) "Household responses to pricing garbage by the bag". *Am Econ Rev*, 86(4), 971–84.

Giddens, A. (2006) *Global inequality*, *Sociology*, 5th edition. Cambridge: Polity Press.

Giffinger, R. and Gudrun, H. (2010) "Smart Cities Ranking: An Effective Instrument For The Positioning Of Cities?". *Architecture, Environment and City*, 12, 7-25.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., and Meijers, E. (2007) "Smart Cities: Ranking of European Medium-Sized Cities". Vienna, Austria: Centre of Regional Science (SRF), Vienna University of Technology, Available at: http://www.smart- cities.eu/download/smart_cities_final_report.pdf. (Accessed on 20th January 2018).

Giffinger, R., Kramar, H., and Haindl, G. (2008) "The role of rankings in growing city competition". *In Proceedings of the 11th European Urban Research Association (EURA) Conference*, Milan, Italy, October 9-11, Available at: http://publik.tuwien.ac.at/files/PubDat_167218.pdf.(Accessed on 12th September 2015).

Gil-García, J. R., and Pardo, T. A. (2005) "E-government success factors: Mapping practical tools to theoretical foundations". *Government Information Quarterly*, 22(2), 187-216.

Gimenez, C., Sierra, V., and Rodon, J. (2012) "Sustainable operations: Their impact on the triple bottom line", *International Journal of Production Economics*, 140, 149–159.

Giovanis, E., (2015) "Relationship between recycling rate and air pollution: Waste management in the state of Massachusetts". *Waste Management*, 40, 192–203.

Girardi, P. and Temporelli, A. (2017) "Smartainability: a methodology for assessing the sustainability of the smart city". *Energy Procedia*, 111, 810 – 816.

Government of India (GoI) and Government of Telangana State (GoTS), (2017) *Power for All*, Ministry of Power, Available at: https://powermin.nic.in/sites/default/files/uploads/Power_For_All_4_12_Final_Telangana_Signed.pdf (Accessed on 15th December, 2018).

Graham, S. (2002) "Bridging Urban Digital Divides? Urban Polarisation and Information and Communications Technologies (ICTs)". *Urban Studies*, 39 (1), 33-56.

Grazhdani, D. (2016) " Assessing the variables affecting on the rate of solid waste generation and recycling: An empirical analysis in Prespa Park". *Waste Management*, 48, 3-13.

Guba, E.G. and Lincoln, Y.S. (1989) *Forth Generation Evaluation*. California: Sage Publication.

Gubrium, J.F. and Holstein, J.A. (1997) *The New Language of Qualitative Method*. New York: Oxford University Press.

Guerrero, L.A., Maas, G. & Hogland, W. (2013) "Solid waste management challenges for cities in developing countries". *Waste Management*, 33(1), 220–232.

Gupta, S.K. (2012), *Integrating the Informal Sector for Improved Waste Management*, available at: http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/E-Learning/Moocs/Solid_Waste/W2/Integrating_informal_sector_improved_waste_management.pdf.(Accessed on 26th March, 2018).

GVMC Website (2017) *Greater Visakhapatnam Municipal Corporation, About Vizag Corporation,* Available at https://www.gvmc.gov.in/gvmc/index.php/layout/introduction (accessed on 2nd March 2017).

Haan, H. C., Coad, A., Lardinois, I. (1998). *Municipal waste management: Involving micro-and-small enterprises*. Guidelines for municipal managers. Turin, Italy: International Training Centre of the ILO, SKAT, WASTE.

Hall, R. E. (2000) "The vision of a smart city". *In Proceedings of the 2nd International Life Extension Technology Workshop*, Paris, France, September 28, Available at: http://www.osti.gov/bridge/servlets/purl/773961-oyxp82/webviewable/773961.pdf

Hancke, G.P., Silva, B.C., and Hancke Jr., G.P. (2013) "The Role of Advanced Sensing in Smart Cities". *Sensors*, 13, 393-425.

Haque, U. (2012) "Surely There's a Smarter Approach to Smart Cities?". *Wired*, 17 April. Available at: http://www.wired.co.uk/news/archive/2012-04/17/potential-ofsmartercities-beyond-ibm-and-cisco

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., and Williams, P. (2010) "Foundations for Smarter Cities". *IBM Journal of Research and Development*, 54(4)

Henry, R.K., Yongsheng, Z., Jun, D. (2006) "Municipal solid waste management challenges in developing countries – Kenyan case study". *Journal of Waste Management*, 26, 92–100.

Hiremath, R.B., Balachandra, P., Kumar, B., Bansode, S.S. and Murali, J. (2013) "Indicator-based urban sustainability—A review". *Energy for Sustainable Development*, 17, 555–563.

Hollands R.G. (2008) "Will the real smart city please stand up?". *City*, 12 (3), 303-320.

Hollands, R. G. (2008) "Will the real smart city please stand up?" *City: Analysis of Urban Trends, Culture, Theory, Policy, Action*, 12(3), 303–320.

Hoornweg, D. and Bhada-Tata, P. (2012) "What a waste: a global review of solid waste management". *World Bank Open Knowledge Repository*, Available at http://documents.worldbank.org/curated/en/2012/03/16537275/waste-global-reviewsolid-waste-management (Accessed on 20th August 2016).

"Huang, S. L., Wong, J. H., & Chen, T. C. (1998). "A framework of indicator system for measuring Taipei's urban sustainability". *Landscape and Urban Planning*, 42, 15-27.

Huang, S. -L., Yeh, C. -T., Budd,W.W., & Chen, L. -L. (2009). "A Sensitivity Model (SM) approach to analyze urban development in Taiwan based on sustainability indicators". *Environmental Impact Assessment Review*, 29, 116–125.

Huberman, A. M., and Miles, M. B. (1994). "Data management and analysis methods". In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 428-444). Thousand Oaks, CA, US: Sage Publications, Inc.

Ilic, M. and Nikolic, M. (2016a) "Waste management benchmarking: A case study of Serbia". *Habitat International*, 53, 453-460.

Ilic, M. and Nikolic, M. (2016b) "Drivers for development of circular economy: A case study of Serbia". *Habitat International*, 56, 191-200.

India Brand Equity Foundation (2017) *Indian Economy Overview*, Available at http://www.ibef.org/economy/indian-economy-overview (Accessed on 5th March, 2017)

Iriarte A., Gabarrell X., and Rieradevall, J. (2009) "LCA of selective waste collection systems in dense urban areas". *Waste Management*, 29, 903-914.

Iskandar, L. K. (2003). "Integrating local community-based waste management into international contracting". *In proceedings of solid waste collection that benefits the urban poor, 9–14 March, Dar Es Salaam, Tanzania*. Switzerland: The SKAT Foundation

ITC (2015) *WOW –Wellbeing out of Waste a CSR Initiative of ITC Limited*, Available at: http://cdma.telangana.gov.in/docs/WOW%20info%20Updated.pdf (Accessed on 20thDecember, 2016).

Jahre, M. (1995) "Household waste collection as a reverse channel". *International Journal of Physical Distribution and Logistics Management,* 25(2), 39-55.

Jaligot, R., Wilson, D.C., Cheeseman, C.R., Shaker, B. and Stretz, J. (2016) "Applying value chain analysis to informal sector recycling: A case study of the Zabaleen". *Resources, Conservation and Recycling*, 114, 80–91.

Jaysawal, N. and Saha, S. (2014) "Urbanization in India: An Impact Assessment". *International Journal of Applied Sociology*, 4(2), 60–65.

Jick, T.D. (1979) "Mixing Qualitative and Quantitative Methods: Triangulation in Action". *Administrative Science Quarterly*, 24(4), 602-611.

Joseph, K. (2006) “Stakeholder participation for sustainable waste management”, *Habitat International*, 30(4), 863–871.

Kaplinsky, R., and Morris, M. (2001) *A Handbook for Value Chain Research*. Canada: IDRC, Available at: http://asiandrivers.open.ac.uk/documents/Value chain Handbook RKMM Nov 2001.pdf (Accessed on 30th December, 2018).

Kaseva, M. E. and Gupta, S. K. (1996) "Recycling—An environmentally friendly and income generating activity towards sustainable solid waste management. Case study—Dar es Salaam City, Tanzania". *Resources, Conservation and Recycling*, 17, 299–309.

Kaseva, M.E. and Mbuligwe, S.E. (2005) "Appraisal of solid waste collection following private sector involvement in Dar es Salaam city, Tanzania". *Habitat International*, 29(2), 353–366.

Kassim, S.M. and Ali, M. (2006) "Solid waste collection by the private sector: Households’ perspective-Findings from a study in Dar es Salaam city, Tanzania". *Habitat International*, 30(4), 769-780.

Kelemen, M. and Rumens, N. (2008) *An introduction to Critical Management Research*. London: Sage Publications.

Khajuria, A., Matsui, T., Machimura, T. and Morioka, T. (2010) "Assessment of the challenge of sustainable recycling of municipal solid waste management in India". *International Journal of Environmental Technology and Management*, 13(2), 171-187.

Klundert, AV. and Anschutz J. (2001) *Integrated Sustainable Waste Management - the Concept: Tools for Decision-makers Experiences from the Urban Waste Expertise Programme (1995-2001),* Netherlands: Waste

Kotzab. H., Securing, S., Muller, M., and Reiner, G. (2005*) Research Methodologies in Supply Chain Management*, Heidelberg: Physica-Verlag HD

Kourtit, K., and Nijkamp, P. (2012) "Smart cities in the innovation age". *Innovation: The European Journal of Social Sciences*, 25(2), 93–95.

Koushki, PA., Al-Duaij and Al-Ghimlas (2004) "Collection and transportation cost of household solid waste in Kuwait" *Waste Management*, 24: 957–964.

Kumar, S., Bhattacharyya, J.K., Vaidya, A.N., Chakrabarti, T., Devotta, S. and Akolkar, A.B. (2009) "Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: an insight". *Waste Management*, 29(2), 883-95.

Kummitha, R.K.R. and Crutzen, N. (2017) "How do we understand smart cities? An evolutionary perspective". *Cities*, 67, 43–52.

Kvale, S. and Brinkman, S. (2009) *Inter Views: Learning the craft of qualitative research interviewing*, London: Sage Publications.

Lazaroiu, G. and Roscia, M. (2012) "Definition methodology for the smart cities model". *Energy*, 47(1), 326–332.

Lee, J.H., Hancock, M.G. and Hu, M.C. (2014) "Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco". *Technological Forecasting & Social Change*, 89, 80–99.

Lee, N. and Lings, I. (2008*) Doing Business Research: A Guide to Theory and Practice*, London: Sage Publishers.

Letaifa, S.B. (2015) "How to strategize smart cities: Revealing the SMART model". *Journal of Business Research*, 68, 1414–1419.

Lewis, J.C. and Nain, M.M (1995) "Benchmarking of aftermarket supply chains", *Production Planning and Control*, 6, 258-269.

Likert, R. (1932) "A technique for the measurement of Attitudes" in Woodworth, R.S (Ed), *Archives of Psychology*, New York.

Lincoln, Y. and Guba, E. (1985) *Naturalistic Enquiry*. Newbury park: CA, Sage Publications.

Linderhof, V., Kooreman, P., Allers, M. and Wiersma, D. (2001), "Weight-based pricing in the collection of household waste: The Oostzaan case". *Resource and Energy Economics*, 23(4), 359–371.

Linzer, R. and Lange, U. (2013) "Role and size of informal sector in waste management – a review", *Proceedings of the Institution of Civil Engineers Waste and Resource Management*, 166, 69–83.

Linzner, R. and Salhofer, S. (2014) “Municipal solid waste recycling and the significance of informal sector in urban China”, *Waste Management & Research*, 32(9), 896-907.

Lohri, C.R., Camenzind, E.J. and Zurbrugg, C. (2014) "Financial sustainability in municipal solid waste management – Costs and revenues in Bahir Dar, Ethiopia". *Waste Management*, 34, 542–552.

Lombardi, P., Giordano, S., Caragliu, A., Del Bo, C., Deakin, M., Nijkamp, P. and Kourtit K. (2011) “An Advanced Triple-Helix Network Model for Smart Cities Performance”. *Research Memorandum 2011-45*, Available at https://www.researchgate.net/publication/241755976_An_Advanced_Triple-Helix_Network_Model_for_Smart_Cities_Performance (Accessed on May 29th, 2017)

Lombardi, P., Giordano, S., Farouh, H., and Yousef, W. (2012) "Modelling the smart city performance". *Innovation: The European Journal of Social Science Research*, 25(2), 137–149.

Longhurst, R (2009) "Interviews: In-Depth, Semi Structured". *In International Encyclopaedia of Human Geography*, United Kingdon: Elsevier.

Marsal-Llacuna, M.L., Colomer-Llinàs and Meléndez-Frigola, J. (2015) “Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative”. *Technological Forecasting & Social Change*, 90, 611–622.

Marshall, RE. and Farahbakhsh, K. (2013) “Systems approaches to integrated solid waste management in developing countries”. *Waste Management*, 33, 988–1003.

Matete, N. and Trois, C. (2008) “Towards Zero Waste in emerging countries – A South African experience”. *Waste Management*, 28, 1480–1492.

Mayangsari, L. and Novani, S. (2015) “Multi-stakeholder co-creation analysis in smart city management: an experience from Bandung, Indonesia”. *Procedia Manufacturing*, 4, 315 – 321.

Medina, M., (1997) "The effect of income on municipal solid waste generation rates for countries of varying levels of economic development: a model". *Journal of Solid Waste Technology and Management*, 24 (3), 149–155.

Miles, M. B. and Huberman, A. M. (1994) *Qualitative Data Analysis*, 2nd Edition, Thousand Oaks, CA, Sage Publications.

Ministry of Urban Development (MoUD). (2017), *Swachh Survekshan 2017*, available at: https://swachhsurvekshan2018.org/Images/SS_2017_Report.pdf.(Accessed on 24th March 2018)

MIT (2013) *Smart Cities Group*, Cambridge, MA.

Moghadam, M.R.A., Mokhtarani, N., Mokhtarani, B. (2009) "Municipal solid waste management in Rasht City. Iran". *Journal of Waste Management*, 29, 485–489.

MoUD (2017) CPHEEO, Ministry of Urban Development, India, Available at: http://www.moud.gov.in/cms/cpheeo.php (Accessed on 23rd April 2017)

MSW Rules, 2000, (2000). *The Gazette of India. Municipal Solid Waste (Management and Handling) Rules, 2000*, Ministry of Environment and Forests (MoEF), New Delhi, India.

Mutz, D. (2015) "Circular economy and informal waste management in India - a contradiction?".*Resource Politics,Institute of Development Studies* 7 – 9 September 2015, Available at:https://resourcepolitics2015.files.wordpress.com/2015/09/mutz.pdf (Accessed on 20th November, 2017).

Nam, T. and Pardo, T. A. (2011) "Conceptualizing Smart City With Dimensions of Technology, People, and Institutions". *from Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*, ACM New York, NY. Available at: http://smartcitiescouncil.com/system/files/resources/Conceptualizing%20smart%20city.pdf

Navigant Research (2014). *Smart Waste Advanced Collection, Processing, Energy Recovery, and Disposal Technologies for the Municipal Solid Waste Value Chain: Global Market Analysis and Forecasts*, USA: Navigant Consulting, Inc.

NIC (2017) *Visakhapatnam District*, Ministry of Communication and Information Technology, Government of India (Online) Available at http://visakhapatnam.nic.in/ (Accessed on 5th March 2017).

NSWAI-ENVIS (2014) *Municipal Solid Waste Management Newsletter: Training and Awareness*, Ministry of Environment & Forests, Government of India.

Oteng-Ababio, M. (2011) "Missing links in solid waste management in the Greater Accra Metropolitan Area in Ghana". *GeoJournal*, 76(5), 551–560.

Partridge, H. (2004) "Developing a human perspective to the digital divide in the smart city". *In Proceedings of the Biennial Conference of Australian Library and information Association (ALIA),* Queensland, Australia, September 21-24, Available from http://eprints.qut.edu.au/1299/1/partridge.h.2.paper.pdf (Accssed on 5th March, 2015)

Patel, A. (2012) *Waste Management Miracle In Warangal*, India: Supreme Court Committee for Solid Waste Management.

Patzer, G. M., (1995) *Using secondary data in marketing research*, Westport: Quorum.

Paul, J.G., Arce-Jaque, J., Ravena, N. and Villamor, S.P. (2012) "Integration of the informal sector into municipal solid waste management in the Philippines –What does it need?". *Waste Management*, 32 (11), 2018–2028. in Aparcana, S. (2017) "Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: Review of barriers and success factors" *Waste Management*, 61, 593–607.

Peltola, T., Aarikka-Stenroos, L., Viana, E. and MCakinen, S. (2016) "Value capture in business ecosystems for municipal solid waste management: Comparison between two local environments". *Journal of Cleaner Production*, 137, 1270-1279.

Pires, A., Martinho, G., and Chang, N. (2010) "Solid waste management in European countries: A review of systems analysis techniques". *Journal of environmental management*, 92(4), 1033-1050.

Pitney, W.A. and Parker, J.(2009) *Ensuring Trustworthiness of Data. In Qualitative Research in Physical Acitivty and the Health Profressions*. HumanKinetics: Champaign, IL.

Planning Commission, Government of India (2014) *Report of the task Force on waste to energy (Volume I) in the context of integrated municipal solid waste management*, Available at: http://planningcommission.nic.in/reports/genrep/rep_wte1205.pdf (accessed on 12th April, 2017).

Pokhrel, D. and Viraraghavan, T. (2005) "Municipal solid waste management in Nepal: practices and challenges". *Journal of Waste Management*, 25, 555–562.

Polese, F. (2009) “The Influence of networking culture and social relationships on value creation”, in Quaderni di Sinergie, “Firms' Management: Processes, Networks and Value”, n.16, *supplemento al n. 80 Sett-Dic*, pp. 193-215.

Porritt, J. (2007) *Capitalism as If The World Matters*. London: Earthscan

Powell, J. and Lovelock, R. (1987) "The role of consumers' view in the evaluation of services: a case study - traveling to the hospital". *Social Services Research*, 16(1),16-29.

Praveena, G.S., Prasad, D.C. and Rao, P. (2015) “The Plight of Rag-pickers at Dump yard Socio -Economic Profile A Case Study of Visakhapatnam”. *International Journal of Innovative Research and Creative Technology*, 1(4), 374-378.

Prokic, D., & Mihajlov, A. (2012). “Contaminated sites. Practice of solid waste management in a developing country (Serbia)”. *Environment Protection Engineering*, 38(1), 81-90.

Qdais, H.A.A. (2007) “Techno-economic assessment of municipal solid waste management in Jordan”. *Waste Management*, 27, 1666–1672.

Rahim, M. and Jalaladeen, J. (2016) "The Role of Social Media on Environmental Awareness of Undergraduate Students in University of Sulaimani in Iraq". *Journal of Arts, Literature, Humanities and Social Sciences*, 10, 218-231.

Rapley, T. (2007), *Doing conversation, discourse and document analysis*, London: Sage.

Rathi, S., (2006) "Alternative approaches for better municipal solid waste management in Mumbai, India". *Waste Management*, 26(10), 1192–1200.

Reddy, P.L. (2017) *Underground dumper bins mooted for Warangal*, Warangal Urban: Telangana Today, Available at: https://telanganatoday.com/underground-dumper-bins-mooted-warangal (Accessed on 20th November 2017)

Richardson, N. (1989) *Land use and planning and sustainable development in Canada*, Ottawa: Canadian Environmental Advisory Council.

Rios, P. (2008). *Creating the smart city*, Available at: http://dspace.udmercy.edu:8080/dspace/bitstream/10429/20/1/2008_rios_smart.pdf. (Accessed on 07th August 2015)

Rode, P. and Burdett, R. (2011) "Cities: investing in energy and resource efficiency". In United Nations Environment Programme, (corp. ed.) *Towards a green economy: pathways to sustainable development and poverty eradication*. United Nations Environment Programme, 453-492.

Sanjeevi, V. and Shahabudeen P. (2015) "Development of performance indicators for municipal solid waste management (PIMS): A review". *Waste Management & Research*, 33(12), 1052–1065.

Sankar, K.N.M. (2017) *Plastic roads help civic body tackle waste, save cost*, Kakinada: The Hindu, Available: https://www.thehindu.com/news/national/andhra-pradesh/Plastic-roads-help-civic-body-tackle-waste-save-cost/article17070628.ece (Accessed on 20th November 2018).

Sanroma, M. (2012) *Barcelona Smart City*, Available at: https://www.majorcities.eu/misc/workshops/2012-02-helsinki/ (accessed on 10 November 2018).

Saunders, M. N. K., Lewis, P. and Thornhill, A. (2016), *Research Methods for Business Students*, 7th ed., Pearson Publication, Harlow, England.

Scheinberg, A., Simpson, M. and Gupt, Y. (2011). *The Economics of the Informal Sector in Solid Waste Management*, Eschborn, Germany: GTZ (German Technical Cooperation) and the Collaborative Working Group on Solid Waste Management in Low- and Middle-income Countries (CWG).

Scheinberg, A. (2011) "Value Added: Modes of Sustainable Recycling in the Modernisation of Waste Management Systems", Thesis, Wageningen University, Wageningen NL.

Serbanica, C. and Constantin, D.L. (2017) "Sustainable cities in central and eastern European countries. Moving towards smart specialization". *Habitat International*, 68, 55-63.

Sharholy, M. Ahmad, K., Mahmood, G., and Trivedi, R.C. (2008) "Municipal solid waste management in Indian cities - A review". *Waste Management*, 28(2), 459–467.

Sharholy, M., Ahmad, K., Vaishya, R.C., and Gupta, R.D. (2007) "Municipal solid waste characteristics and management in Allahabad, India". *Waste Management*, 27, 490–496.

Sharpley, R. (2000) "Tourism and sustainable development: exploring the theoretical divide". *Journal of Sustainable Tourism*, 8(1), 1-19.

Sharpley, R. (2009) *Tourism Development and the Environment Beyond Sustainability?* London: Earthscan.

Shaw, P. (2008) "Nearest neighbor effects in kerbside household waste recycling". *Resources Conservation and Recycling*, 52, 775–84.

Shekdar, A. V. (2009) "Sustainable solid waste management: An integrated approach for Asian countries". *Waste Management*, 29(4), 1438–1448.

Shen, LY., Ochoa, J.J., Shah M, N. and Zhang, X. (2011) "The application of urban sustainability indicators: A comparison between various practices" , *Habitat International*, 35, 17-29.

Singleton, R. A., and Straits, B. C. (2005) *Approaches to social research*, 4th Edition. New York: Oxford University Press.

Smart Cities and Communities (2013) *Key Messages for the High-Level Group from the Smart Cities Stakeholder Platform Roadmap Group*, Available at: http://eusmartcities.eu/sites/all/files/Final%20key%20messages%20to%20HLG%20from%20Stakeholder%20Platform_FINAL.pdf (Accessed on 15th August 2015)

Smart Cities Council India (2018) *Warangal*, Available at: https://india.smartcitiescouncil.com/cities/warangal (Accessed on 30th December 2018).

Smart Cities Mission (2016), *Smart City Mission Transform-nation*, Available at: http://smartcities.gov.in/content/ (Accessed on 30th November 2017).

Smart Warangal (2018) *Warangal Smart City Vision*, Available at: http://smartcitywarangal.org/ (Accessed on 12th August 2018).

Smartnet (2018) *Urban Sector Missions in India, Ministry of Housing and Urban Affairs*, Available at: https://smartnet.niua.org/missions, (Accessed on 12th October 2018)

Sorbom, A. (2003) *Review of Source Separation of MSW*, FMS-Report 180, Swedish Defence Research Agency, The Environmental Strategies Research Group, Stockholm, Sweden.

Srivastava, P.K. Kulshreshtha, K., Mohanty, C.S., Pushpangadan, P. and Singh, A. (2005) "Stakeholder-based SWOT analysis for successful municipal solid waste management in Lucknow, India". *Waste Management*, 25(5), 531–537.

Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P. (2015) "Urban solid waste management in the developing world with emphasis on India: challenges and opportunities". *Rev Environ Sci Biotechnol*, 14, 317–337.

Stake, R. (1995) *The Art of Case Research*. Newbury Park, CA: Sage Publications.

Starr, J. and Nicolson, C. (2015) "Patterns in trash: Factors driving municipal recycling in Massachusetts, *Resources, Conservation and Recycling*, 99, 7-18.

Sujata, J., Saksham, S., Tanvi, G. and Shreya (2016) "Developing Smart Cities: An Integrated Framework". *Procedia Computer Science*, 93, 902 – 909

Sujauddin, M., Huda, S.M.S. and Hoque, A.T.M.R. (2008) "Household solid waste characteristics and management in Chittagong, Bangladesh". *Waste Management*, 28(9), 1688–1695.

Suthar, S. and Singh, P. (2015) "Household solid waste generation and composition in different family size and socio-economic groups: A case study". *Sustainable Cities and Societies*, 14, 56-63.

Swachh Survekshan (2016) *Government of India, Ministry of Urban Development* (Online) Available at http://swachh-survekshan.in/SS_2016_report.pdf (Accessed on 6th March 2017.

Swachh Survekshan (2017) *Ministry of Urban Development Swachh Survekshan 2017*, Available at: https://swachhsurvekshan2018.org/Images/SS_2017_Report.pdf.(Accessed on 24th March 2018)

SWM Rules, 2016. (2016), *The Gazette of India. Solid Waste Management Rules, 2016,* Ministry of Environment and Forests (MoEF), New Delhi, India.

Terraza, H., Sturzenegger, G. (2010) "Organization dynamics of informal recyclers. Three case studies from Latin America". *Infrastructure and environment sector*. Technical note N117 in Aparcana, S. (2017) "Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: Review of barriers and success factors" *Waste Management*, 61, 593–607.

The World Bank (2015) *Leveraging Urbanization in India*, Available at http://www.worldbank.org/en/country/india/brief/leveraging-urbanization-india (Accessed on 5th March 2017)

The World Bank (2017a) *Urban Population* (Online) Available at http://data.worldbank.org/indicator/SP.URB.TOTL?end=2015&locations=IN&start=196 0 (Accessed on 7th march, 2017)

The World Bank (2017b) *World Development Indicators* (Online) Available at http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.CD &country=# (Accessed on 7th march, 2017)

Thomas V.M. (2003) "Product Self-Management: Evolution in Recycling and Reuse". *Environmental Science & Technology*, 37 (23), 5297-5302.

Thomas, V.M., (2009) "A universal code for environmental management of products". *Resources, Conservation and Recycling*, 53(7), 400–408.

Thuzar, M. (2011) "Urbanization in southeast Asia: Developing smart cities for the future?" *Regional Outlook*, 96–100.

Toppeta, D. (2010) "The Smart City Vision: How Innovation and ICT Can Build Smart, Livable, Sustainable Cities". *The Innovation Knowledge Foundation*. Available at: http://www.thinkinnovation.org/file/research/23/en/Toppeta_Report_005_2010.pdf. (Accessed on 10th Augutst, 2015).

Troschinetz, A.M. and Mihelcic, J.R. (2009) "Sustainable recycling of municipal solid waste in developing countries". *Waste Management*, 29, 915–923.

Tsiatsis, V., Anantharam, P., Barnaghi, P., Fischer, M., Ganz, F., Ali, M., Kolozali, S., Kuemper, D., Mileo, A., Nechifor, Puiu, D., Tonjes, R. and Iggena, T. (2016) *Real-Time IoT Stream Processing and Large-scale Data Analytics for Smart City Applications*, Available at: http://www.ict-citypulse.eu/page/sites/default/files/citypulse_d3.1_semantic_data_stream_annotation_for_automated_processing_final.pdf (Accessed on 21st June 2018).

Tukahirwa, J. T., Mol, A. P. J., and Oosterveer, P. (2010) "Civil society participation in urban sanitation and solid waste management in Uganda". *Local Environment*, 15(1), 1-14.

Turcu, C. (2013) "Re-thinking sustainability indicators: local perspectives of urban sustainability", *Journal of Environmental Planning and Management*, 56(5), 695-719.

UMC (2015) *Urban Solid Waste Management In Indian Cities*, India: National Institute of Urban Affairs.

UN-Habitat. (2010) *Solid Waste Management In The World's Cities Water And Sanitation In The World's Cities 2010*, Washington DC, USA: United Nations Human Settlements Programme; London, UK: Easrthscan.

United Nations (2015) *World Urbanization prospects, the 2014 version*, New York: Department of Economic and Social Affairs.

Uyarra, E. and Gee, S. (2013)"Transforming urban waste into sustainable material and energy usage: the case of Greater Manchester (UK)". *Journal of Cleaner Production*, 50, 101-110.

Vartanian, T. P. (2011) *Secondary Data Analysis*. New York: Oxford University Press.

Velis, C.A., Wilson, D.C., Rocca, O., Smith, S.R., Mavropoulos, A. and Cheeseman, C.R. (2012) "An analytical framework and tool ('InteRa') for integrating the informal recycling sector in waste and resource management systems in developing countries". *Waste Management and Resources*, 30 (9), 43–66.

Vining, J. and Ebreo, A. (1992) "Predicting recycling behavior from global and specific environmental attitudes and changes in recycling opportunities". *Journal of Applied Sociology and Psychology*, 22(20),1580–607.

Wager, P.A., Eugster, M., Hilty, L.M. and Som, C. (2005) "Smart labels in municipal solid waste — a case for the Precautionary Principle?". *Environmental Impact Assessment Review*, 25, 567-586.

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N. M., and Nelson, L. E. (2010) *Helping CIOs Understand "Smart City" Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO*. Cambridge, MA: Forrester Research, Inc.

Wilson, D.C. (2007) "Development drivers for waste management". *Waste Management & Research*, 25(3), 198–207.

Wilson, D.C., Rodic, L., Mdak, P., Soos, R., Rogero, A.C., Velis, C. Iyer, M. and Simonett, O. (2015b) *Global Waste Management Outlook*, United Nations Environment Programme.

Wilson, D.C, Rodic, L. and Scheinberg, A. (2012) Comparative analysis of solid waste management in 20 cities. *Waste Management & Research* 30(3): 237–254.

Wilson, D.C., Araba, A.O., Chinwah, K. and Cheeseman, C.R. (2009) "Building recycling rates through the informal sector". *Waste Management,* 29 (2), 629-635.

Wilson, D.C., Velis, C. and Cheeseman, C. (2006) "Role of informal sector recycling in waste management in developing countries". *Habitat International*, 30 (4),797–808.

Wilson, D.C., Rodic, L., Cowing, M.J., Velis, C.A., Whiteman, A.D., Scheinberg, A., Vilches, R., Masterson, D., Stretz, J. and Oelz, B. (2015) "Wasteaware benchmark indicators for integrated sustainable waste management in cities". *Waste Management*, 35, 329–342.

Wilson, D.C., Velis, C.A. and Rodic, L. (2013) "Integrated sustainable waste management in developing countries". *Proceedings of the Institution of Civil Engineers: Waste and Resource Management,* 166 (2), 52 - 68.

Winters, J. V. (2010) "Why are smart cities growing? Who moves and who stays". *Journal of Regional Science*, 20(10), 1-18.

World Bank, (2001) *Philippines Environment Monitor, World Bank* – Country Office Manila, Pasig City, Philippines: World Bank

WCED- World Commission on Environment and Development (1987), *Our Common future (The bruntland report),* Oxford: Oxford University Press.

Wyld, D.C. (2010) "Taking Out The Trash (And The Recyclables): RFID And The Handling Of Municipal Solid Waste". *International Journal Of Software Engineering & Applications (IJSEA)*, 1(1), 1-13.

Xu, W., Zhou, C., Lan, Y., Jin, J. and Cao, A. (2015) "An incentive-based source separation model for sustainable municipal solid waste management in China". *Waste Management and Research,* 33(5), 469–476.

Yigitcanlar, T., Dur, F. and Dizdaroglu, D. (2015) “Towards prosperous sustainable cities: A multiscalar urban sustainability assessment approach”. *Habitat International*, 45, 36-46.

Yin, R. K. (2003) *Case study research: design and methods*, Applied Social Research Methods Series, Vol. 5, Thousand Oaks: Sage

Yin, R.K. (1994) *Case Study Research Design and Methods*, 2nd ed., Sage Publications, London.

Yin, R.K. (1994) "Discovering the future of Case Study method in evaluation research". *Evaluation Practice*, 15, 283-290.

Yin, R.K. (2014) *Case Study Research: Design and Methods*, 5th Edition, USA: Sage Publication.

Yuan-Young, C., Ni, S.P., and Fan, K.S. (2010) "Working towards a zero-waste environment in Taiwan". *Waste Management and Research*, 28, 236-244.

Zaman, A.U. (2014) "Identification of Key Assessment Indicators of the Zero Waste Management Systems". *Ecological Indicators*, 36, 682-693.

Zaman, A.U. (2014) “Identification of key assessment indicators of the zero waste management systems”. *Ecological Indicators*, 36, 682– 693.

Zaman, A.U., and Lehmann, S. (2011) “Urban growth and waste management optimization towards zero waste city”. *City, Culture and Society*, 2, 177–187.

Zaman, A.U., and Lehmann, S. (2013) “The zero-waste index: a performance measurement tool for waste management systems in a zero-waste city". *Cleaner Production*, 50, 123-132.

Zaman, I. (2015) *White paper on smart cities*, Daywatcher.com 2009-15.

Zerowaste Scotland (2018) *Using social media to prevent litter and fly tipping*, Available at: https://www.zerowastescotland.org.uk/litter-flytipping/social-media (Accessed on 20th November 2018).

Zhang, Y. and Wildemuth, B. M. (2009) "Qualitative analysis of content". In Wildermuth, B. (ed.), *Applications of Social Research Methods to Questions in Information and Library Science*. Westport, CT: Libraries Unlimited, 308-319.

Zhou L, Naim, MM & Yan Wang (2007) "Soft systems analysis of reverse logistics battery recycling in China". *International Journal of Logistics: Research and Applications*, 10(1), 57-70.

Zia, H., Devadas, V. and Shukla, S. (2008) “Assessing informal waste recycling in Kanpur City, India”. *Management of Environmental Quality: An International Journal*, 19 (5), 597–612.

Zurbrügg, C. (2002) "Urban Solid Waste Management in Low-Income Countries of Asia-How to Cope with the Garbage Crisis". *Scientific Committee on Problems of the Environment (SCOPE)*, Urban Solid Waste Management Review Session, Durban, South Africa.

Appendix 1: Participant information sheet

Research Topic: "Waste Free Cities: Pathways to Future Smart Cities in India"
University of Greenwich, London, UK

The project is a part of PhD research and is intended for academic purposes. The research considers waste management as an important activity in the cities and identifies the key factors that affect sustainable waste management and value generating activities. The research aims to develop a framework for waste free cities. It also aims to provide practical recommendations and collects information related to factors and stakeholder interaction and identifies the barriers in applying the framework. Therefore, the questions for the interviews will be related to each of the factor and interactions and reasons for their effective implementation. This helps in drawing inferences on how or why each factor is helping in achieving waste free cities.

You have the right to withdraw from participating any time before the start of the interview or survey. You have right to skip any question if you do not wish to answer.

All the information given by you will be kept confidential and will be used for the research purpose only. Your identity will be kept confidential. The data collection and storage will be in accordance to the UK Data Protection Act 1998 and will be stored for a period of three years. On completion of the research, the data will be securely disposed.

This research project is a part of academic research conducted at the University of Greenwich, London. For any further information the participant can feel free to contact the Faculty of Business of University of Greenwich or the research team using the contact information below.

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Appendix 2: Questionnaires

2.1 Questionnaire 1 (*for interviews with local authorities*)

1-POLICY OR LEGAL FRAMEWORK

- Is there a waste policy in place? Are there any guidelines for policy implementation?
- Is there a city wide/ level solid waste management strategy?
- How many government agencies are involved in SWM?
- Are there any waste restriction or waste ban laws?
- Are there any extended producer responsibility schemes and laws?
- What are the challenges or barriers in effective policy implementation?

2-GOVERNANCE OR DECISION MAKING

- How is the coordination between the state and central government maintained and is there any lack in it (Example, delay in information flow or central government decisions not suitable for the city, monetary problems, etc.)?
- Do citizens have role in decision making or policy design? If yes, what are the challenges in implementing it?

3-INFRASTRUCTURE

- What is the distance between houses and communal bins?
- What types of vehicles are used for collection and transportation of waste?
- Number of each type of vehicle used?
- Are the vehicles covered or over loaded (on a scale of 1-5 or percentage of vehicles)?
- Is there a separate collection and transportation system for waste? If yes, what types?

4-HUMAN RESOURCES

- Number of employees in
    a. Waste collection and transportation
    b. Waste recycling
    c. Waste processing including composting
    d. Waste disposal
- Is there any training offered to the staff for better performance or material recovery at least manually?

5-WASTE PROCESS

- Do you import or export waste? If yes, what kind of waste and for what benefit?
- Waste collection:
    a. Is there door to door collection in place? What is the percentage of households to which it is offered?
    b. Number of waste types collected separately from households?
    c. What is the frequency of organic and recycling waste collection?
    d. What is the quantity of waste collected through formal collection?
- Waste treatment/Processing:

a. Sorting efficiency- How is waste sorted?
How much of dry and wet waste sorted?

- What materials are recovered from waste?
- How much waste is composted and produced?
- Is biogas produced from Mech-Biological treatment (MBT)? If yes, provide details.
- Is electricity generated from waste currently or in future?
    a. How much waste is used for it?
    b. What is the capacity of electricity generation of the plant?
    c. How is the waste supplied?
- Waste disposal:
    a. What is the total amount of waste disposed (controlled and uncontrolled)?
- Waste recycling:
    a. What is the percentage of formal recycling?
    b. Number of recycling depots or units?
    c. What is the capacity of recycling units?
    d. What is the amount of total waste recycled?
    e. Number of waste categories recycled?
    f. What is the recycling efficiency?

6-DATA AVAILABILITY

- How is the data related to waste collected or monitored?
- Is there an information management system in place?
- Is time series data available?

7-TECHNOLOGY

- Do you GPS or RFID in waste management? (Vehicles or bins)
- Do you think *Swachata* application is useful
    a. what percentage of city's population use it?
    b. Did it effect the number of complaints received (increase or decrease?)
- Do you think use of smart bins or solar compaction bins are useful for the city? (Why or why not?)
- Any scope for underground waste collection system? (if not why?)
- Do you use social media for citizen awareness or participation?
- Do you use social media or any other way to consult the citizens for local policy design or decision-making process?
- What is the waste treatment/recovery technologies in place and in future implementation?

8-STAKEHOLDER ENGAGEMENT

- Informal sector:
    a. What are the efforts to formalise the informal sector?
    b. What percentage of the sector has been formalised or contacted?
    c. How will formalising the informal sector help in waste management?
    d. How will the informal sector benefit from formalisation process?
    e. Is there any form of support given to them?

- Are there any form of subsidies or incentives provided to the waste traders (including itinerant waste buyers, retailers, wholesalers and suppliers)?
- Number of complaints received?
    a. Manually
    b. Electronically
    c. *Swachata* app
- What percentage of complaints are actioned?
- Do you have a service level agreement?
- How many awareness raising programmes are in place?
- To what percentage of population are such programmes reached?
- Is education at primary school given related to waste? Either curriculum or workshops?
- What are the challenges for source segregation and citizen motivation?

9-PARTNERSHIPS

- Are there any steps taken to strengthen public private partnerships?
- Is there any part of the waste process outsourced to private company? If yes, to what extent do the LA's have control over them?
- Is the concept of cluster (between LA's or regions) being followed? If yes, how and how does that benefit?
- Are NGOs and CBOs used as a part of waste management process (collection, transportation, sorting, composting, etc.) or awareness programmes?
    a. Is there any measured outcome because of the programme or activity?
    b. How does it benefit the local authorities or citizens?
    c. Are there any subsidies or other forms of support given to them?

10-COSTS

- Is the annual budget adequate to cover the full costs of providing the service?
- Is there user charges system in place?
    a. If yes how is the price fixed/calculated?
    b. Is there any exemptions / subsides given to any class of people?
    c. What percentage of households pay the user charges?
- Is there gate fee charged at disposal facility?
- What is the cost of:
    a. collection
    b. sorting
    c. recycling
    d. Processing
    e. resource recovery
    f. waste disposal
- Total waste management
- What is the revenue from recycling?

11-ENVIRONMENTAL ISSUES

- Are there any reported environmental issues at the dumpsites?
- Is a scientific reclamation of open dump planned?
- Is there an environmental monitoring process and how is it performed?

2.2 Questionnaire 2 (*for interviews with waste traders, NGOs and PPP*)

1. From where do you buy waste?
2. Is the waste already sorted or do you sort it after buying? If it is already sorted, is there any problem in sorting?
3. Do you buy waste from households?
    a. Are these households you buy waste from are regular customers to you?
        i. How frequently do you buy the waste from the same households?
        ii. Do you stay in touch with them? If yes, how?
4. What kind of people or households sell waste to you? Can you describe them based on their profession or income group generally?
5. What type of waste do you buy? Please provide details of their quantity and cost of purchase.

Waste type	Quantity	Cost

6. What is the composition and cost of waste you buy and sell?

Waste type	Cost Price/kg		Selling price/kg	
	Min. price	Max. price	Min. price	Max. price
Paper				
Cardboard				
Books				
Hard plastics				
Soft plastics				
Iron				
Cans (Tin/aluminium)				
Glass				
Others				

7. How is the price of the waste type determined?
8. Which type of waste is the most profitable on an average?
9. Which type of waste is mostly traded?
10. To whom do you sell the waste?
11. Are there different buyers for each type of waste or the same buyer buys all types of waste?
12. How is the contact with the waste buyer maintained?
13. Does any portion of the waste you buy gets wasted?
    If yes,
    a. What proportion of the material collected gets wasted?
    b. What are the reasons for it getting wasted?
    c. Any contamination of waste?
    d. Then what do you do with the contaminated waste? Clean it and sell or discard?
14. How long do you work during the day?
15. For how long have you been doing this work?

16. Why did you choose to do this business?
17. How much do you earn per day or how much is traded per day?
18. Where do you store the waste?
19. What is the volume of waste traded?
20. How frequently do you sell the waste?
21. What are the costs incurred?

Infrastructure/process	Cost	Frequency	Comments

22. Is this a family run business?
    a. If yes, who are involved and how many?
23. What is your educational background?
24. Do you use a motor vehicle or cycle or manually collect and transport the waste?
25. Are you receiving any kind of support from central or local government?
26. Do you benefit from any subsidies for recycling waste and reducing the burden on local authorities?
27. Do you expect any form of support from the local authorities or others to support your business? If yes, what kind of support?
28. Estimated number of recyclists in the city?
    a. How much waste is collected by them?
    b. What is the composition of waste that is collected?
29. Do you have a bank account?
30. Did you register your business or trade?
    a. Do you pay tax for the work?
    b. DO you employ people? If yes how many?
31. What are the challenges you face during the process or in doing this business?
    a. In buying waste
    b. In storing the waste
    c. In processing/storing the waste
    d. In transporting waste
    e. In selling the waste
    f. Any other challenges like infrastructure, employees, pricing, etc.
    g. Or from any other people
32. Do you have any barriers in communicating with local authorities?
33. Do you use any technology to sort the waste?
34. Would you be willing to use/buy technology if any subsidy is given to you? (for separating waste types/crushing or chipping plastic, etc.)

2.3 Questionnaire 3 (*for in-depth interviews with rag pickers / waste pickers*)

1. From where do you collect waste?
2. What type of waste do you collect? Please provide details of their quantity.

Waste type	Quantity

3. What do you do with the waste?
4. To whom do you sell the waste?
5. What is the composition of waste you sell?
6. For how much do you sell? How much for each type of waste?

Waste type	Selling price/kg	
	Min. price	Max. price
Paper		
Cardboard		
Books		
Hard plastics		
Soft plastics		
Iron		
Cans (Tin/aluminium)		
Glass		
Others		

7. Who decides the cost of waste when selling them? You or the buyer?
8. Do you sell the waste to the same buyer or different? If same buyer, why? If different, how do you decide whom to sell?
9. Which type of waste is the most traded?
10. Which type of waste is most profitable?
11. How much waste is collected or recycled from dumpsites?
12. How much waste is collected or recycled from common bins on streets?
13. How much do you earn per day or how much is traded per day?
14. What proportion of the material collected gets wasted?
    a. What are the reasons for it getting wasted?
    b. Any contamination of waste?
    c. Then what do you do with the contaminated waste? Clean it and sell or discard?
        i. If discarding, where?
15. Do you use a cycle or manually collect the waste?
16. How long do you work during the day?
17. For how long have you been doing this work?
18. Why did you choose this work?
19. Estimated number of recyclists in the city?
    a. How much waste is collected by them?
    b. What is the composition of waste that is collected in total?

20. The government is trying to formalise the rag pickers.
    a. Do you know about it?
    b. Are you willing to be part of formal waste chain?
        i. If yes, why?
        ii. If no, why?
21. Do you have any type of associations/cooperatives/unions for rag pickers?
22. Are you receiving any kind of support from central or local government?
23. Do you expect any kind of help or support?
    If yes, what kind of help and how will that improve your condition or solve your problems.
24. What are the challenges you face during the process?
    a. In collecting waste
    b. In storing the waste
    c. In processing/sorting the waste
    d. In transporting waste
    e. In selling the waste
    f. Any other challenges
25. How do people or waste buyers and government treat you generally?
26. Are women and children involved in this activity?
    a. If yes, roughly how many?
    b. What is the age group of the children?
27. What is your educational background?
28. What are your living conditions?
29. Do you have any personal protection equipment or has the government given you any (Example, gloves, masks, etc.)?
30. Do you have a bank account or pay tax for the work?
    a. If yes, how much?

2.4 Questionnaire 4 (*for citizens survey)*

1. According to you, which of the following steps in waste management is the most important?
    a. Waste segregation
    b. Collection
    c. Transportation
    d. Storage
    e. Disposal
    f. Processing
    g. Recycling
    h. Reuse
2. On a scale of 1-5, how do you rate your knowledge on waste management (1 being the least and 5 being the highest)?
    1 2 3 4 5
3. How important is it for the local authorities to consult citizens when designing policies related to waste management for the city?
    a. Very unimportant
    b. Unimportant
    c. Neither important nor unimportant
    d. Important
    e. Very important
4. On a scale of 1-5, do you think you have power in the waste management programs or decisions in your city (1 being no power and 5 being very powerful)?
    1 2 3 4 5
5. How interested are you in waste management activities or decisions in your city?
    a. Very uninterested
    b. Uninterested
    c. Neither interested nor uninterested
    d. Interested
    e. Very interested
6. Do you think awareness programs will increase your interest in waste management activities?
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly Agree
7. Do you consider that smart cities should be waste free?
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree
8. How frequently do your local authorities interact or communicate with you regarding the waste handling practices?
    a. Never

b. Rarely
c. Sometimes
d. Usually/Most of the time
e. Always

9. Are you satisfied with the level of interaction you have with the local authorities?
    a. Very dissatisfied
    b. Dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Satisfied
    e. Very satisfied
10. How willing are you to segregate your waste into wet and dry categories for waste collection by your local authority?
    a. Strongly unwilling
    b. Unwilling
    c. Neither willing nor unwilling
    d. Willing
    e. Strongly willing
11. If you are not separating waste into wet and dry categories, which of the following reasons best suits you.
    a. It does not benefit me
    b. Not clear how to separate the waste
    c. I tried separating, but the collection staff mix it
    d. There is no use of doing it
    e. I do not know why I should do it
12. How likely are you to separate dry and wet wastes if you are given any form of benefit (example, incentives, money, discount cards for shopping, free gifts, etc).
    a. Very unlikely
    b. Unlikely
    c. Neither likely nor unlikely
    d. Likely
    e. Very likely
13. How likely are you to pay a user charge to your local authorities for waste collection service, if they use waste for recycling or energy generation?
    a. Very unlikely
    b. Unlikely
    c. Neither likely nor unlikely
    d. Likely
    e. very likely
14. Do you think your interest in waste management activities would increase if waste is used to recover resources or generate energy?
    a. Strongly Disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. strongly agree
15. Local authorities have trained NGOs and CBOs for waste management awareness programs. How often have you heard of such activities or attended them?

a. Never
b. Rarely
c. Sometimes
d. Usually/Most of the time
e. Always

16. Do you use *Swachhata* application in your smart phone or other devices?
    a. Never
    b. Rarely
    c. Sometimes
    d. Usually/Most of the time
    e. Always
17. Do you generally use social media?
    a. Never
    b. Rarely
    c. Sometimes
    d. Usually/Most of the time
    e. Always
18. Do you use social media to communicate problems in your area to local authorities (municipality)?
    a. Never
    b. Rarely
    c. Sometimes
    d. Usually/Most of the time
    e. Always
19. Do you use internet to discuss about the environmental problems or waste related issues?
    a. Never
    b. Rarely
    c. Sometimes
    d. Usually/Most of the time
    e. Always
20. Do you sell your unused items (waste) to waste buyers?
    a. Never
    b. Rarely
    c. Sometimes
    d. Usually/Most of the time
    e. Always
21. What is your preferred method of communication for any awareness campaign in your city?
    a. Mobile
    b. Telephone
    c. Emails
    d. Social media
    e. Leaflet
    f. Newspaper
    g. Television
    h. Radio

i. Letters

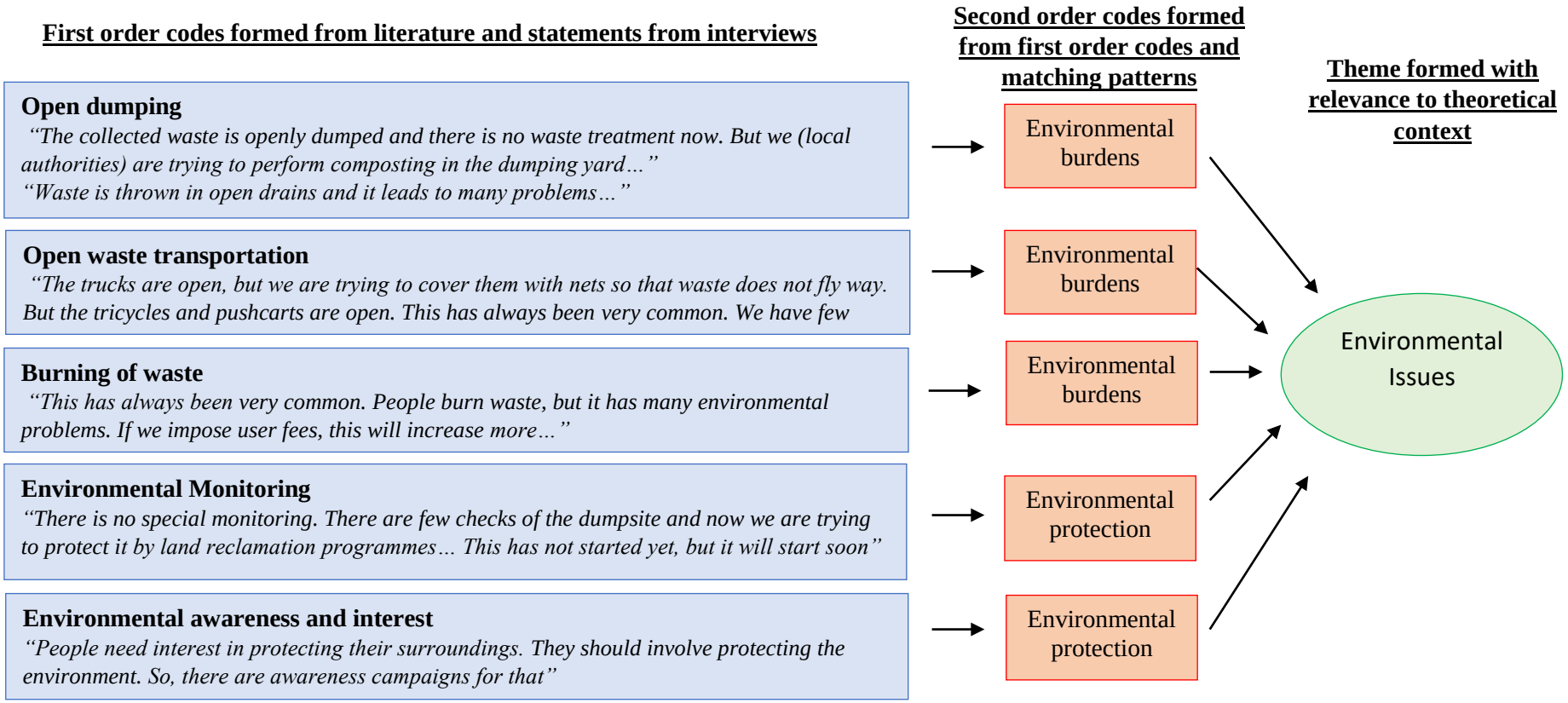
22. How satisfied are you with the waste collection facility provided to you by your municipality?
    a. Very dissatisfied
    b. Dissatisfied
    c. Neither dissatisfied nor satisfied
    d. Satisfied
    e. Very satisfied
23. Do you think involving private sector (fully or partly) in waste management would improve the waste management services?
    a. Strongly disagree
    b. Disagree
    c. neither agree nor disagree
    d. Agree
    e. Strongly agree
24. Do you think education related to waste and its management should be provided to children through school curriculum?
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree
25. How willing are you to change your behaviour and consumption patterns to protect environment through waste minimization?
    a. Very unwilling
    b. Unwilling
    c. Neither willing nor unwilling
    d. Willing
    e. Very willing
26. How likely are you to use RFID tagged products in your daily use commodities to improve source separation (note: using this means, by observing your waste your daily products purchases can be tracked through the RFID tags)?
    a. Very unlikely
    b. Unlikely
    c. Neither likely nor unlikely
    d. Likely
    e. Very likely
27. Are you aware of the environmental benefits of separating your dry and wet wastes?
    a. Fully unaware
    b. Unaware
    c. Neither aware nor unaware
    d. Aware
    e. Fully aware
28. How frequently were you or your households contacted by the local authorities to express your opinions or feedback on any aspects related to waste management activities?

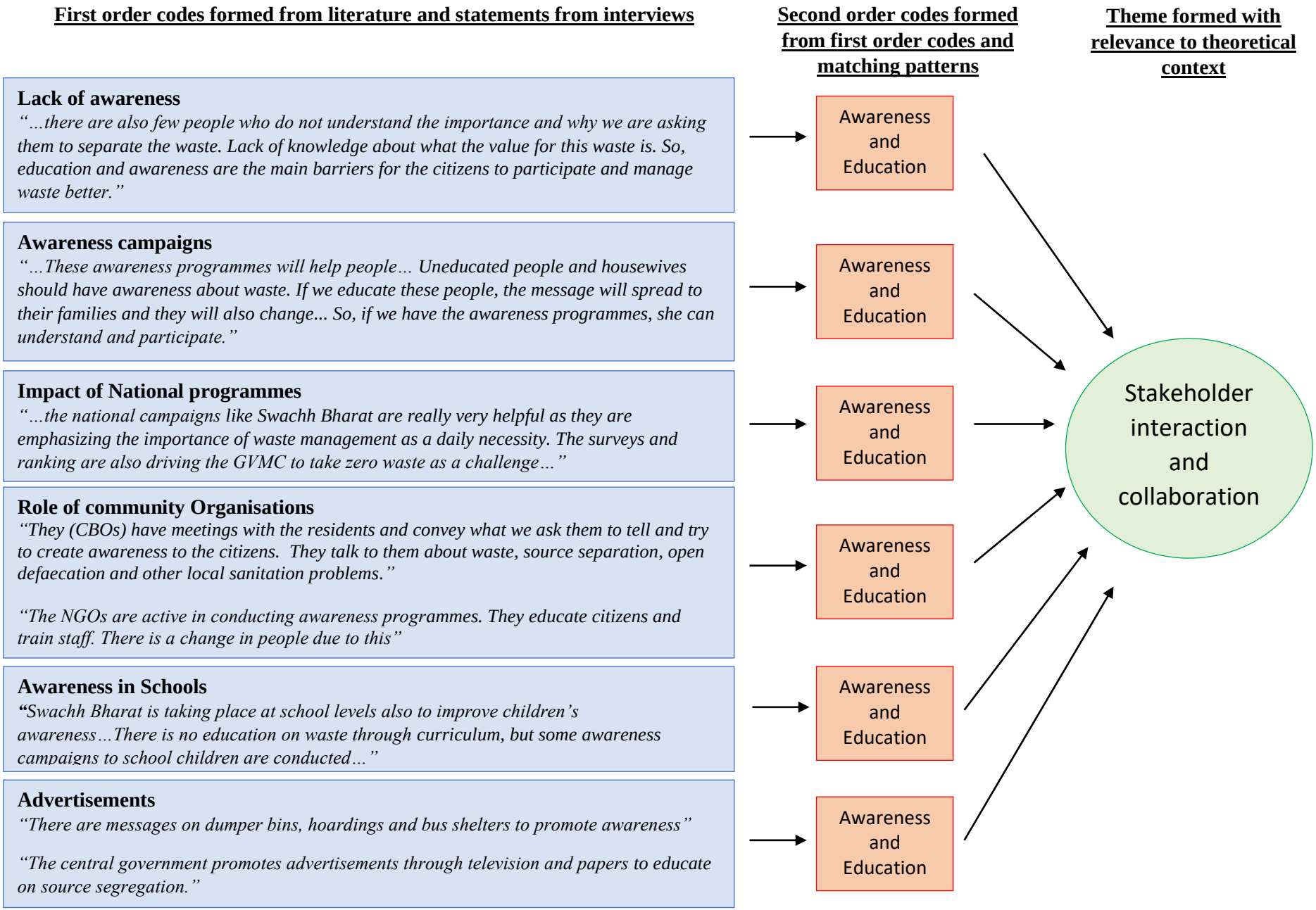
a. Never
b. Rarely
c. Sometimes
d. Usually/Most of the time
e. Always

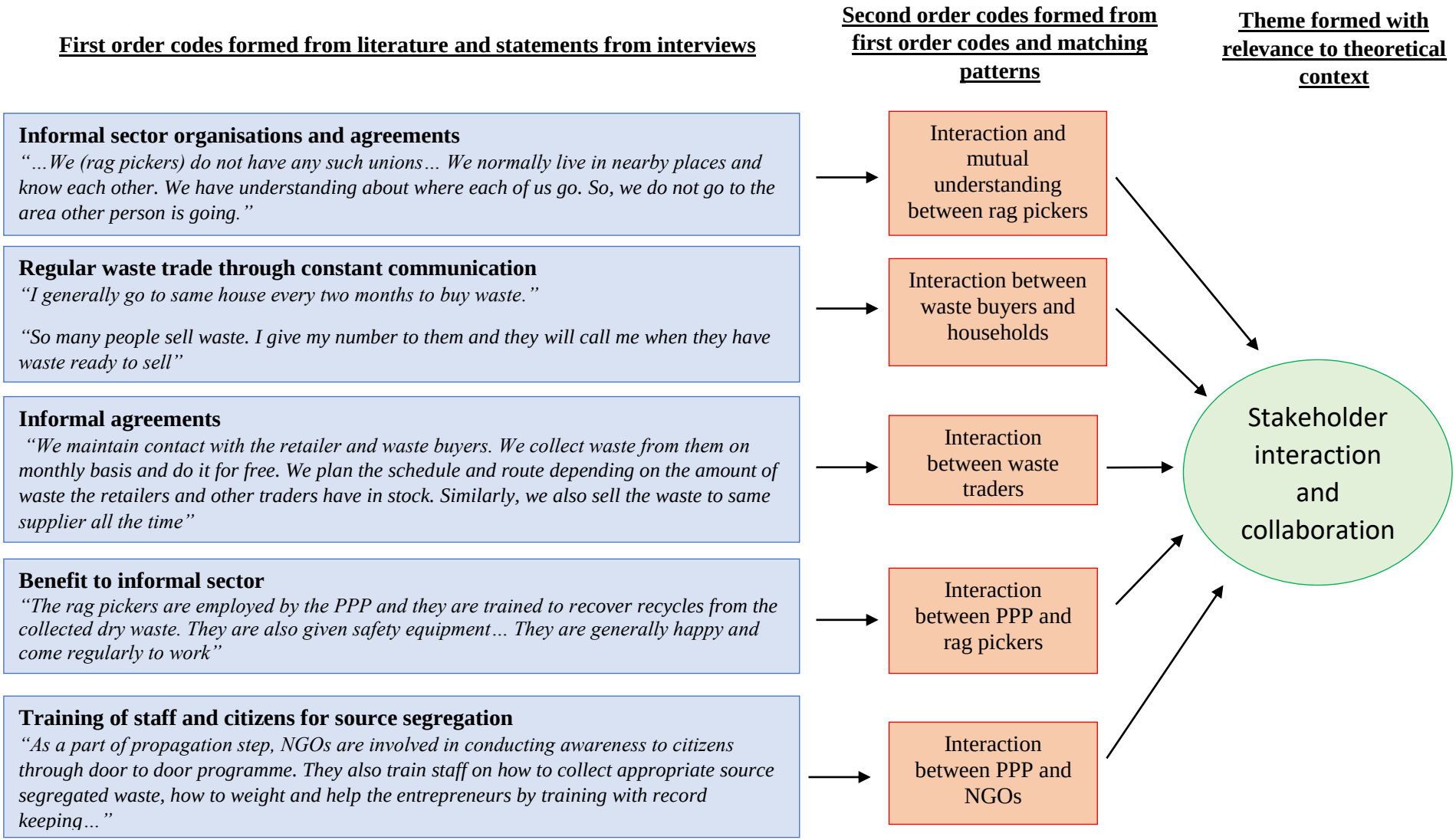
29. Citizen engagement is considered as a major barrier to improve any waste management activities in the city. What do you think will are the reasons for this and what motivates citizens to participate better?
30. Your city was selected under the Smart Cities Mission in India. Since then have you noticed any changes in the waste management of your city that helped in improving cleanliness and hygiene in the city?
    a. No changes at all
    b. Negligible changes
    c. Few changes, but not particularly related to waste management
    d. Lot of positive changes
    e. Other (please specify)

Appendix 3: Coding process

The figures in this appendix indicate the coding process followed in analysing the primary data collected through interviews. Thematic analysis was followed in this process as explained in chapter 4. Examples of the statements from the interview transcripts are provided to show the relevance to the codes formed in the first order codes.




First order codes formed from literature and statements from interviews
Second order codes formed from first order codes and matching patterns
Theme formed with relevance to theoretical context
Lack of awareness
"…there are also few people who do not understand the importance and why we are asking them to separate the waste. Lack of knowledge about what the value for this waste is. So, education and awareness are the main barriers for the citizens to participate and manage waste better."
Awareness campaigns
"…These awareness programmes will help people… Uneducated people and housewives should have awareness about waste. If we educate these people, the message will spread to their families and they will also change... So, if we have the awareness programmes, she can understand and participate."
Impact of National programmes
"…the national campaigns like Swachh Bharat are really very helpful as they are emphasizing the importance of waste management as a daily necessity. The surveys and ranking are also driving the GVMC to take zero waste as a challenge…"
Role of community Organisations
"They (CBOs) have meetings with the residents and convey what we ask them to tell and try to create awareness to the citizens. They talk to them about waste, source separation, open defaecation and other local sanitation problems."
"The NGOs are active in conducting awareness programmes. They educate citizens and train staff. There is a change in people due to this"
Awareness in Schools
"Swachh Bharat is taking place at school levels also to improve children's awareness…There is no education on waste through curriculum, but some awareness campaigns to school children are conducted…"
Advertisements
"There are messages on dumper bins, hoardings and bus shelters to promote awareness"
"The central government promotes advertisements through television and papers to educate on source segregation."
Awareness and Education
Awareness and Education
Awareness and Education
Awareness and Education
Awareness and Education
Awareness and Education
Stakeholder interaction and collaboration


First order codes formed from literature and statements from interviews
Second order codes formed from first order codes and matching patterns
Theme formed with relevance to theoretical context
Informal sector organisations and agreements
"…We (rag pickers) do not have any such unions… We normally live in nearby places and know each other. We have understanding about where each of us go. So, we do not go to the area other person is going."
Regular waste trade through constant communication
"I generally go to same house every two months to buy waste."
"So many people sell waste. I give my number to them and they will call me when they have waste ready to sell"
Informal agreements
"We maintain contact with the retailer and waste buyers. We collect waste from them on monthly basis and do it for free. We plan the schedule and route depending on the amount of waste the retailers and other traders have in stock. Similarly, we also sell the waste to same supplier all the time"
Benefit to informal sector
"The rag pickers are employed by the PPP and they are trained to recover recycles from the collected dry waste. They are also given safety equipment… They are generally happy and come regularly to work"
Training of staff and citizens for source segregation
"As a part of propagation step, NGOs are involved in conducting awareness to citizens through door to door programme. They also train staff on how to collect appropriate source segregated waste, how to weight and help the entrepreneurs by training with record keeping…"
Interaction and mutual understanding between rag pickers
Interaction between waste buyers and households
Interaction between waste traders
Interaction between PPP and rag pickers
Interaction between PPP and NGOs
Stakeholder interaction and collaboration

First order codes formed from literature and statements from interviews

Second order codes formed from first order codes and matching patterns

Theme formed with relevance to theoretical context

Attempts by Local authority

"…we are making efforts to formalise the informal sector, but they are not interested… we ask them to go for waste collection along with our staff, and we allow them to take whatever they want from the waste…"

"… The government is trying their best to identify the rag pickers, but they are so many, and we cannot identify all of them… The identified rag pickers were given identify cards, but they expect salary from us. How can the government give salaries to all…"?

"…Out of hundreds of rag pickers we identified, only 10-20 people are now in contact. They are never seen and do not want to participate in what we ask them to do… The government is unable to do anything as we do not have their information in government records…"

Problems for collaborations

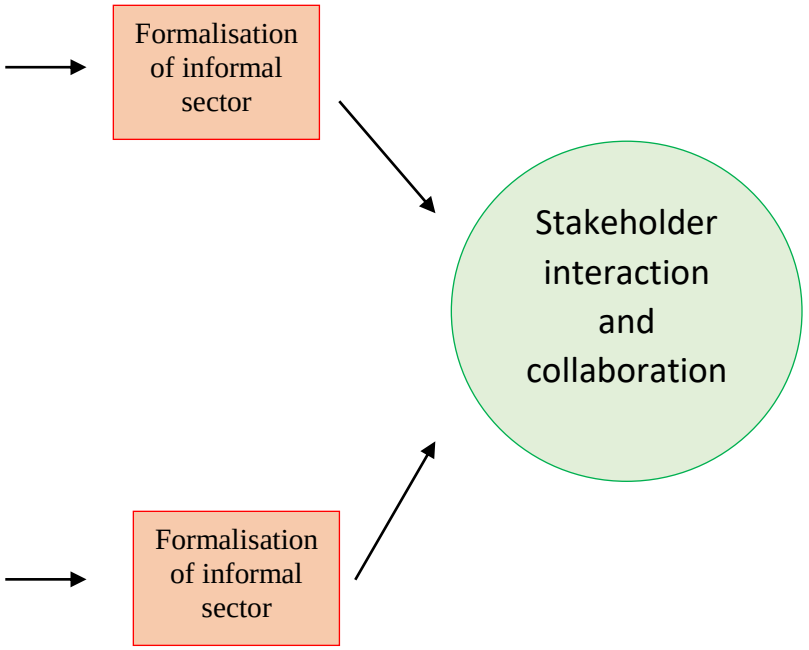
"The government asks us to collect the waste by going all with their staff… We do not get any money… I can do this work quickly if I go to every street myself."

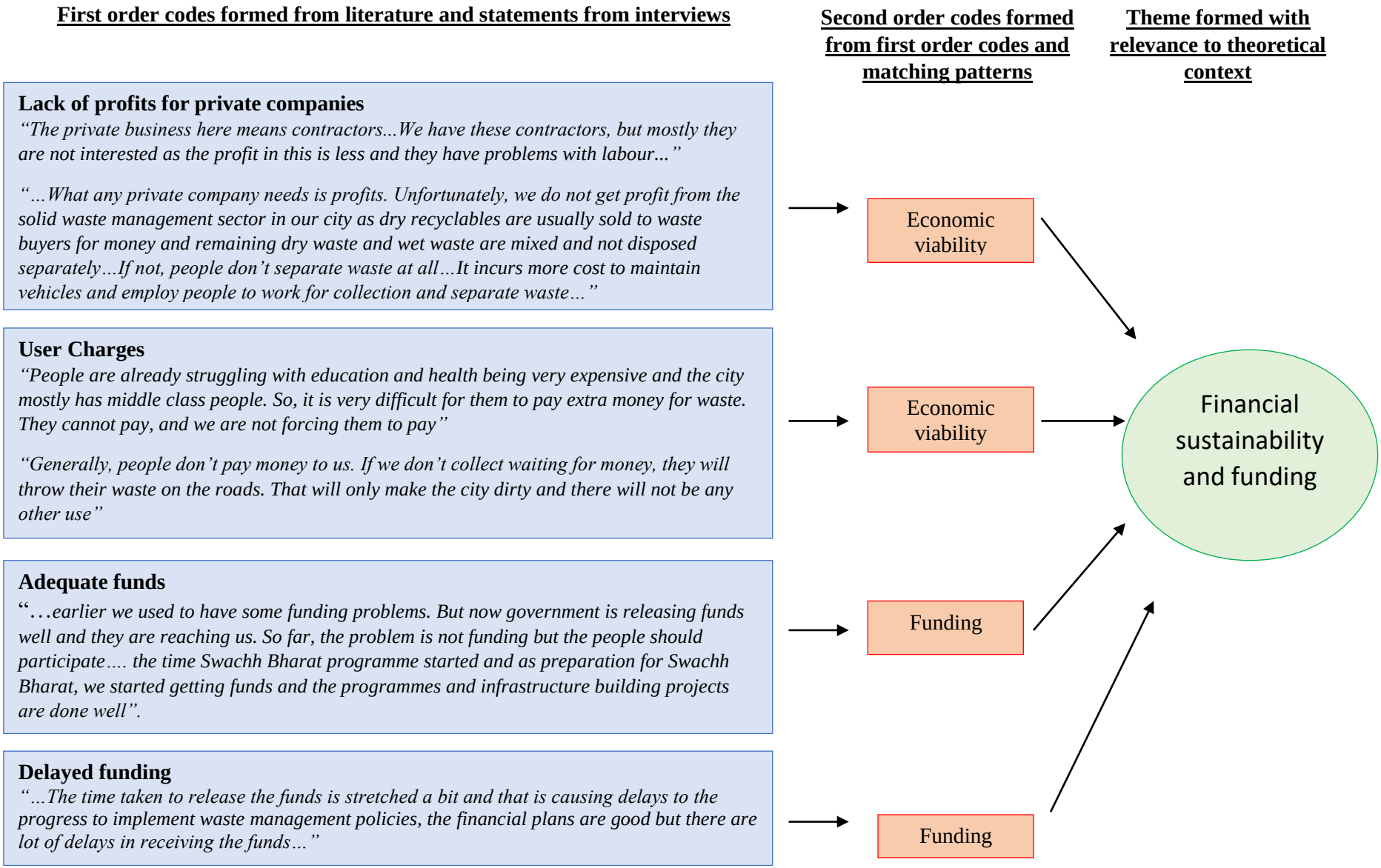
"There is no use of listening to the officers. They will not give us any money. If they give money, why will I not go"

"They are not supporting us… They will not pay for the work I do…"

"if I should do the same work, why should I go with them? I can do the work whenever I want to do…"

"I went few times for with their staff to collect waste. They argue with us as they want to take to take the things, I am taking… They get salary for doing their work, but I do not get any money. If I cannot get waste that I need, how can I survive?"




First order codes formed from literature and statements from interviews
Second order codes formed from first order codes and matching patterns
Theme formed with relevance to theoretical context
Lack of profits for private companies
"The private business here means contractors...We have these contractors, but mostly they are not interested as the profit in this is less and they have problems with labour..."
"...What any private company needs is profits. Unfortunately, we do not get profit from the solid waste management sector in our city as dry recyclables are usually sold to waste buyers for money and remaining dry waste and wet waste are mixed and not disposed separately...If not, people don't separate waste at all...It incurs more cost to maintain vehicles and employ people to work for collection and separate waste..."
User Charges
"People are already struggling with education and health being very expensive and the city mostly has middle class people. So, it is very difficult for them to pay extra money for waste. They cannot pay, and we are not forcing them to pay"
"Generally, people don't pay money to us. If we don't collect waiting for money, they will throw their waste on the roads. That will only make the city dirty and there will not be any other use"
Adequate funds
"...earlier we used to have some funding problems. But now government is releasing funds well and they are reaching us. So far, the problem is not funding but the people should participate.... the time Swachh Bharat programme started and as preparation for Swachh Bharat, we started getting funds and the programmes and infrastructure building projects are done well".
Delayed funding
"...The time taken to release the funds is stretched a bit and that is causing delays to the progress to implement waste management policies, the financial plans are good but there are lot of delays in receiving the funds..."
Economic viability
Economic viability
Funding
Funding
Financial sustainability and funding

First order codes formed from literature and statements from interviews

Social media

"…social media is useful, but we are not using it that well…"

"…social media reach is more we just started the pages but not intensely campaigning on it. We are able to receive many complaints from it, so it is very useful to improve things on a daily basis…"

Mobile applications

"…Swachhata is the mobile application we use, and it is very useful. It helps in identifying the location of the person using the app and they can give complaints and upload pictures to report an issue. This will be very helpful to act fast and, we send messages to these users for promoting awareness."

"Our page always posts many things for awareness…If people are using our apps, they can contact us directly for any complaints and we can access their location. According to that we redirect the complaint to a local in charge…We send messages for awareness through app also. But people are not very active as we expected in using these."

GPS tagging

"The collection trucks have GPS and we know if the workers really went to the designated route to collect the waste and we also get the time recorded in it. So, we can monitor them. We have GPS for dumper bins so that the bins are placed back in the correct place and not misplaced"

Underground waste collection channels

"We started them as smart city initiatives. We are testing it now and planning to expand to 10-12 places…. Each will have more than 1ton capacity… We are not sure how many waste categories we can have…Based on our pilot test result, we will plan further"

Roads from recycled plastic

"As a smart city, we laid roads from recycled plastic… Waste is not brought from here. It was contracted to outsiders and I do not know from where it comes exactly…"

Second order codes formed from first order codes and matching patterns

Communication

Communication

Infrastructure

Infrastructure

Infrastructure

Theme formed with relevance to theoretical context

Smart initiatives in waste managing activities

First order codes formed from literature and statements from interviews

Segregation and sorting

"we buy waste that is already separated into books, papers, plastics. But I must divide based on the type of paper, type of printing on it… If I buy from people without checking quality, I cannot sell later, and it becomes waste for me."

"I employ daily labour to sort waste into types. Without separating them properly, the wholesaler will not buy from me or they will give less money for this. We have very low margin and if they pay less, I will have loss"

Processing

"We have lot of work after buying. We sometimes get dirty bottles. And everything should be cleaned properly. If it is plastic, we should separate them based on material and colours. Then we chip them in that machine. We sell based on that weight. Some colours have different price. If there is any mixing with this, the factories do not pay properly… If it is paper, we separate oil prints, hard binding, colour papers and then pack them."

Scope of business for waste traders

"I entered this business as there is good scope to get money. I get a profit from selling waste and that is the only source of income for me and my family…If I have a team I would like to grow into a wholesaler as well as this generates good revenue."

Amount of waste trade and profit

"If I can trade more waste, I can get more profit. What I get now is less, but I cannot buy more as I cannot store waste it"

"We can get profit only if I have more weight with me. Then the buyer knows I have more stock with me and will be ready to pay little more money"

Fluctuations in waste trade

"This is a good business and I started it as my father did the same. I was able to expand it and have more godowns than my father's time and we trade more volume now. We generally do well, but at times it does become difficult due to other conditions like market price, demands, etc…"

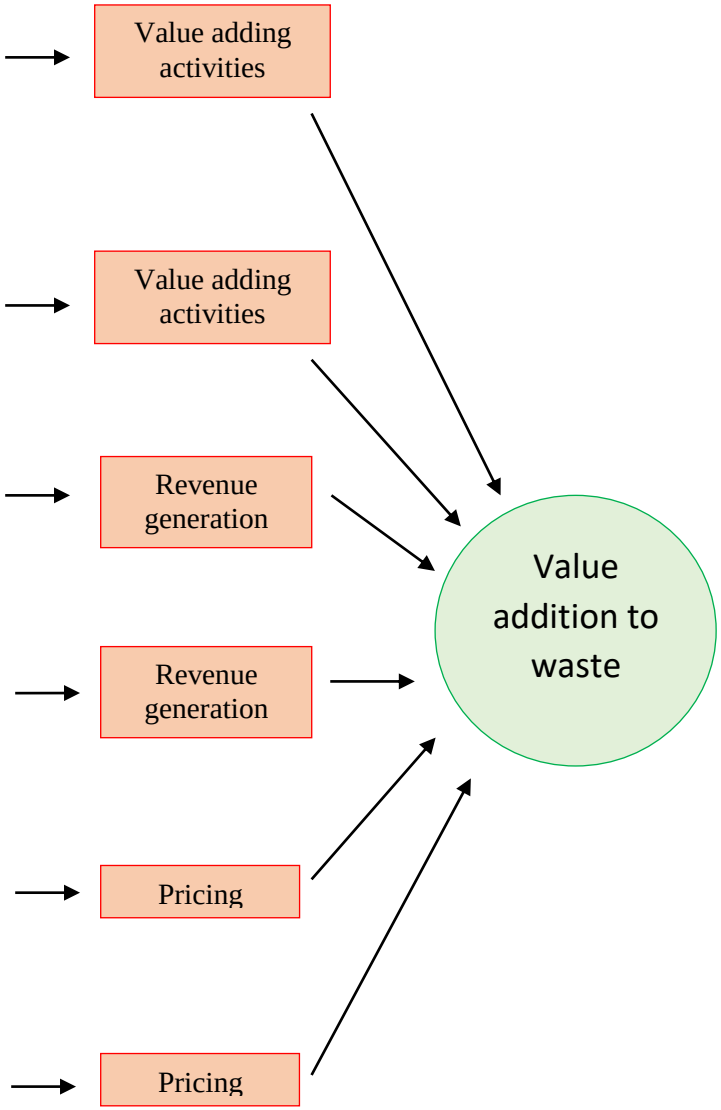
Price determination

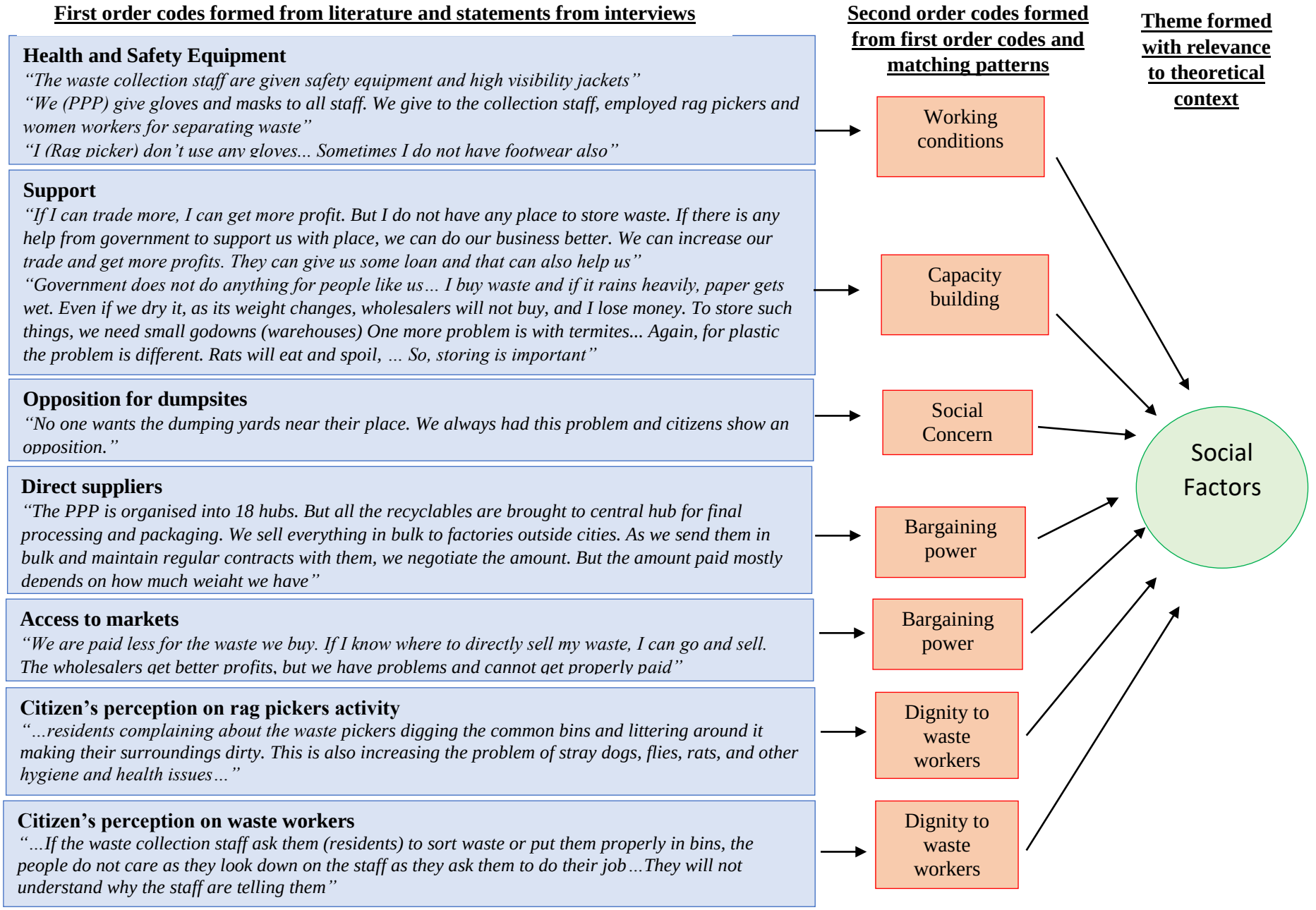
"the price is already fixed by wholesalers, and we cannot bargain with them"

"Our wholesalers inform what the price is before we buy waste. Depending on that, we pay to the sellers. Sometimes, if we have more waste, we can ask for higher price"

Second order codes formed from first order codes and matching patterns

Theme formed with relevance to theoretical context




First order codes formed from literature and statements from interviews
Second order codes formed from first order codes and matching patterns
Theme formed with relevance to theoretical context
Health and Safety Equipment
"The waste collection staff are given safety equipment and high visibility jackets"
"We (PPP) give gloves and masks to all staff. We give to the collection staff, employed rag pickers and women workers for separating waste"
"I (Rag picker) don't use any gloves... Sometimes I do not have footwear also"
Support
"If I can trade more, I can get more profit. But I do not have any place to store waste. If there is any help from government to support us with place, we can do our business better. We can increase our trade and get more profits. They can give us some loan and that can also help us"
"Government does not do anything for people like us… I buy waste and if it rains heavily, paper gets wet. Even if we dry it, as its weight changes, wholesalers will not buy, and I lose money. To store such things, we need small godowns (warehouses) One more problem is with termites... Again, for plastic the problem is different. Rats will eat and spoil, … So, storing is important"
Opposition for dumpsites
"No one wants the dumping yards near their place. We always had this problem and citizens show an opposition."
Direct suppliers
"The PPP is organised into 18 hubs. But all the recyclables are brought to central hub for final processing and packaging. We sell everything in bulk to factories outside cities. As we send them in bulk and maintain regular contracts with them, we negotiate the amount. But the amount paid mostly depends on how much weight we have"
Access to markets
"We are paid less for the waste we buy. If I know where to directly sell my waste, I can go and sell. The wholesalers get better profits, but we have problems and cannot get properly paid"
Citizen's perception on rag pickers activity
"…residents complaining about the waste pickers digging the common bins and littering around it making their surroundings dirty. This is also increasing the problem of stray dogs, flies, rats, and other hygiene and health issues…"
Citizen's perception on waste workers
"…If the waste collection staff ask them (residents) to sort waste or put them properly in bins, the people do not care as they look down on the staff as they ask them to do their job…They will not understand why the staff are telling them"
Working conditions
Capacity building
Social Concern
Bargaining power
Bargaining power
Dignity to waste workers
Dignity to waste workers
Social Factors

First order codes formed from literature and statements from interviews

Routing

"The collection staff usually work for municipality and know all the routes. They can plan the collection times. We (PPP) don't train them for that. We only train to check quality for collection. It saves lot of time and money…"

"The retailers and itinerant waste buyers sell waste to us. We (wholesaler) monitor how much waste is there with each of them and accordingly we hire vehicles to collect waste from them. We plan a route accordingly to reduce transportation costs."

Sorting

"In the same way, we (PPP) employ rag pickers for sorting. This also saves money as they have the skill to sort waste"

Infrastructural support

"To form the PPP, local government provided land. Company and government shared in providing infrastructure. This helped in reducing the initial set up costs and we started getting profits quickly"

Transport Vehicles

"For primary waste collection, it is easier to use tricycles and push carts so that they can easily access the households even if the lanes are too small. If we use trucks, then it is a problem. They are also expensive to buy so many trucks. These tricycles are cheaper, and it is easy to buy more in number and we don't have to worry about how the drivers are and maintenance costs."

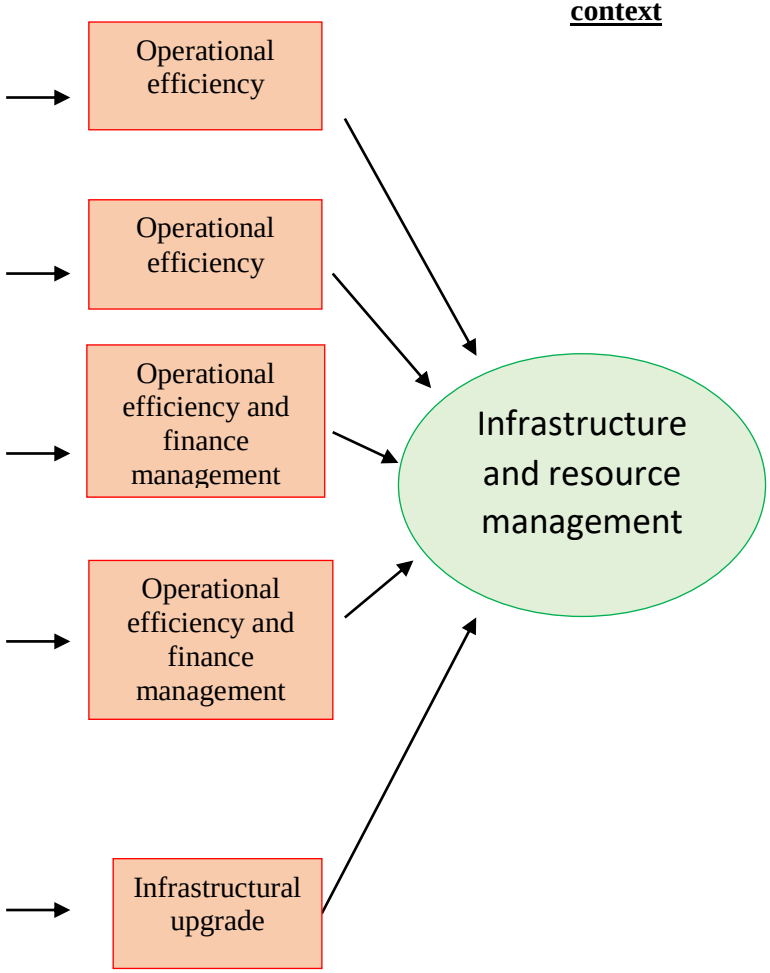
"I (itinerant waste buyer), use cycles to transport the waste I buy from houses. IF the waste is too much, then I hire some vehicle, usually an auto rickshaw or cycle rikshaw depending on the cost and weight I have with me"

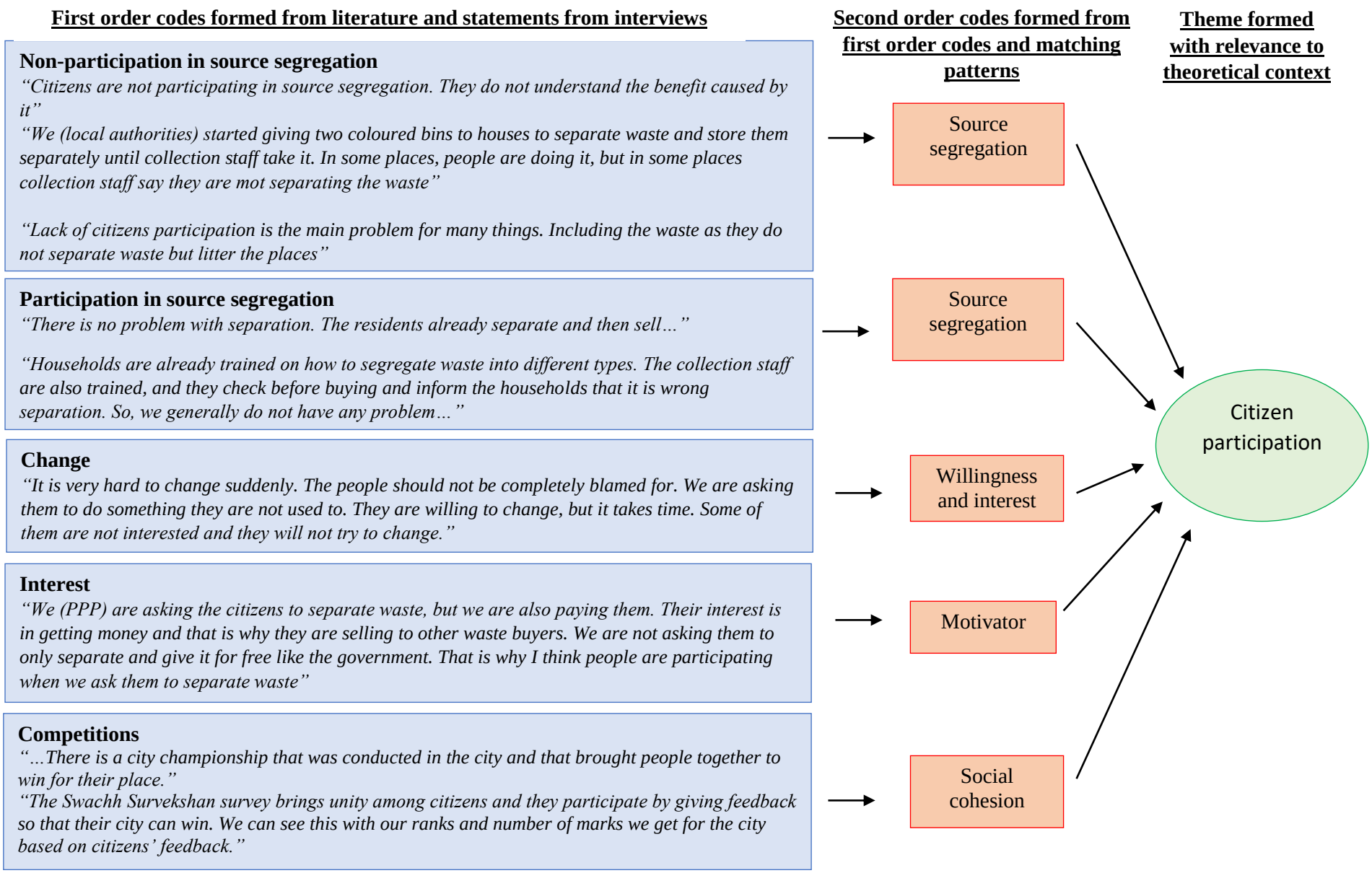
Treatment

"There is no waste treatment performed now...This (waste to energy plant) is under construction. If it starts functioning it will be good, but the main problem is to give continuous supply of separated wet waste to the companies. These are mentioned in their agreements that they need 1000MT of wet waste daily as the plant will be able to make use of its capacity to generate 15MW energy daily. If they do not have this supply, the plant cannot be used to the fullest and it will be expensive to maintain it."

Second order codes formed from first order codes and matching patterns

Theme formed with relevance to theoretical context




First order codes formed from literature and statements from interviews
Second order codes formed from first order codes and matching patterns
Theme formed with relevance to theoretical context
Non-participation in source segregation
"Citizens are not participating in source segregation. They do not understand the benefit caused by it"
"We (local authorities) started giving two coloured bins to houses to separate waste and store them separately until collection staff take it. In some places, people are doing it, but in some places collection staff say they are mot separating the waste"
"Lack of citizens participation is the main problem for many things. Including the waste as they do not separate waste but litter the places"
Participation in source segregation
"There is no problem with separation. The residents already separate and then sell…"
"Households are already trained on how to segregate waste into different types. The collection staff are also trained, and they check before buying and inform the households that it is wrong separation. So, we generally do not have any problem…"
Change
"It is very hard to change suddenly. The people should not be completely blamed for. We are asking them to do something they are not used to. They are willing to change, but it takes time. Some of them are not interested and they will not try to change."
Interest
"We (PPP) are asking the citizens to separate waste, but we are also paying them. Their interest is in getting money and that is why they are selling to other waste buyers. We are not asking them to only separate and give it for free like the government. That is why I think people are participating when we ask them to separate waste"
Competitions
"…There is a city championship that was conducted in the city and that brought people together to win for their place."
"The Swachh Survekshan survey brings unity among citizens and they participate by giving feedback so that their city can win. We can see this with our ranks and number of marks we get for the city based on citizens' feedback."
Source segregation
Source segregation
Willingness and interest
Motivator
Social cohesion
Citizen participation

Glossary

Behavioural change: Change in behaviour depending on external conditions.

Benchmarking: Evaluate (something) by comparison with a standard.

Brundtland Report: Report which highlighted three fundamental components to sustainable development: environmental protection, economic growth and social equity.

Capital cost: One-time setup cost of a plant or project, after which there will only be recurring operational or running costs.

Circular flow: A model of the economy in which the major exchanges are represented as flows of money, goods and services, etc. between economic agents.

Citizen centric: When governments deliver services based on the needs of the people they serve.

Composting: A controlled process involving microbial decomposition of organic matter.

Contamination: Failure of collection and processing systems to maintain separation or effectively sort materials to required specifications. With respect to waste management, a contaminant is a material that has been placed into an incorrect waste stream. Example, placing organic good waste into the paper stream.

Digital divide: It is a term that refers to the gap between demographics and regions that have access to modern information and communications technology, and those that don't or have restricted access.

Disposal: The final and safe disposal of post processed residual solid waste and inert street sweepings and silt from surface drains on land to prevent contamination of ground water, surface water, ambient air and attraction of animals or birds.

Door to door collection: Collection of solid waste from the door step of households, shops, commercial establishments, offices, institutional or any other non-residential premises and includes collection of such waste from entry gate or a designated location on the ground floor in a housing society, multi storied building or apartments, large residential, commercial or institutional complex or premises.

Dry waste: Waste other than bio-degradable waste and inert street sweepings and includes recyclable and non-recyclable wastes.

Dump sites: A land utilised by local body for disposal of solid waste without following the principles of sanitary land filling. Also referred as dumping yards.

Extended Producer Responsibility (EPR): Responsibility of any producer of packaging or products for environmentally sound management, till end-of-life of the products.

Facility: Any establishment wherein the solid waste management processes namely segregation, recovery, storage, collection, recycling, processing, treatment or safe disposal are carried out.

Fine: Penalty imposed on waste generators or operators of waste processing and disposal facilities under the bye-laws for non-compliance of the directions contained in these rules and/or bye-laws.

Generator: The individual or group that generates waste like household, commercial outlet, institution etc.

Handling: All activities relating to sorting, segregation, material recovery, collection, secondary storage, shredding, baling, crushing, loading, unloading, transportation, processing and disposal of solid wastes.

Hazardous waste: Products which due to their nature and quantity, are potentially hazardous to human health and the environment and which require special disposal techniques to eliminate or reduce the hazard.

Incineration: An engineered process involving burning or combustion of solid waste to thermally degrade waste materials at high temperatures.

Inert: Wastes which are not bio-degradable, recyclable or combustible street sweeping or dust and silt removed from the surface drains.

Informal waste collector: Includes individuals, associations or waste traders who are involved in sorting, sale and purchase of recyclable materials. They are also small-scale private waste traders.

Itinerant waste buyer: Itinerant waste buyer is a person who buys the pre-sorted waste from households and the price is negotiated based on the market dynamics

Materials recovery facility (MRF): A facility where non-compostable solid waste can be temporarily stored by the local body or any person or agency authorised by any of them to facilitate segregation, sorting and recovery of recyclables from various components of waste by authorised informal sector of waste pickers, informal recyclers or any other work force engaged by the local body or entity for the purpose before the waste is delivered or taken up for its processing or disposal.

Organic waste: They are defined as vegetative matter, food processing waste, landscaping, garden and horticultural wastes, kitchen scraps, feed processing waste, landscaping, garden and horticultural wastes, kitchen scraps, feed processing wastes and other organic wastes which can be readily composted in composting facilities.

Participating: Contributing some or all requested materials to recovery programme.

Primary collection: Collecting, lifting and removal of segregated solid waste from source of its generation including households, shops, offices and any other non-residential premises or from any collection points or any other location specified by the local body.

Processing: The upgrading of materials at an MRF or other facility to meet a market specification. Upgrading operations include for example, sorting densification, shredding etc.

Processing: Any scientific process by which segregated solid waste is handled for the purpose of reuse, recycling or transformation into new products.

Public private partnerships: It is a cooperative arrangement between two or more public and private sectors, typically of a long-term nature.

Quality of life: The standard of health, comfort, and happiness experienced by an individual or group.

Recovered: Materials recycled, composted, regenerated or whose energy value can be used as an energy source.

Recovery: Conversion of waste to energy, generally through the combustion of processed or raw refuse to produce steam.

Recyclables: Post-use materials that can be recycled for the original purpose or for other purposes but excluding energy recovery.

Recycling: The process of transforming segregated non-biodegradable solid waste into new material or product or as raw material for producing new products which may or may not be like the original products.

Reuse: The use of product more than once in its same form for the same purpose. Example, a soft drink bottle is reused when it is returned to the bottling company for refilling.

Secondary storage: The temporary containment of solid waste after collection at secondary waste storage depots or MRFs or bins for onward transportation of the waste to the processing or disposal facility.

Segregation: Sorting and separate storage of various components of solid waste namely biodegradable wastes, non-biodegradable wastes, non-recyclable combustible waste, non-recyclable inert waste, domestic hazardous wastes, and construction and demolition wastes.

Service provider: An authority providing public utility services like water, sewerage, electricity, telephone, roads, drainage, etc.

Sorting: Separating various components and categories of recyclables such as paper, plastic, cardboards, metal, glass, etc., from mixed waste as may be appropriate to facilitate recycling.

Tipping Fee: A fee charged for the unloading or dumping of material at a waste processing facility.

Transfer station: A facility created to receive solid waste from collection areas and transport in bulk in covered vehicles or containers to waste processing and, or, disposal facilities.

Transportation: Conveyance of solid waste, either treated, partly treated or untreated from a location to another location in an environmentally sound manner through specially designed and covered transport system to prevent the foul odour, littering and unsightly conditions.

Treatment: The method, technique or process designed to modify physical, chemical or biological characteristics or composition of any waste to reduce its volume and potential to cause harm.

User fee: A fee imposed by the local body and any entity mentioned in rule 2 on the waste generator to cover full or part cost of providing solid waste collection, transportation, processing and disposal services.

Valorisation: Transformation of material which extracts value from processed recoverable.

Waste generator: It includes every person or group of persons, every residential premises and non-residential establishments including Indian Railways, establishments, which generate solid waste.

Waste hierarchy: The priority order in which the solid waste should be managed by giving emphasis to prevention, reduction, reuse, recycling, recovery and disposal, with prevention being the most preferred option and the disposal at the landfill being the least.

Waste picker: A person or groups of persons informally engaged in collection and recovery of reusable and recyclable solid waste from the source of waste generation the streets, bins, material recovery facilities, processing and waste disposal facilities for sale to recyclers directly or through intermediaries to earn their livelihood.

Waste traders: They include itinerant waste buyers and also the retailers, wholesaler and suppliers who usually have license to buy and sell waste with a profit.