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## **Towards A Carbon-Neutral City by 2035: Innovative Transformation of Domestic Solid Waste Collection and Recovery Services in Sharjah**

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**Towards A Carbon-Neutral City by 2035: Innovative Transformation of  
Domestic Solid Waste Collection and Recovery Services in Sharjah**

By

**Basem Abu Sneineh**

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of  
Science in Service Leadership and Innovation

Department of Leadership and Innovation  
Faculty of the Saunders College of Business

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Rochester Institute of Technology

Rochester, Dubai

(July 14, 2022)

**ABSTRACT**

This study quantifies the impact of an identified major step in the process of significant contribution to the transformation of Sharjah into a carbon-neutral city by the year 2035. This identified step applies to the concept of waste segregation at the residential sector source which means that the waste generators, i.e. Sharjah residents, are required to segregate the waste that they generate in their houses while disposing it. The march towards a carbon neutral city means driving the carbon dioxide emissions of the city to reach net-zero. This requires the UAE adopt this concept to ensure that the emitted amount of carbon dioxide is equal to the amount of removed carbon dioxide.

One of the best methods for increasing the recovery rate from generated domestic waste is applying the concept of waste segregation at source. Waste collection is considered as a relevant activity in the field of reverse logistics. The term reverse logistics include all the operations that are related to the materials and products reuse. This study will focus on the smart transformation of domestic waste collection service as well as improving the rate of recovery from domestic waste in Sharjah city. This study also emphasizes the field of waste management services and processes in Bee'ah Company which is the sole entity in-charge of fully handling the municipal solid waste in Sharjah.

The current method of waste collection used in most cities around the world is the constant waste collection route and this method was introduced in the 1800s. In order to obtain the view and perceptions of people on the impact of carbon neutral city, structured responses from 100 respondents using the mixed method approach was collected along with 10 managerial workers responses using qualitative method of a partially structured interview that was conducted. Additionally, this study discusses the transformational capabilities for an innovative transformation of Domestic Solid Waste Collection and Recovery Services using digital transformation utilities.

## ACKNOWLEDGEMENT

First and foremost, I wish to state that my research work on this thesis would not have been accomplished without the mercy of the Almighty Allah, without the constant support of my supervisor, colleagues and the love and encouragement of my family.

My sincere appreciation goes to my supervisor Dr. Phillippa Thiuri for sharing her research knowledge and experience. I am especially grateful for her constant assistance and encouragement throughout my Master's journey.

## ABBREVIATIONS

CNC- Carbon Neutral City

CN - Carbon-neutrality

IT – Information Technology

RM – Research Methodology

AI – Artificial Intelligence

IoT- Internet of Things

ML- Machine Learning

DSW- Domestic Solid Waste

SPSS- Statistical Package for the Social Sciences

GHG- Green House Gas

MRF - Material Recovery Facility

PHS - Public Health Sector

PPM - Particles Per Million

IEA - International Energy Agency

CFCs - Chlorofluorocarbons

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**DECLARATION**

I hereby certify that I am the sole author of this thesis. The author of this thesis takes the full responsibility for all the content herein contained.

Signature: BASEM ABU SNEINEH

Date: 07.07.2022

## CHAPTER ONE

### Introduction and Background

#### 1.0 General Overview

Waste management has become the story of the era and one of the most essential environmental topics. Regardless of the level of technological advancement that we reach, humans will keep generating solid waste forever. In a real-world scenario, there is no perfect solution for treating solid waste but there is always a space for improvement. In general, the level of development of a waste management system in a country is directly proportional to the level of development of that country (Mmereki, 2013). Since the world population and associated solid waste production are increasing, there is a limited time window until we, as humans, fix the world environmental crisis. The increasing number of populations is directly proportional to the generation of waste and to the consumption of energy. Moreover, the increase in waste generation and energy consumption will negatively affect the environment because most of the energy that is produced in the world, 64% of it as in 2019, is produced from burning fossil fuels while waste alone produced 3.1% of all greenhouse gases in Europe by 2017. The more greenhouse gases are generated globally, the shorter the time the humanity has before the global warming and associated climate change reaches irreversible stage.

As an expert in the field of environmental management, the researcher confidently advise that we must solve this problem once and for all. In short, the more we delay the more we pay.

Carbon-neutrality is the desired goal of every developed country and must be the goal of every country in the world. Almost all nations have ratified the Paris Climate Agreement, which aims to limit global warming to "1.5°C above pre-industrial" levels. However, temperatures will keep increasing well beyond 1.5, to levels that endanger the lives and livelihoods of people all

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over the world if the practice continuous to pump out the gases that cause climate change. For this reason, an increasing number of nations are pledging to reach "net zero" emissions, or carbon neutrality, within the next several decades. It's a massive assignment that calls for bold acts to be taken immediately away. The target is net zero by 2035. However, nations must also show how they will achieve the goal. The mobilization of climate funds for poor nations, together with resilience and adaption measures, must be combined with efforts to attain net-zero. For a country to reach carbon-neutrality, the total amount of carbon that they generate by all means must be equal to the total amount of carbon that they eliminate. Therefore, reaching carbon-neutrality means that either countries do not produce carbon at all, which is not an easy mission, or countries eliminate the carbon they produce by methods like using carbon capture devices or by planting trees. When it comes to air pollution, the whole humanity is sailing on the same ship, thus, if we sink we sink together. It is estimated that the earth may cross the threshold of global warming by as early as 2027 (McGill University, 2020). Once we cross that threshold, there will be irreversible consequences on the climate change. The impacts of climate change are literally catastrophic.

After Paris Agreement in 2016, the environmental target of each country and city in the world has become "Reaching Carbon Neutrality" which is not an easy goal. This target can only be achieved by shifting the behavior of humanity so that they reduce the generation of Greenhouse Gases (GHGs) to the minimum and at the same time by increasing the carbon absorption to counteract the effect of the carbon that was released into the atmosphere. Carbon absorption can be done by different methods like Afforestation and Direct Air Capture techniques.

#### **1.1 Zero-Waste-to-Landfill**

In the waste management business, the phrase "Zero Garbage to Landfill" is frequently used to describe a mindset aimed at decreasing the quantity of waste that ends up in landfills. Achieving Zero-Waste-to-Landfill is another ambitious sub-goal that contribute to

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reaching the bigger goal which is carbon neutrality. To clarify, the journey of domestic waste goes through five main steps;

i. Waste collection from all the residents and businesses in a locale is transported through the integrated waste management complex that consists of multiple waste recovery and waste recycling facilities,

ii. Waste recovery which takes place in different recovery facilities like Material Recovery Facility (MRF),

iii. Waste recycling which occurs at different facilities like a compost plant which transforms the organic waste into compost,

iv. Waste incineration for the residues that are left after the recovery takes place in the MRF, as well as for hazardous and hygiene waste, and;

v. Landfilling the remaining ash, left after incineration, in the landfill. Note that although this amount of waste requires a landfill, it is a very small amount, compared to the amount of waste before incineration. Reaching this point is considered as a successful achievement of zero-waste-to-landfill target.

In today's rapid evolving world, waste has become a wealth. The amount of garbage produced per person is steadily rising in high-income GCC cities. At the end of 2016, the GCC produced an estimated 27 million tons of solid municipal garbage annually, up to 5 percent over the previous year's estimate, according to the "UN Environment Programme (UNEP)". These towns spend a lot of money on trash management each year, and landfill expenses are becoming an increasing environmental burden. The cost of waste management in the West Asia area is estimated to be over \$3.6 billion annually, according to the same UNEP study, which also reveals a strong association between high wealth and high waste creation. An integrated system that diverts 85% of the region's garbage from landfills would cost up to \$7.86 billion yearly,

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opening up a market opportunity of up to \$4.7 billion. A circular economy, according to the research by the "World Government Summit", may help the GCC countries save \$138 billion by 2030. Focusing on the four major kinds of waste—wasted capacity, wasted lifetime, wasted embedded value, and wasted resources—remains a commercial potential worth more than \$4.5 trillion globally. One of the main issues related to waste management is the carbon footprint that is generated by this whole system of “collection to landfilling”. Landfilling the waste without processing it through recovery and recycling is simply obsolete. Engineered landfills produce a significant amount of methane which is a greenhouse gas. So, reducing the amount of waste that is landfilled will automatically lead to reduction in GHGs emissions and hence approaching carbon neutrality. Moreover, there are modern ways that are better than landfilling waste like incinerating it in a waste-to-energy facility.

Bee’ah Company is the sole entity that is in-charge of fully handling the municipal solid waste in Sharjah. The waste management system, processes and services at Bee’ah can all be improved. This study will focus on the smart transformation of domestic waste collection service as well as improving the rate of recovery from domestic waste in Sharjah city.

## **1.2 Background of the Study**

### **1.2.1 General Purpose of the Study**

The purpose of this experimental study is to evaluate the impact of a major step that will significantly contribute to the transformation of Sharjah into a carbon-neutral city by the year 2035. This step is to apply the concept of waste segregation at source on the residential sector which means that the waste generators, i.e. Sharjah residents are required to segregate their waste generated at their homes while disposing it. In this study, the independent variable will be the level of compliance of Sharjah residents to the concept of waste segregation at source.

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The dependent variable will be defined generally as rate of recovery from domestic waste, which is segregated at source, in the Material Recovery Facility (MRF). The MRF is an essential component of the modern waste treatment process. The MRF is the place where the mixed domestic waste is received and all the materials that can be recovered, i.e. recyclables. The application of waste segregation at source concept will carry a significant impact on the environment through increasing the rate of recovery from waste. The more we recover from waste, i.e. the more waste is diverted from landfill, the better the environmental outcome will be. This is because sending the waste to landfill is considered the last resort when treating domestic waste and it carries negative impact and risk on the environment. Some of the negative impact include: contaminating the underground water and polluting the air with the methane gas that is results from anaerobic conditions in the landfill.

So, the general purpose of this study can be summarized in the following points;

- i. To overcome the lack of understanding of Sharjah residents about waste segregation at source and this will increase the recovery rate from generated waste by educating the residents of those 5000 apartments involved in this study to guarantee maximum compliance level
- ii. To meet the environmental obligations which UAE agreed to follow according to Paris Agreement that was signed by UAE and another 191 parties. This will be done by maximizing the efficiency of waste collection and recovery services. The performance of these services is currently low and this research will significantly increase it.
- iii. To improve the performance of waste collection service in Sharjah.
- iv. To increase the income by increasing the recovery rate of generated waste.
- v. To save the environment by maximizing the efficiency of waste collection and recovery services

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The second purpose of this study is to improve the waste collection service by optimizing the collection trip by two means;

- i. Placing a sensor in each waste bin, firstly in three selected areas, that monitors the filling level of the bin and send a notification to the collection team when it becomes 80% full.
- ii. Using a software to plan the best collection journey by determining the shortest route. This will save a huge amount of money and time. Meanwhile, this will also reduce GHG emissions.

#### **1.2.2 The Population or Sample that will be Studied**

In this study it is crucial to determine the expected compliance level of Sharjah residents with the waste segregation at source. This will be done by selecting a random sample from Sharjah residents and providing them with 3 rolls of different colors plastic bags for them to fill with the suitable waste type from what they generate.

The sample will be the waste that is generated by randomly selected 5000 houses and apartments from all over Sharjah city.

#### **1.3 Statement of the Problem**

The health of the public and the economic situation in every country in the world is negatively affected by carbon emissions (Gavurova et al., 2021). The environmental obligations of the UAE as well as all other countries in the world is to reduce their carbon footprint. This can be done by finding the sources of Greenhouse Gases (GHGs) emissions and considering whatever adjustment required for that source. One of the GHG sources is the domestic waste that is generated by occupants in residential houses. The waste management system in Sharjah needs

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to be improved by various methods in order to reduce the carbon emissions from this sector (Couth & Trois, 2010).

There are two main problems found in the current waste management system of Sharjah. The first problem is the domestic waste generated by Sharjah residents is mixed and to increase the recovery rate to the maximum, however the waste should be segregated at source. The second problem is that the waste collection team collects waste from every waste bin in Sharjah every day. Many of these waste bins do not need to be collected every day because they do not become full every day. By applying waste segregation at source and improving the waste collection service, a significant amount of GHGs will be reduced.

## **1.4 Research Aims and Objectives**

To develop a theoretical model which examine the impact of Carbon Neutral City on waste management system in Sharjah, UAE.

### **1.4.1 Research Objectives**

- To review the existing literature on carbon emissions, waste management collection mechanism and waste characterization both globally and locally,
- To determine the factors which influence the establishment of a carbon neutral city,
- To examine the existing models, and
- To develop a theoretical model which examines the influence of carbon neutral city and its impact on the waste management system in Sharjah, UAE.



**1.5 Research Questions/Hypotheses**

PRQ: How will applying the Carbon Neutral City concept impact the waste management system in Sharjah, UAE?

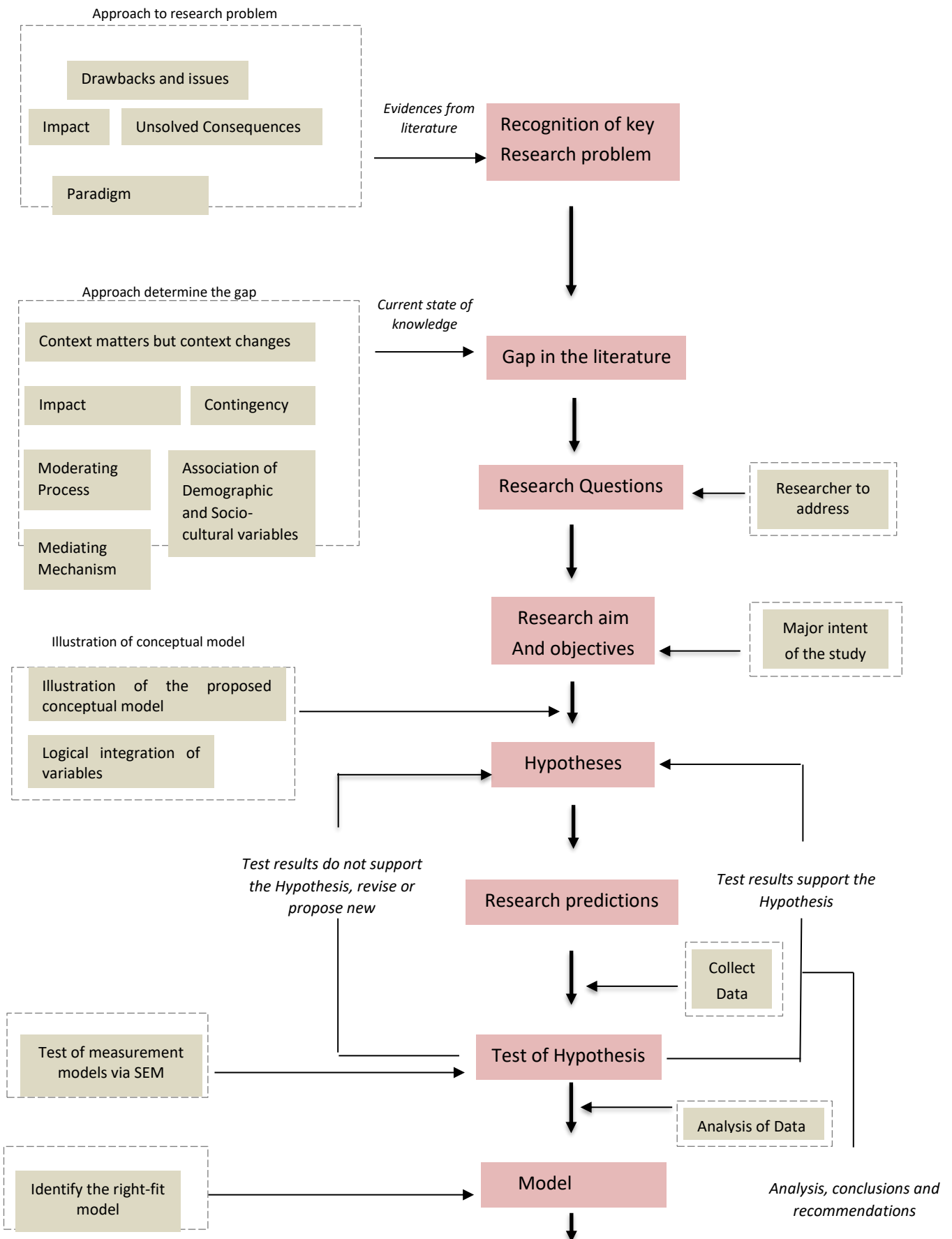
SRQ: What factors determine the participants, from Sharjah residents, who will be selected for waste segregation at source experiment?

SRQ: What is the impact of renewable energy automobiles on waste collection mechanism?

The theoretical framework that will be used in this research is deductive quantitative research. The research questions are:

- i. How much compliance level from the residents of Sharjah will the imposition of waste segregation at source concept get?
- ii. What will the recovery rate be after imposing the waste segregation at source in Sharjah city?
- iii. What machineries are required to be bought for separating the plastic bags, according to the color, in the transfer station?
- iv. What will the cost of buying these machineries be?
- v. What modifications are required for the collection trucks to collect the waste that is segregated at source in different plastic bags?
- vi. What will the cost of modifying collection trucks be?
- vii. What modifications are required for the Material Recovery Facility (MRF) in order for it to be able to handle the waste that is segregated at source?
- viii. How can the waste collection service at Bee'ah be optimized to maintain the maximum efficiency with the minimum possible cost?

1.6 Research Methodology





Research Conclusions

This research used a quantitative approach and the interpretative group of methods and was completed using the following steps:

- i. A random sample of 5000 apartments in Sharjah city was selected and the compliance level of the residents of these apartments to the application of waste segregation at source concept was evaluated.
- ii. The sample was carefully studied and the recovery rate from each type of waste will be determined. The concept of waste segregation at source was imposed on the residents of Sharjah regardless of the compliance level of the first 5000 selected houses and apartments. When the compliance level was found to be less than 60%, then the reasons that caused this decrease were determined by collecting feedback from the residents.
- iii. Sharjah is a big city, and therefore was divided into sectors. Sectors that received the plastic bags were asked to comply with the waste segregation at source and were selected based on multiple factors like the population and economic situation (i.e. annual rental cost) of the area.
- iv. The machinery that was placed in the transfer station was chosen in accordance with different set of parameters like their cost and efficiency. Later in the study, the most suitable machineries were bought accordingly.
- v. The modifications of waste collection trucks were studied and selected by a collaboration of two technical teams; one from inside Bee'ah and one from outside it.
- vi. A sensor was placed in each waste bin to determine its filling level sent a message to the collection team when it becomes 80% full. A smart application like Google Maps

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was used to find the optimal waste collection journey route by only considering the waste bins that are 80% full or more. This information was provided by the sensors that are placed in the waste bins.

#### **1.6.1 Research Paradigm:**

The research paradigm used in this research study is Epistemology with an interpretivism research philosophy approach

#### **1.7 Scope of the Research**

In this research, only the domestic (household) solid waste that is generated by the residential sector in the city of Sharjah was considered. The research focused on reducing carbon emissions from the waste management system in Sharjah by two means; enforcing the concept of waste segregation at source on Sharjah residents and improving the waste collection service.

#### **1.8 Significance of the Research**

Multiple reasons make this study especially important. Firstly, UAE must fulfill the requirements of Paris agreement that was signed by UAE and another 192 parties in 2016. Secondly, applying the concept of waste segregation at source will come with a financial cost (for making necessary modifications) so it is crucial to determine the expected compliance level of Sharjah residents with this concept. If the compliance level is too low, the study will offer various advanced solutions to increase the compliance level and these suggestions will need more future studies. Thirdly, the upgrading of waste bins by equipping them with sensors will save a lot of time, effort and money for the collection service. This will also have a positive impact on conserving the environment and contribute to far more recovery from the waste that is generated by Sharjah residents. Minor modifications on the waste management system in

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Sharjah will highly improve the financial outcome and increase the work efficiency. Finally, this research will push Sharjah one step forward towards achieving carbon neutrality which will carry health and economic benefits.

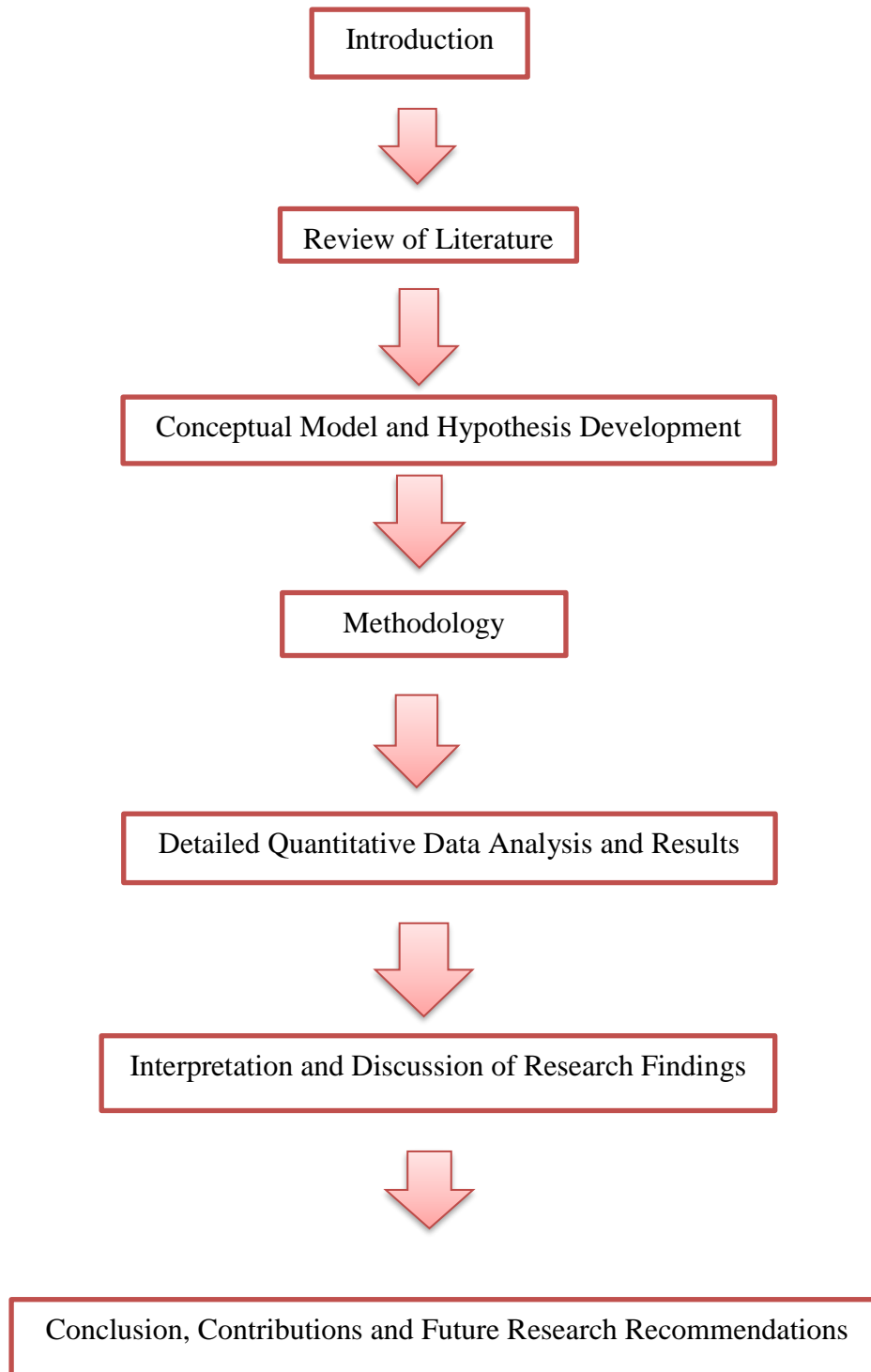
#### **1.9 Limitations of the Research**

- i. The cost of the new machinery will be relatively significant and this will require a full analysis of expected costs and profits.
- ii. The cost of modifying the equipment and waste recovery lines at the Material Recovery Facility (MRF) will be justified by the expected significant profits that will be gained from the waste that is segregated at source.
- iii. The time of modifying the waste collection trucks must not exceed three months.

The reason for three months threshold is in order to be certain that selecting the efficient model of waste collection trucks and it is important to provide enough time at the beginning of the process to explore the options. It's possible that there will be a need to create a new model since a current one won't meet the requirements or specifications. Additionally, there should be adequate time at the start of the process to consider any problems with the change in the modification of the waste trucks to come up with solutions. At the beginning of the process of modifying the waste collection trucks enough time is required to lay the groundwork for a successful shift. This time frame can be considered a challenge but with careful planning and execution, it can be handled.

**1.6.1 Overall Approach and Chapter Summary**

The existing structure of the thesis remains, as below depicted in diagram



## CHAPTER TWO

**Review of Literature****2.0 Summary of the chapter:**

This section thoroughly captured the theoretical area of the information related to the Innovative Transformation of Domestic Solid Waste Collection and Recovery Services in Sharjah emphasizing the carbon neutrality of a city. It is impossible to address the climate change matter of building a carbon neutral environment without transforming cities. The concept of carbon neutrality means driving the carbon dioxide emissions to reach net-zero. This requires the country that adopt this concept to ensure that the emitted amount of carbon dioxide is equal to the amount of removed carbon dioxide. Building carbon neutral cities will take tremendous effort from both the corporate and governmental sectors, but this can be easily done with the help of the current innovative technologies. The journey to become a carbon-neutral city is a challenging one. A carbon neutral city will reap the advantages of enhanced health of the public, a sustainable economy, and biodiversity preservation

This chapter also cover up the area of decarbonization along with the zero waste to landfill and the impact of GHG's emission and its reduction. The term decarbonization means all these steps taken by any business sector or an entity like a government organization to minimize their carbon footprint, mainly focusing on the greenhouse gas emissions of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) to lessen their climate effect. One of the very significant steps of decarbonization would be towards achieving the Paris Agreement's aim of having Europe carbon neutral by 2050. The UAE is a party in the Paris Agreement which was signed in April of 2016. The main point of this agreement is limiting the climate change and mitigating its effects. Carbon Footprint Reduction through Waste Collection Optimization are also discussed in the chapter.

## **2.0 Carbon Neutrality**

The concept of carbon neutrality means driving the carbon dioxide emissions to reach net-zero. This requires the country that adopt this concept to ensure that the emitted amount of carbon dioxide is equal to the amount of removed carbon dioxide. As of October 2021, more than 125 countries in the world has pledged to achieve the target of carbon neutrality. Most of the countries are planning to make this happen by 2050 or 2060. (Jing, 2021)

The global concentration of CO<sub>2</sub> in the preindustrial era, specifically in 1850, was 285 particles per million (ppm) but the concentration in 2020 reached 415 ppm. The average global surface temperature in this period, 1850 to 2020, increased by 1.2°C. The results of this continuous irresponsible release of greenhouse gases emissions will make the global warming worse. In the best-case scenario, reaching carbon neutrality by the year 2050 will only ensure that the increase in global surface temperature by the year 2100 will be 1.5°C – 2.0°C.

The environment is negatively affected by the global warming. This includes having many devastating phenomena like loss of biodiversity, floods, rise in sea level as a result of ice melt in the north and south poles and droughts.

The world population is expected to reach about 10 billion by the year 2050. The growing number of world population means that the demand on energy will increase by 80% and the demand on food will increase by 70%. This will result in more carbon and waste generation. In the year 2016, more than 90% of all global emissions of Greenhouse Gases were from the activities related to food and energy. (Ritchie, 2017)

The high dependency of the world since the first industrial revolution on natural resources, especially fossil fuels, and the deforestation have all contributed to the current climate crisis. (IISD, 2020) (Rabaey, 2014). The goal of reaching carbon neutrality by the year 2050 may be too ambitious because the International Energy Agency (IEA) claims that in order to achieve



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that goal, the world must completely stop the development and extraction of fossil fuels from the year 2021. (IEA, 2021). So, the world is not currently on the track for achieving the goal of carbon neutrality by the year 2050.

The good news is that renewable energy sources are far more than enough to cover the global energy needs. In fact, renewable energy sources are able to provide the world with more than 3000 times its current energy needs. (Ellabban, 2014).

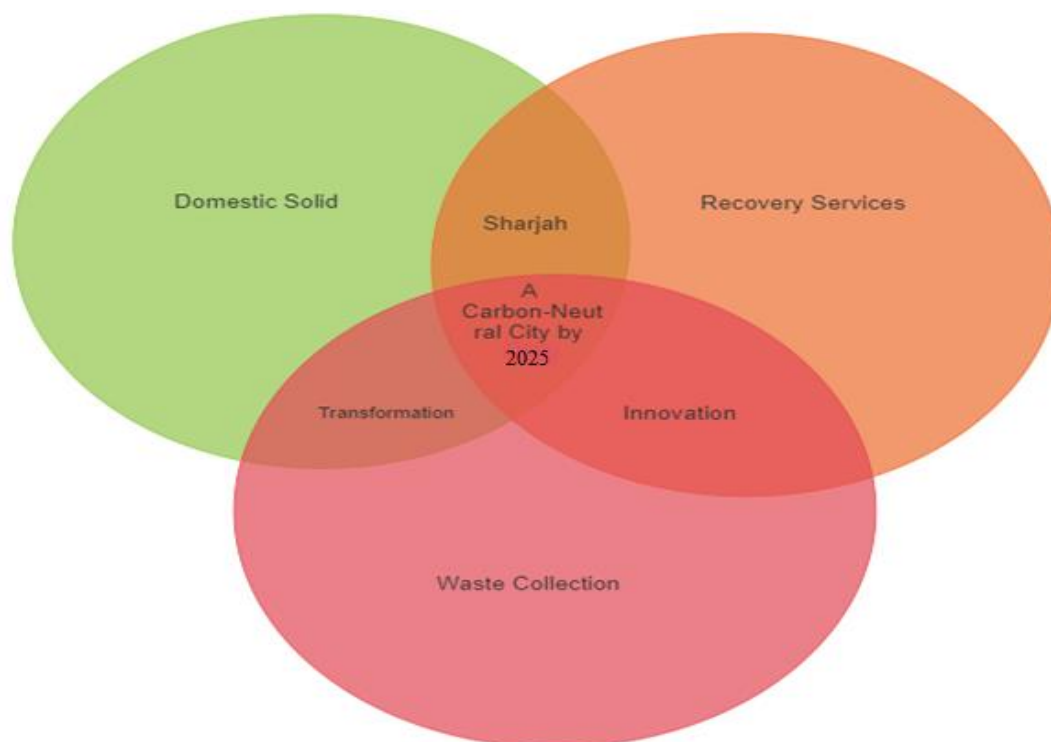


Figure 1: Venn diagram depicting the key components of a Carbon-Neutral city by 2035

( Banerjee & Sarkhel, 2020).

### **2.1 Key Components of Innovative Transformation towards a Carbon Neutral City**

It is impossible to address the climate change matter of building a carbon neutral environment without transforming cities. Building carbon neutral cities will take tremendous effort from both the corporate and governmental sectors, but this can be easily done with the help of the current innovative technologies. There are two key reasons cities constitute the cornerstone of

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universal decarbonization. To start with, the cities account 70% of global emissions. Buildings alone account for around 40% of the total. The buildings will account for up to 50% if the construction sector and its related environmental factors are included. Secondly, with the increasing speed of urbanization, it is expected to reach around 68% by the year of 2050, where currently it is 55% which is increasing the present building stock.

The journey to become a carbon-neutral city is a challenging one. Due to the industry's inherent variety of prototypes and the fragmentation of the market, particularly in this short period of time, some would claim that the sector is more difficult to decompose than many heavier sectors (Mckinsey Sustainability, 2022). This is more of a value-chain integration related to business problem rather than a technology issue. The cities and structures transformation towards a carbon neutral city should be addressed promptly, or else the possible areas of targets of implementing this innovative transformation will be missed out (World Economic Forum, 2020). This is a difficulty that all organizations must face and address, but it is also a potential platform for innovation.

### **2.2 Decarbonization and Energy Efficiency:**

The term decarbonization means all these steps taken by any business sector or an entity like a government organization to minimize their carbon footprint, mainly focusing on the greenhouse gas emissions of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) to lessen their climate effect. One of the very significant steps of decarbonization would be towards achieving the Paris Agreement's aim of having Europe carbon neutral by 2050.

Improving the energy efficiency policies can help reduce CO<sub>2</sub> emissions significantly, especially when the global energy generation is not environmentally friendly. However, in the waste sector industries, increasing energy efficiency is insufficient to totally reduce the

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emission of greenhouse gas. Transforming towards a carbon neutral city by decarbonizing cities and structures at scale necessitates a rethinking of their future roles. With the recent rise in temperature, decarbonization has gained traction, notably with the establishment of the Paris Agreement, which aims to keep global warming below 2°C until the year of 2050.

Decarbonization plays a huge role in the transformation towards a carbon neutral city focusing in the field of domestic solid waste management. Methane emissions are also considered as a threat to the waste sector (Li et al., 2020). Based on a 20-year timeline, methane is a momentary climatic pollutant which contains 84 times the global warming effect when compared to carbon dioxide (Union Environment programme, 2021). And, although accounting for approximately 20% of the emissions of global greenhouse gas, methane has contributed for more than half of the net rise in global temperature ever since the pre-industrial period (Kenis, A., & Lievens, M., 2017). On a 20-year time horizon, the emissions of methane gases due to the human activities just from the landfills of the municipal urban area had a similar warming effect as 4 billion metric tons of carbon dioxide which is almost the same as the yearly emissions from 900 million passenger automobiles (Laine et al., 2020). A rising consumption and waste creation are being driven by a larger global population like the Middle East, North Africa and South Asia regions which have greater purchasing power (Huovila et al., 2022). The problem of domestic solid waste disposal in these fast-growing globally populous regions increases the emission of methane which eventually increases the risk of the Public Health Sector (PHS). To meet the goal of reducing global warming to 1.5 degrees Celsius by the middle of the century mainly by maintaining a carbon neutral city, concrete strategies and approaches to decarbonize the domestic solid waste industry and dramatically cut methane emissions would be required (Tozer, L., & Klenk, N, 2019).

Some of the strategies that can be used to mitigate the methane emissions problem in the domestic waste sector are:

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1. Conducting a detailed assessment study on the methane emissions and learning about the efficient ways for lowering the methane emissions mainly by analyzing the mitigation possibilities of various mitigation solutions (Gaikwad et al., 2004).
2. Creating a strategy for quickly establishing a worldwide monitoring and analytics platform, which includes a deliberate effort to develop innovative incentives, conducts, and regulations to maximize methane moderation which will be a contributing factor to a carbon neutral city.

The components used in this process, as well as the source of CO<sub>2</sub> emissions, varied per industry. As a result, the decarbonization methods that are used are process specific. Carbon is employed as both a source of energy and a feedstock in several sectors, making decarbonization challenging (Li et al., 2020). Europe has already pledged to cutting CO<sub>2</sub> emissions by a minimum of 55% by the year of 2030 as a first step. This indicates that drastic adjustments must be made as soon as possible.

### **2.3 Domestic Solid Waste**

Based on the concept that average national waste creation rate and composition change depend on average total income level, a novel approach for projecting domestic solid waste production and waste breakdown by income class was created (Nyenje et al., 2013). Presently, 59 percent of carbon in trash is squandered (ditched, dispersed, and publicly burnt without energy recovery), 18 percent is recycled/composted, and 23 percent is transformed to energy on a worldwide scale (Visvanathan, C., & Glawe, U., 2006). Industrial waste accounts for 35% of carbon content in garbage, whereas domestic solid waste accounts for 65%. In the recent decade, waste quantities in the UAE have grown due to population expansion and economic activities. The majority of the garbage is disposed in municipal landfills or dumpsites, where organic waste produces a significant quantity of methane which is a powerful greenhouse gas. The presence of carbon content that is required to produce energy is determined by the quantity

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and type of waste generated (Mbuligwe et al., 2002). According to the studies conducted (SWEETNET 2012, UNEP and ISWA 2015) show that the structure of municipal or domestic solid waste in the households is influenced by other contributing factors like geographic regions, socioeconomic factors, and environmental factors (Gómez-Sanabria, 2018). Mostly in the high-income nations, paper and plastic waste dominate the domestic solid waste, whereas food waste prevails in low-income countries (Xi et al., 2005).

Because of the effect of waste composition on the carbon content, the energy regeneration possibilities and waste composition estimates are required (Aziz et al., 2011). Landfill gas production is calculated with a ten-year lag for quickly degrading types of organic waste and a twenty-year lag for weakly degrading types of organic waste. The solid waste and the climate change are linked to each other based on various factors (Pan et al., 2022). The formation of methane from microbial digestion of waste in landfills and the release of nitrous oxide produced from the solid waste burning units both significantly contribute to emissions of greenhouse gas (Igbinomwanhia et al., 2014). Inorganic garbage manufacturing and incineration consume natural resources such as metal, water, wood, resulting in greenhouse gas emissions, mainly other pollutants along with carbon dioxide. Aiming at preventing or reducing the domestic solid waste helps to reduce the greenhouse gases emissions effectively (Bai et al., 2002). This is true through the following means;

1. It will help to decrease landfill methane emissions. Organic waste is diverted from landfills through waste avoidance and recycling like composting which reduces the amount of methane generated as these items are mostly decomposable (Jin et al., 2006).
2. It reduces the energy consumption-related emissions. Recycling reduces energy use. This is because items made from recycled materials consume less energy than those made from raw materials (Tran et al., 2020). Apart from that, preventing waste is also considered more

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beneficial. When individuals reuse items or goods that are manufactured with less material, less energy is required to collect, transport, and process the raw materials to manufacture products (Visvanathan & Glawe, 2006).

There are other challenges caused by domestic solid waste. The waste placed on the land pollutes the soil, making it infertile. Contaminates water bodies, affecting aquatic life, which then reaches humans via the food chain and organic substances (Caruso et al., 1993). Drain obstruction occurs as a result of abandoned plastic bags and uncollected debris, resulting in stagnant water that serves as a breeding ground for the insects. All of this occurs due to a lack of adequate solid waste management and collection, which poses a serious hazard to the living being's life (Hui et al., 2006).

## **2.4 UAE's Obligations to Paris Agreement on Climate Change**

The UAE is a party in the Paris Agreement which was signed in April of 2016. The main point of this agreement is limiting the climate change and mitigating its effects. The agreement was stating that the rise of global temperature must not exceed 2°C when compared to the average global temperature during the preindustrial era (Dargin, 2021). This can be done in multiple ways; reducing the emissions of greenhouse gases and by using different techniques for carbon capture and sequestration (Luomi, 2021). The Paris Agreement gives its parties flexibility in choosing the options they prefer and methods they desire as well as they stick to the main goal which is preventing the rise in average global temperature from exceeding 2°C (Ari & Sari., 2017). However, all of the agreement signatories are required to provide continuous updates and transparency regarding their efforts in reaching that goal. (Jacoby, 2017)

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The purpose of improving waste collection and recovery services in Sharjah is to drive the emirate of Sharjah towards carbon neutrality as soon as possible (Alam, T., & Luomi, M., 2018).

## **2.5 Positive Impacts of Carbon Neutrality**

Creating a carbon neutral city will not only help in preventing the worst effects of the climate change, but it will also help the society and communities as a whole. Carbon neutrality is one of the most effective ways to help in the battle against global climate change. A carbon neutral city will reap the advantages of enhanced health of the public, a sustainable economy, and biodiversity preservation (Wu et al., 2022).

### **2.5.1 Health Benefits**

Climate change poses a hazard to both our environment and our health. Especially the fossil fuels that are burned are directly responsible for poor indoor and outdoor air quality (Monjardino et al., 2021). Breathing of impure air can have serious health hazards like Colon cancer, cardiovascular disease, obesity, diabetes, breast cancer, dementia, and depression etc. By producing energy from renewable energy sources, the air pollution can be reduced. The co-benefits for health that have been discovered over the last few years clearly outweigh the costs of carbon-reduction initiatives (Zhang et al., 2021).

As policy reforms are implemented, reductions in greenhouse gas emissions and carbon emissions are accompanied by reductions in air pollutants, resulting in purified air which improves the cardiac health and contribute to better respiratory of the citizens (Ramanathan et al., 2016). This will improve the quality of the air which will benefit the citizens from other air-prone diseases.

### **2.5.2 Economic Benefits**

One of the most significant advantages of lowering carbon emissions in the economy is that it would drastically cut down the percent of fatalities caused by air pollution, easing burden on the healthcare systems of the country. An association between these two factors will be required to accomplish economic development while still prioritizing the reduction of the emissions of carbon in the economy (Chen et al., 2022). This may be accomplished in a variety of ways, one of which is the implementation of a carbon tax. The economy's operation can be enhanced with the help of carbon taxes which will result in less reliance on the imported fossil fuels, reduction in pollution and minimization of governments cost by reducing emissions which will also make the economy more efficient. In short, Cutting GHGs will improve the economy, notably when it becomes financially beneficial to develop new methods to resolve the environmental issues as well as to combat climate change by using, for example, renewable energy sources (Shafiei et al., 2017).

### **2.5.3 Environmental Benefits**

One of the most effective methods of evaluating the consequences of human-caused global climate change is through the carbon footprint (Shi et al., 2021). It largely emphasizes on consumption-related GHGs, but it also covers other pollutants including nitrous oxide, chlorofluorocarbons (CFCs) and methane. Reduced carbon emissions help to minimize the consequences of climate change, which has a beneficial cascading effect on the health of the public as well as plants and animal's variety (Alola & Onifade, 2022). Furthermore, this benefits the world economy which will result in more inventive, environmentally friendly



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solutions. Overall, carbon neutrality will reduce the rate of temperature rise, ocean acidification, sea-level rise and glacier melting.

#### **2.6 Zero-Waste-to-Landfill**

Zero-waste-to-landfill is increasingly becoming the goal of every city in the world. This goal means that all the recyclables that are in the generated waste are recovered (García et al., 2019). In reality, it is impossible to achieve this goal but it is conventional that if all recyclable materials in the generated waste are recovered and the rest of the waste that cannot be recycled is sent to waste-to-energy plant for incineration then the volume of the waste after incineration will be reduced by 90% and hence this can be considered as reaching zero-waste-to-landfill (Snyman & Vorster. , 2011). The remaining 10% of waste after incineration, called residue, that is in the form of ash is sent to landfill and this is considered as a significant achievement when compared to the original volume of waste before recovery and incineration (Veleva et al., 2017). The impact of this step on the health, economy and the environment is massive and is considered one of the main cornerstones of driving a city to carbon neutrality because the more waste is diverted from landfill, the more material and resources are saved and the more GHGs are prevented (Tennant-Wood, 2003).

#### **2.7 Transforming Sharjah into a Carbon Neutral City by 2035**

Although the United Arab Emirates (UAE) has pledged to achieve this target by 2050, Sharjah can achieve it by 2035 due to multiple reasons (Reiche, 2010).

In the real-world scenarios, the change is comprehensive and many steps are involved. There is no one-size-fits-all solution to drive any country or even any city into carbon neutrality. The best solution must be tailored to suit all the factors that are related to that specific city (Udemba, 2021). For example, renewable energy sources that can be exploited in the UAE, like solar

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energy, are different from those renewable sources that can be exploited in a European country where solar energy is not feasible for exploitation because sunlight is present for a much lower period of the day as well as the year (Reiche, D., 2010).

A city like Sharjah must not undergo any problem while planning or executing the plan that is supposed to transform it to carbon neutrality. This is because prevention is better than cure which means that Sharjah should follow the path of smart cities. (Batty, 2012)

#### **2.7.1 Sources of GHGs Emissions**

Most of the GHGs emissions, at least 80%, are released on the form of CO<sub>2</sub>. There are three main activities that contribute to the generation of most of the carbon dioxide. These are transportation, electricity production and industry (Duxbury, 1994).

#### **2.8 Negative Impacts of Greenhouse Gases (GHGs) Emissions**

##### **2.8.1 Climate Change**

Greenhouse gases are the major cause of climate change which in turn have devastating effects on the health and the environment. These gases trap heat and prevent it from being reflected from the surface of the earth (Althor et al., 2016). The increase in the temperature of earth's surface which causes the climate change will result in extreme weather conditions. This means that some areas will suffer from droughts while others will suffer from floods, Moreover, the number of wildfires will significantly increase and these fires will, in turn, increase the emissions of CO<sub>2</sub> and other greenhouse gases (O'Connor et al., 2002). This endless vicious cycle is a serious challenge especially in the countries where this kind of fires is common or

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expected. Climate change will also negatively affect agriculture. The worse the climate change gets, the more disruptions in food supply will occur (Jiang et al., 2020).

#### **2.8.2 Air Pollution**

Air pollution that is resulted from GHGs emissions means that everyone loses. The air does not stop on the borders of any country. It is the commodity that every single human needs and will always need. We, as humans, all share the same air (Ramanathan & Feng., 2009).

### **2.9 Methods of GHGs Reduction**

#### **2.9.1 CO<sub>2</sub> Reduction**

There are multiple ways to reduce the emissions of carbon dioxide;

#### **2.9.2 Energy Conservation.**

This step requires the consumer to reduce his electricity consumption by turning off lights and electronic devices when not using them (Mills, 2011). The consumer can also reduce fuel consumption through driving less and driving wisely.

#### **2.9.3 Energy Efficiency**

Building contractors as well as houses residents can improve the thermal insulation of the buildings and houses. People can also use electrical appliances that are energy efficient and drive fuel-efficient vehicles ( Nguyen et al., 2016).

#### **2.9.4 Carbon Capture and Sequestration**

This relatively new term is about a set of innovative technologies that can highly reduce carbon dioxide emissions from power plants, whether new or existing, that work on gas or coal (Hussain et al., 2019). The CO<sub>2</sub> that is produced by these power plants is collected from their stacks before entering the atmosphere and then channeled through pipelines to a deep subsurface formation that is located underground (Nanda et al., 2016). Then this CO<sub>2</sub> is kept and stored securely. (<https://www.epa.gov/ghgemissions/overview-greenhouse-gases>)

#### **2.9.5 Methane Reduction**

The methane gas CH<sub>4</sub> that is released to the atmosphere comes from two main sources and the opportunity of reducing this gas emissions will also come from controlling the emissions that come from these same sources (Lynch & Garnett., 2021). These sources are;

##### **2.9.5.1 Domestic Waste**

The methane gas is released by landfill as a result of aerobic decomposition of organic waste. This happens with the presence of oxygen and produces small amount of methane (Lee et al., 2016). Afterwards, within a year from landfilling the organic waste, methane gets generated in large amounts by bacteria that decompose the waste in that established anaerobic conditions (Magazzino et al., 2020). The solution for this problem is by using any technique to capture the methane (CH<sub>4</sub>) that is leaving the landfill and treating it.

##### **2.9.5.2 Industry**

The methane gas is a hydrocarbon which is a main component of natural gas. So, the best way to reduce methane gas emissions is by reducing the leaks that are present in the processes of production, storage and transportation of natural gas and oil (Latake et al., 2015). Meanwhile, the methane that is produced by coal mines should be captured as well.

## **2.10 The Importance of Waste Segregation at Source**

One of the best methods, if not the best, for increasing the recovery rate from generated domestic waste is applying the concept of waste segregation at source (Phu et al., 2019). This concept means that the people who generate the waste are required to separate it into different categories before disposing it (Otitoju & Seng, 2014). Every residential unit; house, apartment, etc. will receive four rolls of biodegradable plastic bags for four different waste types (Bernstad, 2014). These four are; Green color bags roll (for General Waste), Red color bags roll (for Hazardous Waste), Blue color bags roll (for Recyclables) and Yellow color bags roll (for Hygiene Waste) (Gani et al., 2012).

Waste segregation at source is important because if the waste that is generated by the public (i.e. Sharjah residents) is disposed as it is, mixed not segregated, then there will be a significant loss from this waste (Bernstad, 2014)

. The recovery of recyclables will be more difficult and less efficient. As an example, the organic waste is usually humid and contains a large amount of liquids (Chen & Lee, 2020). When this organic waste is mixed with fibers (papers and cardboards), the fibers will lose the ability of being recycled as a result of becoming wet. There are countless examples of how recovery of recyclables is far less feasible when it is done to mixed waste compared with the waste that is segregated at source (Cheng et al., 2019). There is no magic solution for this problem. Simply, people who generate the waste should segregate it before disposal.

### **2.10.1 Main Steps Needed for the Waste Segregation at Source to Succeed**

1. In order to apply this concept on the residential sector, the municipality of that city must provide, at least, the different colors plastic bags to the residents of that city. This will include

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all residents in villas, apartments of small buildings, apartments of high-rise buildings, hotels and all other forms of residency (Pietzsch et al., 2017).

2. It is crucial, in order for this step to be fruitful, to educate all the residents and to spread awareness in all possible means; organizing awareness sessions, sending messages to the mobile phones containing educational videos or written instructions, sending messages through social media means, etc (Dinh et al., 2021).

3. The waste collection trucks fleet of Bee'ah that consists of 320 trucks will need a significant modification. The purpose of this modification is to make the waste collection trucks capable of collecting the waste that is segregated at source which come in four different colors plastic bags (Akinade et al., 2017). The easiest way to modify trucks is to convert the waste compactor trucks into dump trucks.

## **2.11 Carbon Footprint Reduction through Waste Collection Optimization**

### **2.11.1 Waste Collection Trucks Modification**

The first step in this project is to modify the waste collection trucks so that they become suitable to collect the waste in an open box without breaking the plastic bags. So, current waste compactor trucks need to be modified to become tipper trucks.

### **2.11.2 Waste Collection Vehicle Routing Problem**

This research aims to enhance the waste collection service in Sharjah by finding the best method that will reduce the traveled time and distance by each vehicle (truck) of the Bee'ah fleet to the minimum level (Han & Cueto. , 2015).

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Waste collection is considered as a relevant activity in the field of reverse logistics. The term reverse logistics include all the operations that are related to the materials and products reuse (Kim et al., 2006).

The current method of waste collection that is used in most cities around the world is the constant waste collection route and this method was introduced in the 1800s. (Statheropoulos, 2005)

People will continue to generate waste for a very long time, probably forever. This point is very critical because the earlier this problem is solved and optimized, so an optimal route is used instead of following a constant route, the better the outcome and the more money, effort and time will be saved (Buhrkal et al., 2012).

#### **2.11.3 Machines for Separating Plastic Bags Based on their Colors**

Waste sorting machines will be used to separate the waste plastic bags which come in four different colors of biodegradable plastic bags that are designed for four different waste types (Das et al., 2013). Certain waste sorting machines are designed specifically for color-based surfaces which will be used to identify the colors of these bags that will be separated into four categories; general, hazardous, recyclables and hygienic waste. These four are; Green color bags (for General Waste), Red color bags (for Hazardous Waste), Blue color bags (for Recyclables) and Yellow color bags (for Hygiene Waste) ( Ozdemir et al., 2021).

#### **2.11.4 Route Planning Software**

The Sharjah municipality is attempting to use the google map software in order to locate the waste bins that are at least 80% full and other strategic parameters that are related to where

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they want to collect the garbage for transferring and recycling purposes (Guzolek & Koch., 1989). The google map software will be linked to waste bins sensors which send a signal or message to the collection team. The mechanism of locating these waste bins with the help of google maps software interface will be able to make timely pickups thanks to with help of the seamless route planning that is linked with the sensors and optimization (Mátrai et al., 2016). It guarantees that garbage collectors follow the quickest path and only consider the correct waste bins thanks to its ability to offer real-time information on current events.

#### **2.11.5 Waste Bin Fullness Monitoring Sensors**

Sharjah municipality aim to circulate and distribute specifically designed waste bins to buildings, streets and businesses where the bins are sensor enabled (Mustafa & Azir., 2017). The mechanism of the sensor will be placed in each waste bin to determine its filling level and will send a message to the collection team when it becomes 80% full. The sensor passes the message alert to the google enabled technology (Samann, 2017). This informs the Sharjah municipality about the number and location of waste bins that are full and ready to be collected (Catania & Ventura, 2014).



## CHAPTER THREE

### Conceptual Model and Hypothesis Development

#### **3.1 Summary of the Chapter**

This chapter explains the key theoretical construct of the model used in order to build the hypothesis (Zaefarian & Henneberg, 2010). The conceptual framework was viewed as an analysis based on the concept of Innovative Transformation of Domestic Solid Waste Collection and Recovery Services in Sharjah. The theoretical framework used in this research is deductive quantitative research. The theoretical framework was assessed based on the interrelationship of the independent variables domestic waste collection and recovery with the dependent variable innovative transformation that are constitutive towards a carbon neutral city which becomes the road map to analyze the qualitative data (Snyder & Cummings , 1998).

The chapter also discusses the operationalization of the research on how the various constants transformed into linkable hypothesis (Lookingbill et al., 2007). The research philosophy used in this research case study is interpretivism research philosophy approach which is a qualitative research methodology that is directly linked to the existing conceptual model which enables to sketch out multiple options for action (Zaefarian & Henneberg, 2010). Testable hypotheses were established based on the theoretical framework to assess theory formulated on innovative transformation on carbon neutrality. Following that, the hypothesized associations may be evaluated using proper statistical analysis (Kazzazi & Nouri, 2012).

#### **3.2 Description of Research Variables**

Author	Construct	Description
	<p data-bbox="619 255 911 291">Independent variables:</p> <p data-bbox="619 300 997 544"><b>Domestic waste collection-</b> Domestic waste is the waste that is created as a consequence of a domestic premise's normal day-to-day operations.</p> <p data-bbox="619 598 997 965"><b>Recovery services:</b> Any recovery services related to waste management activity, redirects the waste products from the waste stream and produces other products that are economical and benefits the ecology.</p>	<p data-bbox="1034 255 1374 454">The independent variables domestic waste collection and recovery services are positively related to innovative transformation</p>
	<p data-bbox="671 978 948 1014">Dependent variables:</p> <p data-bbox="619 1032 997 1276"><b>Innovative transformation:</b> The transformational innovative techniques that is used to covert waste into useful sources or anything that benefits the environment</p>	<p data-bbox="1034 978 1385 1301">The independent variables are positively related to the dependent variable innovative transformation which results in a positive relationship between innovation, transformation and carbon neutral city.</p>

**3.2.1 Research Outcomes** (Banerjee et al., 2009)

Key Elements	Outcomes of the Proposed Research
Nature of the Reality	Objectively develop and test a 'model that optimises
Hypothesis Testing	Hypotheses are purposeful and objectively formed prior to the study
Research Design Approach	Cross-sectional, objective and comparative study. Well planned and focuses on Perspective.
The Role of Value Approach	Make every attempt to be a transparent, value-free or natural enquiry or neutral.
Context	Independent of the context but purposeful).
Epistemological Stance	Etiological- the researcher is interested in why things happen.
Researchers' Role	Emphasis on understanding the differences.
Study Orientation	Particularistic; studies the elements
Research Focus	Variables and the integrated approach.
Research Basis	Reliability is based on the facts derived via the data.
Sampling	Representative.
Replication	Standard procedure and the replications are assumed.
Data Collections	In the form of responses, quantifiable via numbers or expression.
Data Analysis Approach	Statistical approach within the framework
Interpretation Approach	Performs using statistics or tabular format or chart. The emphasis is on how and why they relate to the proposed hypotheses prior to the study. The Constructive development of the conclusions based upon the data; clarity is based upon interpreting numerical data.
Reporting	Extensively numerical and integrated. However, the description is given to express logical outcomes.

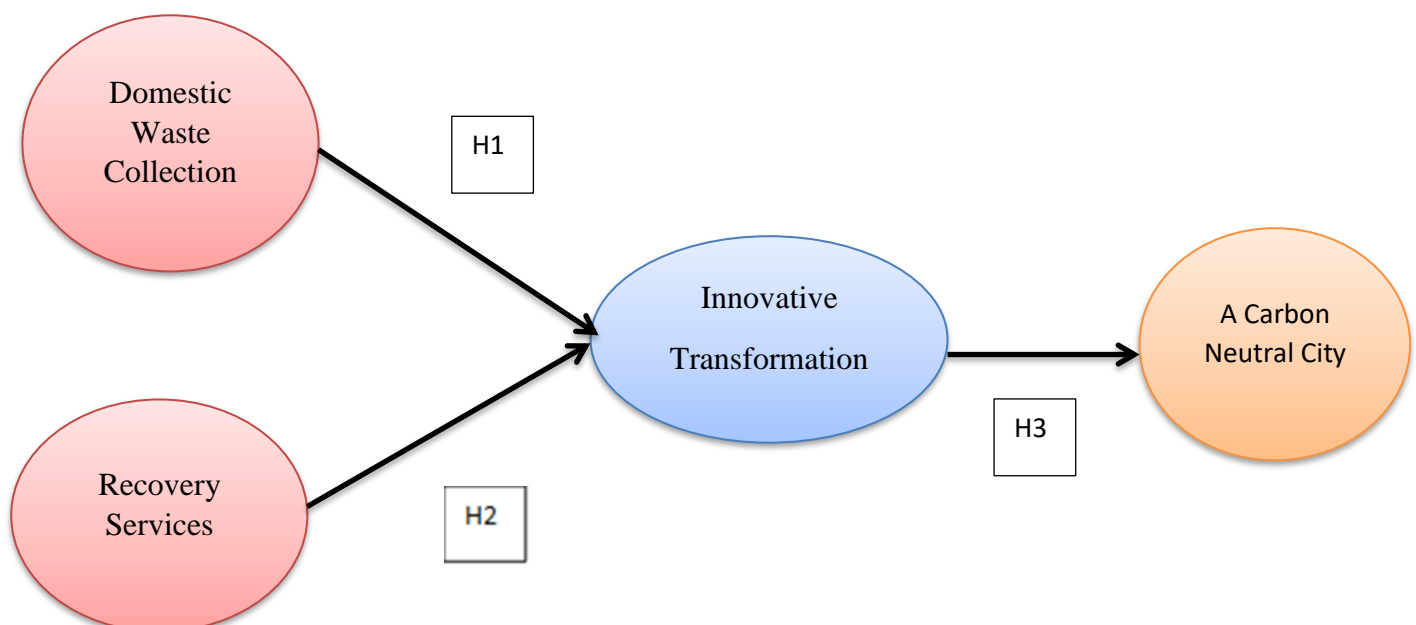
- i. To equip Sharjah residents with better understanding of waste segregation at source concept.
- ii. To find the compliance level of Sharjah residents with the concept of waste segregation at source so that policies and regulations can be added or modified.
- iii. To install an automatic bags separation system in the transfer station. This separation of the plastic bags into three different types will lead to sending only recyclables to the

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MRF. The organic waste will be sent to the compost plant and the hygiene and hazardous waste will be sent to incineration in the waste to energy plant.

- iv. To improve the productivity of the Material Recovery Facility (MRF) by installing new machineries or modifying existing one. This will lead to increasing the recovery rate from waste that is segregated at source.
- v. To distribute three rolls of plastic bags to each of the 5000 apartments that is included in the study.
- vi. To modify a number of waste collection trucks so that they can collect waste that is segregated at source instead of mixed waste.
- vii. To improve the waste collection service in Sharjah by equipping all the 60,000 waste bins with sensors to measure the fullness level in each bin.
- viii. To improve the performance of waste collection team by using a trip planning software that will only consider the waste bins that are 80% full or more and determine the shortest collection journey route.

### **3.3 Development of a Carbon-Neutral City Constructs**



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H1: Any garbage created in a domestic setting is referred to as domestic waste. The majority of material is regularly collected by garbage teams working for local governments; any excess domestic waste can be picked up on demand or by renting a skip.

H2: Waste recovery services are performed with the intention of removing enough waste as possible from landfills by sorting recyclable items from garbage that may be repurposed into new products or used as a fossil fuel substitute. The assurance of a sustainable and waste free future is a component of a bigger global objective.

H3: Innovative transformation in building an integrated system that includes high tech with the waste management business using the domestic waste collection and recovery services is the efficient approach to handle waste.

The above shown hypotheses relationship constructed model of the variables domestic waste collection (H1) and recovery services (H2) are directly related to innovative transformation (H3). The variable approach towards the carbon neutral city is derived from the innovative transformation that has been resulted from the positive relationship between domestic waste collection and recovery services.

### **3.4 Hypothesized Conceptual Model**

The conceptual model adopted for this research study clearly signifies the key elements based on the system of interest along with the hypothesized relationships. The Conceptual model is derived from the existing literature by the researcher. This model is simple, practical and applicable how the topic transforms carbon neutral city. Empirical relationship between the variables H1 and H2 that the researcher tested as part of the process are analyzed and described accordingly.

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Four hypothesized concepts were derived based on the relationship between the variables. The first hypotheses relationship of the variables domestic waste collection and recovery services are directly related to innovative transformation. The innovative transformation results in a positive relationship between innovation, transformation and carbon neutral city.

The second hypotheses relationship of the variables waste management and climate change are directly related to harmful emission of carbon. The production of the carbon-based particles into the air through irresponsible waste management that directly effects the climate change.

The third hypotheses relationship of the variables recycling process and garbage deposition are directly related to air pollution. The variable recycling process that helps to keep the environment clean and ecologically balance has a positive relationship by minimizing waste deposition and consequent pollution.

The fourth hypotheses relationship of the variables recycling process and garbage deposition are directly related to air pollution. waste prevention by reducing the production and increase the production of recycled products that requires less energy resulting in lower emission of GHG's.

### **3.5 Summary of the Hypotheses**

	Hypotheses variable 1	Hypotheses variable 2	Description
1	H1. Domestic waste collection is positively related to innovative transformation	H2. Recovery services is positively related to innovative transformation.	Both H1 and H2 are positively related to innovative transformation which results in a positive relationship between innovation, transformation and carbon neutral city.

2	H1. Waste management process is significantly related to the toxic carbon emission	H2. Climate change is significantly related to the toxic carbon emission	Both H1 and H2 are positively related to when it comes to producing carbon-based particles into the air through irresponsible waste management that directly effects the climate change.
3	H1. Recycling process is significantly related to air pollution	H2. Garbage deposition significantly related to air pollution	Both H1 and H2 are related to the process of recycling that helps to keep the environment clean and ecologically balanced by minimizing waste deposition and consequent pollution.
4	H1. Waste prevention methods are is significantly related to the green-house gas emission	H2. Recycled products are significantly related to the green-house gas emission	Both H1 and H2 are positively related to waste prevention by reducing the production and increase the production of recycled products that requires less energy resulting in lower emission of GHG's.

### **3.6 The Rationale for the Methodological Approach**

The correlation between the elements were found to be positive. The above mentioned Four hypothesized concepts were derived based on the relationship between the variables. The

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hypotheses relationship of the variables H1 and H2 are directly related to each other. The outcome results in a positive relationship between the variables H1 and H2.

#### **3.6.1 Rationale for using SPSS and Nvivo**

Source Segregation Study				
Compactor Description	High Rise Building		Street Bins	
Compactor Weight (KG)	12,770		6,550	
Sample Size (KG)	2,540		1,560	
Sample Percentage (%)	20		24	
Recovered Items	Weight (KG)	Percent (%)	Weight (KG)	Percent (%)
Aluminum	5.36	0.21	1.86	0.12
HDPE	24.17	0.95	6.11	0.39
Wood	5.86	0.23	21.61	1.39
OCC	53.79	2.12	35.14	2.25
PPC	13.67	0.54	8.67	0.56
PPb	0.32	0.01	0.54	0.03
PP Sacks	0	0.00	0.51	0.03
Steel	33.60	1.32	21.52	1.38
Paper	39.5	1.56	23.68	1.52
PET	45.50	1.79	21.42	1.37
Black Film	15.93	0.63	38.31	2.46
Mixed Film	223.1	8.78	116.12	7.44
Textile	64.74	2.55	57.55	3.69
Fines	653.16	25.71	573.62	36.77
Reject	1086.6	42.78	501.34	32.14
Sample Loss	274.7	10.81	112	7.18
Total	2540	100.00	1540	98.72
Recyclables (%)	17.28		15.10	

This section explains the statistical outcome of the data that the researcher has captured that clearly explains the domestic waste recycling is essential and segregation of the study emphasizes about the various waste item and its percentages. This can be viewed as an Epistemological analysis of quantitative data (weight and ratio). The view of approach towards waste disposal have been shaped by the idea of waste as an undesired element with no



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inherent worth. The based on the rationale derived using the research tool SPSS and Nvivo, the Domestic waste activities, garbage disposal related to waste and health perceptions in a city are high which will negatively impact the carbon neutrality.

Additional information on the Compactor Description items can be found in the Appendix.

Date: 05 & 10 / 04 / 2022		
Three Stream	Sample Weight (Ton): 500	
Material	Weight (Ton)	Recovery Percentage %
PE - Film (Mix & Clear)	3.4	3.90%
Cardboard	4	4.59%
Mixed HDPE	1.5	1.72%
PAPER	23.75	27.27%
PET (Clear)	3.5	4.02%
PET (Green)	0.5	0.57%
Alu cans	1	1.15%
Non recyclables	49.43	56.76%
<b>TOTAL</b>	<b>87.08</b>	<b>100.00%</b>

The Sampling analysis study allows the researcher to get meaningful conclusions from the data derived. Inadequate and incorrect results and conclusions may emerge from inappropriate research design and data analysis. The segregation of the study emphasizes about the various waste item and its percentages. The sampling analysis study table developed based on the types of the waste materials generally collected from various households. The above shown table explains the total weight in ton and the recovery percentages with existing capacity of the Sharjah municipality.

## CHAPTER FOUR

## Research Method and Methodology

**4.1 Summary of the Chapter**

This section thoroughly captured the research philosophy and the methodology adapted. The research philosophy used in this research case study is interpretivism research philosophy approach which is a qualitative research methodology. The research method that is used for the research study purpose is the mixed method. Using mixed methodologies for a research study combines the aspects of both quantitative and qualitative research. This chapter also discusses about the sampling and data analysis technique which has been deployed to investigate this research. The sampling technique used for this research study is purposive sampling which is also known as subjective, selective or judgmental sampling. The data analysis technique used is epistemological quantitative and transcribing qualitative data. The epistemology quantitative technique covers up all the aspects of cognitive aspects of the research study.

The qualitative data is collected through questionnaires that are transcribed with proper analysis of the content is explained. The qualitative research method specifically will be used to explore concepts and find out more aspect of quantitative outcomes by analyzing the qualitative data used. Quantitative structured questionnaires which is a positivist research method will be used. The quantitative questionnaires were designed in such a manner that collects all the significant type of data related to the research study. Finally the analytical software used to organize, process and analyze all sort of qualitative and unstructured outcomes of research is also discussed. The data collected from these questionnaires will give help to achieve the conclusion of the outset based on the study of the carbon neutrality.

## 4.2 Research Approach and Methods

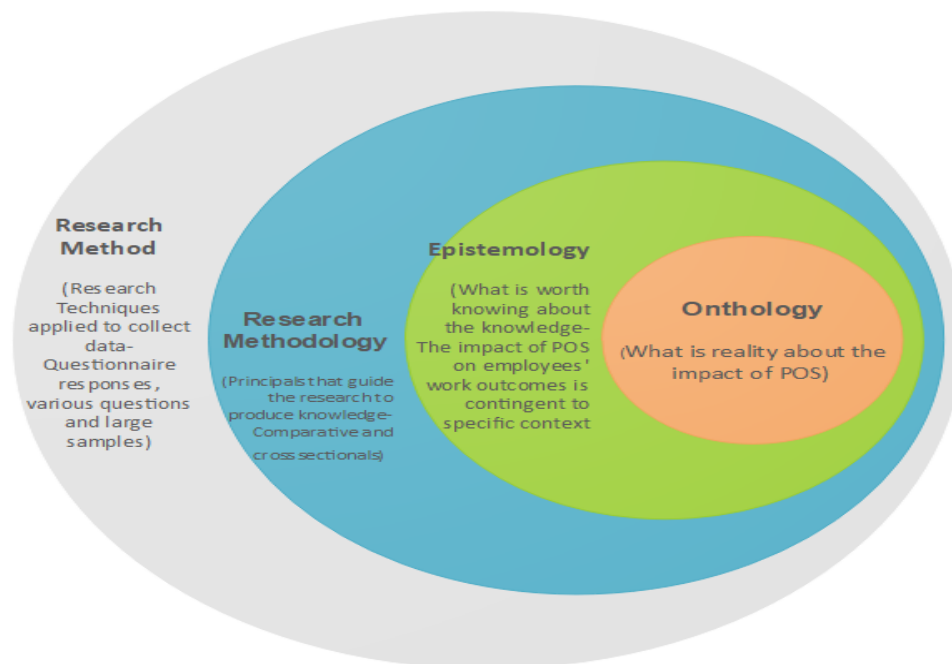


Figure 2: Different research approach and methods (Creswell and David, 2018)

The research method deployed and the methodology is explained in detail in the following parts.

The method that will be used for the research study purpose is the mixed method. Using mixed methodologies for a research study combines the aspects of both quantitative and qualitative research. As this mixed methodology combines the advantages of both quantitative and qualitative research, this methodology will give a clear and deep insight compared to that of a single quantitative or qualitative study.

The research technique for this study anticipates that participants will come from diverse city of Sharjah. Questionnaires and interviews are all used in this strategy. Participants will be given questionnaires to complete in which they will be asked qualitative questions. Questionnaires

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are appropriate for doing research with 10 participants. These questionnaires will include generic questions based on their age, gender, education qualification, marital status and organizational tenure along with the specific questions related to the study. The study team will observe and ask individuals questions based on their perspective and observation on carbon neutral city based on Innovative Transformation of Domestic Solid Waste Collection and Recovery Services time. This will make it easier to get first-hand or primary information.

The research philosophy used in this research case study is interpretivism research philosophy approach which is a qualitative research methodology that aims at the participants perspective of belief or idea on the particular field of study in order to collect data based on the social phenomena of a carbon neutral city focusing on the general domestic solid waste management in the society.

#### **4.3 Research Setting and Data Collection Procedure**

Items	Quantity	Description of the workers	Total No of Companies Targeted	Comments
Total Number of Questionnaire Circulated.	15	Managerial level workers	5	The respondents generic data were also asked and mentioned in the questionnaires responses attached.
Total Number of Returned Questionnaire Responses.	10	Well educated personals with an acknowledged background on the study related and with minimum organizational tenure or 5 years	3	
<b>Total</b>	35		8	

#### 4.4 Research Onion

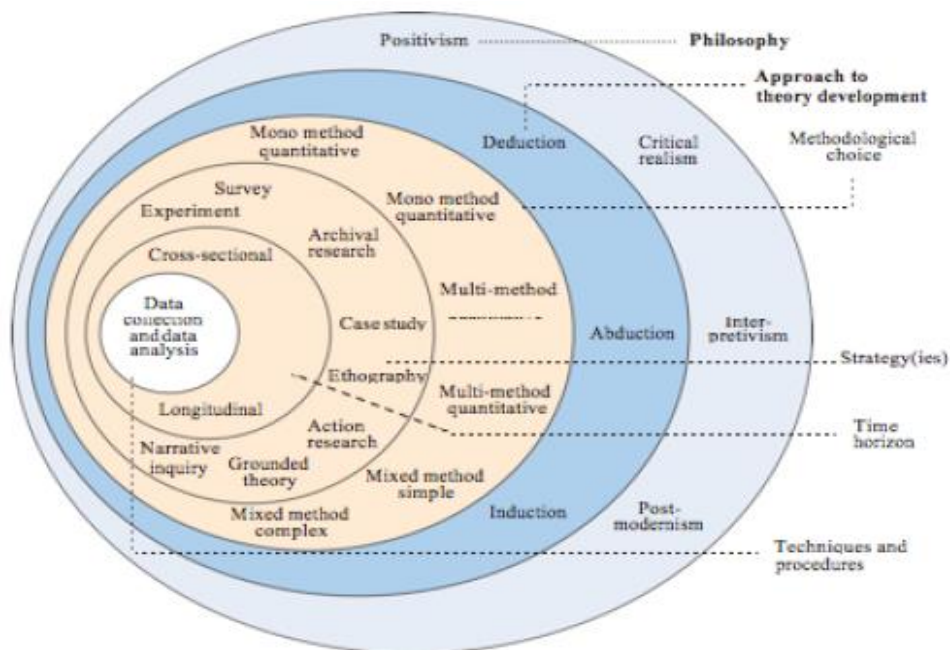


Figure 3: Data connection and data analysis paradigm (UOFGSOTL, 2021)

The research onion consists of six main layers:

- 1. Philosophy:** It alludes to the collection of beliefs or viewpoints that serve as the foundation for the investigation. In this research study the epistemology analysis is chosen. The interpretivism method is chosen under epistemology for this research study.
- 2. Approach:** The interpretivism approach under epistemology is based on the premise of the study that interprets the data, and so cannot be completely impartial and detached from the study of carbon neutrality.
- 3. Strategy:** Based on the information needed for the research and the goal of the study, the questionnaire strategic approach is selected.
- 4. Choices of methods:** For this research study the mixed method of questionnaire and interview is chosen.

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**5. Time Horizons:** The time frame of the research is cross sectional. Since all observations pertain to a single moment in time, cross-sectional data is employed.

**6. Data collection and analysis:** The data analysis method used for this research study is the Qualitative data analysis method. The data collected are primary data through the questionnaires and interviews method.

#### 4.5 Research Paradigms (Abisamra, N.S., 2004)

Descriptive	Positivism	Post-Positivism	Interpretivism	Critical Theory	Pragmatism
Synonym	Verify	Predict	Understand/ Interpret	Emancipate	Dialectic
Ontology What is Real?	Objectivist; findings=truth, realism	Modified objectivist; findings probably true, transcendental realism	Local, relative, co-constructed realities, subjective objectivity, relativism	Historical/virtual realism shaped by outside forces, material subjectivity	Constructed, based on world we live in and explanations that produce the best desired outcomes
Epistemology What is True?	the only knowledge is scientific knowledge – which is truth, reality is apprehensible	Findings approximate truth, reality is never fully apprehended	Co-created multiple realities and truths	Findings are based on values, local examples of truth	Objective and subjective points of view
Methodology How do I examine what is real?	Quantitative – Primarily Experimental, quasi- experimental	Usually Quantitative – Experimental with threats to validity, Qualitative (e.g., Case study)	Often Qualitative and/or Quantitative	Usually Qualitative, but also quantitative	Qualitative & Quantitative
Milman, 2010					4

The research paradigm used in this research study is Epistemology with an interpretivism research philosophy approach (Steup, M., & Neta, R. , 2005). The epistemology analysis is chosen as it significantly shows the impact on the ways to frame the research in the quest for knowledge of the topic carbon neutrality. The concept of epistemology can be discussed based on the design of the relationship between the variable's domestic household waste and the recovery services towards innovative transformation.

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The interpretivism approach under epistemology is based on the premise of the study that interprets the data, and so cannot be completely impartial and detached from the study of carbon neutrality. This approach focuses on the contextualized surroundings that is determined according to the people's perspective and opinion. This philosophical perspective cannot be generalized which makes it more subjective and prone to biases than that of a positivist's research.

#### **4.6 Sample and Sampling**

The sampling technique used for this research study was purposive sampling. Purposive sampling is also known as subjective, selective or judgmental sampling (Alchemer, 2021). This sampling technique is a type of non-probability form of sampling and that was used to select the Sharjah municipality managerial workers to participate in the questionnaire according to which the judgment concluded. The chosen technique of purposive sampling does not use known nonzero selection probabilities. In order to determine which items will have to be included in the sample, subjective methods are used.

For this research study, quantitative structured questionnaires were used which is a positivist research method that has higher involvement of the respondents. This quantitative structured questionnaire was designed in such a manner that collects all the specific type of data related to the research study.

#### **4.7 Data Analysis Technique and Analytical Procedure**

The data analysis technique used was epistemological quantitative and transcribing qualitative data. The epistemology quantitative technique covers up all the aspects of cognitive understanding, authenticity, scale, and methodologies focusing on what makes a factual theory of knowledge based on the study and how this knowledge can be gained or created based on

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its extent of its transferability that can be judged. The Epistemology technique used will have an impact on framing the research in the quest for a proper conclusion of knowledge.

The empirical and theoretical findings will be gathered through questionnaires on qualitative data. The qualitative research method can be used to explore concepts and find out more aspect of quantitative outcomes by analyzing the qualitative data used.

#### **4.8 Analytical Software Used**

The analytical software tools used to get a meaningful insight are SPSS (Statistical Package for the Social Sciences) and NVIVO software programs in order to analyze and take effective decisions based on the research study. With the help of the new version of NVIVO 12, mixed methods for data analysis can now be used together with SPSS, and hence both these software programs were combined in order to use together. NVIVO is a software program or tool that aids in organizing, processing and analyzing all sort of qualitative and unstructured outcomes of research. SPSS is another software program or tool that aids in statistics related analysis based on the outcomes of a quantitative research. These two tools were used together to conduct this mixed method analysis. The raw data collected from the mixed methods – qualitative and quantitative data are inserted into these programs in order to get proper insight based on the results of the outcome.



**CHAPTER FIVE****Detailed Mixed Method Data Analysis and Results****5.0 Analysis**

This particular chapter focuses on analyzing and interpreting qualitative and quantitative data. The entire data has been reviewed before analyzing the data making the study progressed. It highly emphasizes the qualitative data. It also identifies the key data set to develop the conclusion. The data analysis method used for this research study is the Qualitative data analysis method. The main aim to conduct this research is to get perspectives, views and opinions of people to develop a theoretical model which examine the impact of Carbon Neutral City on waste management in the Sharjah in the UAE. The data analysis process mainly focused on the methodological log based on all the insights derived from the study. These insights were related with the data collected from the 10 respondents in order to conclude the research data analysis.

**RESPONDENT NO :1****Generic data:**

Gender: Male

Age: 45

Educational Qualification: MSc in Engineering management

Organizational tenure (in years): 9

Civil Status: Married

**Responses:****Key themes****Existing  
concept****Emerging  
concept****Comment**

<p><b>Specific data:</b>  <b>1.Impact of domestic waste collection-</b>  All activities use fossil fuels impact the carbon neutral city goal. Domestic waste collection in the current situation is one of the activities has a negative impact on neutral carbon because all vehicles and equipment's use fossil fuels to operate and the carbon emissions from diesel are high.</p>	<p>Fossil fuel combustion.  Carbon emissions.</p>	<p>Concept of Fossil fuel and domestic waste collection</p>	<p>NA</p>	<p>This response is particularly an existing concept based on sustainable management of fossil fuels.</p>
<p><b>2.Influence of recovery services-</b>  Recovery of mixed waste will be done in material recovery facilities and all of these facilities operate by electricity coming from diesel generators managed by electrical supply authorities. In case the waste is segregated at source, then there will be no need to operate huge facilities with high power consumption. The impact of such facilities will be negative on carbon neutral target.</p>	<p>Production of electricity from diesel generators.  Waste segregation.  Negative carbon neutral target</p>	<p>NA</p>	<p>Concept of waste disposal management with high power consumption</p>	<p>This response is particularly an emerging concept of maintaining constant availability of supreme resources.</p>
<p><b>3.Innovative transformation approach:</b>  An innovative transformation approach is essential currently to reduce the carbon emissions. Transforming these activities by implementing source segregation to reduce the efforts on recovery service and using vehicles operated by renewable resources will have a positive impact.</p>	<p>Carbon Emission.  Positive innovative transformation approach.  Renewable source of energy.</p>	<p>Concept of carbon emission and source segregation.</p>	<p>NA</p>	<p>This response is particularly an existing concept of carbon emission and source segregation.</p>
<p><b>4.Significance of innovative transformation approach -</b>  Yes, it is, because the main target is to reduce / stop using fossil fuels which has the highest impact on the carbon neutrality.</p>	<p>Fossil fuel combustion.  Carbon Neutrality.</p>	<p>Concept on impact of fossil fuel</p>	<p>NA</p>	<p>This response is an existing theory on impact of fossil fuel</p>

<p><b>5.Impact of other factors on carbon neutral city-</b> Whole domestic waste collection / recovery services have an impact of no more than 5% on carbon neutrality in the world. The highest portion came from industrial combustion, transportation, power industry and others.</p>	<p>Sustainability. Innovative waste management methods.</p>	<p>NA</p>	<p>Concept On other factors like transportation and industrial combustion</p>	<p>This response is an emerging concept on Study of other factors to help heal the environment from different perspectives.</p>
<p><b>RESPONDENT NO: 2</b></p>				
<p><b>Generic data:</b> Gender: Male Age: 51 Educational Qualification: BSc Organizational tenure (in years): 7 Civil Status: Married</p>				
<p><b>Responses:</b></p>	<p><b>Key themes</b></p>	<p><b>Existing concept</b></p>	<p><b>Emerging concept</b></p>	<p><b>Comment</b></p>
<p><b>Specific data:</b> <b>1.Impact of domestic waste collection-</b> Yes, it has an impact on the development of a Carbon – Neutral City. All activities involved in the waste collection process release carbon emissions.</p>	<p>Carbon emission. Process of waste collection.</p>	<p>Concept on carbon emission and waste collection methods.</p>	<p>NA</p>	<p>This response is an existing concept on waste segregation and collection methods.</p>
<p><b>2.Influence of recovery services-</b> Yes, recovery services processes release carbon emissions in the atmosphere.</p>	<p>Air pollution. Recovery services.</p>	<p>NA</p>	<p>Concept on air pollution</p>	<p>Basic prevention of Air pollutants.</p>
<p><b>3.Innovative transformation approach-</b> Sure, implementing an innovative transformation approach will have an impact on the carbon neutral city especially be replacing the</p>	<p>Replacement of fossil fuels. Fossil fuel combustion. Renewable resources.</p>	<p>NA</p>	<p>Concept on saving the environment from carbon emission</p>	<p>This response is an emerging concept on environment saving strategies.</p>

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fossil fuels release high carbon emissions by renewable resources with no carbon emissions.				
<b>4.Significance of innovative transformation approach –</b> It is significant because collection services and recovery ones are an essential part of each developed city – country and regardless of the contribution %, it will have a positive impact even by small percentage.	Recovery process. Economical beneficiaries.	Concept of recovery services and impact on carbon emission.	NA	Mainly focusing on saving the environment with recovery services from toxic impacts.
<b>5.Impact of other factors on carbon neutral city-</b> Actually, whole domestic waste collection / recovery services have an impact of no more than 5% on carbon neutrality in the world. The highest portion came from industrial combustion, transportation, power industry and others.	Sustainable development. Industrial combustion. Automobiles gas emissions.	NA	Concept of other factors like transportation and industrial combustion	This response is an emerging concept on Study of other factors to help heal the environment from different perspectives.
<b>RESPONDENT NO: 3</b>				
<b>Generic data:</b> Gender: Female Age: 36 Educational Qualification: BSc in Industrial Engineering Organizational tenure (in years): 11 Civil Status: Single				
<b>Responses:</b>	<b>Key themes</b>	<b>Existing concept</b>	<b>Emerging concept</b>	<b>Comment</b>
<b>Specific data:</b> <b>1.Impact of domestic waste collection-</b> Domestic waste collection has a limited impact on the Development of a Carbon-Neutral City, its contribution is not much compared to other industrial activities, but each single kilo of CO <sub>2</sub> could make a difference for the long term towards climate change.	Climate change. Harmful emission from industrial activities. Pollution.	NA	Concept of CO <sub>2</sub> on climate change	Emerging concept to enhance the focus on positive impacts on the environment towards climate change by using sustainable methods.

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<p><b>2.Influence of recovery services-</b> I think it influences the Development of a Carbon-Neutral City by the carbon emissions released during the services and processing.</p>	<p>Greenhouse gas emission. Emissions during process.</p>	<p>NA</p>	<p>Concept of green-house gas based on carbon emission</p>	<p>Emerging concept of GHG.</p>
<p><b>3.Innovative transformation approach-</b> Yes, any innovative transformation in both services will have an impact on the Carbon Neutral City, replacing the current technologies / transportation mechanisms by environmentally friendly technologies will definitely reduce the carbon emissions and save ozone layer.</p>	<p>Eco friendly technologies. Save ozone layer. Carbon emission.</p>	<p>NA</p>	<p>Concept of ozone layer depletion and technologies.</p>	<p>This response is an Emerging concept focusing on the ozone layer depletion and technologies</p>
<p><b>4.Significance of innovative transformation approach –</b> Yes, I think it will have a positive impact especially if it will deal with the fossil fuel consumption and the environmentally friendly alternatives (Renewable resources).</p>	<p>Renewable resources. Fossil fuel combustion and consumption.</p>	<p>NA</p>	<p>Concept of renewable resources and fossil fuel combustion.</p>	<p>Emerging concept on impacts of the environment with renewable resources</p>
<p><b>5.Impact of other factors on carbon neutral city-</b> Yes, many other factors are there like transportation and other industries.</p>	<p>Impact of Transportation and industries emission.</p>	<p>NA</p>	<p>Concept of other factors like transportation and industrial combustion</p>	<p>This response is an emerging concept on other factors affecting environment</p>
<p><b>RESPONDENT NO: 4</b></p>				
<p><b>Generic data:</b> Gender: Male Age: 39 Educational Qualification: BSc in environment science Organizational tenure (in years): 14 Civil Status: Divorced</p>				
<p><b>Responses:</b></p>	<p><b>Key themes</b></p>	<p><b>Existing concept</b></p>	<p><b>Emerging concept</b></p>	<p><b>Comment</b></p>
<p><b>Specific data:</b> <b>1.Impact of domestic waste collection-</b></p>	<p>Air pollutants. Emission of automobiles gas. Carbon neutral goal</p>	<p>NA</p>	<p>Concept based on fossil fuel and harmful emission of</p>	<p>Emerging concept of harmful emission of</p>

<p>I believe that domestic waste collection impacts the Development of a Carbon-Neutral City, all activities requires vehicles, machinery operated using fossil fuels or electricity generated by diesel have a negative impact on the carbon neutral goal.</p>			<p>automobiles gas</p>	<p>gases from automobiles</p>
<p><b>2.Influence of recovery services-</b> I believe that recovery services influence the Development of a Carbon-Neutral City because 90% of the waste collected in the world is mixed which will require huge efforts and machinery with high power consumption to process it and recover the recyclables. The impact is negative.</p>	<p>Waste segregation. Recyclables. Requirement of higher power consumption</p>	<p>NA</p>	<p>Concept on waste segregation and recyclables</p>	<p>Emerging concept of Proper waste management process will enhance the quality of environment.</p>
<p><b>3.Innovative transformation approach-</b> I perceive that both domestic waste collection/Recovery services need to be implemented through an innovative transformation approach to have an impact on the Carbon Neutral City. Engaging advanced technologies with less carbon emissions will change the current situation and improve the air quality.</p>	<p>Usage of advanced technologies. Less carbon emissions. Reduce air pollution.</p>	<p>NA</p>	<p>Concept of usage of advanced technologies</p>	<p>This response is particularly an emerging concept based on advanced technologies and air pollution</p>
<p><b>4.Significance of innovative transformation approach –</b> I believe that the innovative transformation approach on Carbon Neutral City will have a positive impact only if it will consider the impact on the environment by reducing carbon and GHG emissions.</p>	<p>Sustainable development. Green-house gas emissions.</p>	<p>Concept of sustainable approach by reducing carbon and GHG emissions,</p>	<p>NA</p>	<p>This response is an existing concept to enhance the sustainable development focusing GHG and carbon emission.</p>
<p><b>5.Impact of other factors on carbon neutral city-</b> All industrial and logistics activities in the world impact the</p>	<p>Industrial emissions. Fossil fuel combustion.</p>	<p>Concept of Fossil fuel and domestic</p>	<p>NA</p>	<p>This response is particularly an existing concept based on industrial</p>

carbon-Neutral city because they all use fossil fuels in their operations.		waste collection		emissions and fossil fuels.
<b>RESPONDENT NO: 5</b>				
<b>Generic data:</b> Gender: Male Age: 43 Educational Qualification: BSc in business administration Organizational tenure (in years): 10 Civil Status: Married				
<b>Responses:</b>	<b>Key themes</b>	<b>Existing concept</b>	<b>Emerging concept</b>	<b>Comment</b>
<b>Specific data:</b> <b>1.Impact of domestic waste collection-</b> I think that domestic waste collection impacts the Development of a Carbon-Neutral City because it is a daily activity require huge number of vehicles to collect the waste from the whole city and then send it to landfills or recovery facilities. Carbon and GHG emissions release are high because it is all operated by internal combustion mechanism.	Landfills facilities. Domestic Waste collection. Green-house gas emission. Carbon emission.	Concept of solid domestic waste collection and GHG.	NA	This response is particularly an existing concept based on sustainable management of waste collection
<b>2.Influence of recovery services-</b> I think that recovery services impact the Development of a Carbon-Neutral City because the collected waste will be processed in a sorting facility which is operated by electricity and if the electricity is generated by diesel generators not alternative resources will release carbon and GHG emissions which have a negative impact on the carbon neutrality.	Production of electricity from diesel generators. Waste segregation. Negative carbon neutral target	NA	Concept on impact generation of electricity that releases harmful gas	This concept is an emerging idea on electricity generated using generators that releases harmful gases.
<b>3.Innovative transformation approach-</b>	Protection from harmful emissions.	Concept of recovery	NA	Existing concept based

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I do believe that both domestic waste collection/recovery services nowadays contribute negatively towards carbon neutral city and an innovative transformation approach should be implemented to save the environment and to reduce these harmful emissions.	Innovative transformation approach to save environment.	services and harmful emissions		on recovery services and its approach
<b>4.Significance of innovative transformation approach –</b>  I perceive that the innovative transformation approach on Carbon Neutral City will have a positive impact if it will be studied experimented carefully considering life cycle impact assessment for each innovative activity.	Impact of life cycle. Innovative activities.	Concept of proper experiment of life cycle assessment for an effective approach to neutral city.	NA	Focus on positive impacts on the environment towards a neutral city by using sustainable methods.
<b>5.Impact of other factors on carbon neutral city-</b>  There are many other factors impact the Carbon-Neutral city goal, all activities related to industry, manufacturing, transportation and will have a negative impact on the carbon – neutral city / cities goal which is a global concern nowadays.	Sustainable development. Industrial combustion. Automobiles gas emissions.	NA	Concept of other factors like transportation and industrial combustion	This response is an emerging concept on Study of other factors to help heal the environment from different perspectives.
<b>RESPONDENT NO: 6</b>				
<b>Generic data:</b>  Gender: Female Age: 33 Educational Qualification: MSc in project management Organizational tenure (in years): 8 Civil Status: Married				
<b>Responses:</b>	<b>Key themes</b>	<b>Existing concept</b>	<b>Emerging concept</b>	<b>Comment</b>
<b>Specific data:</b> <b>1.Impact of domestic waste collection-</b>	Carbon dioxide emission. Combustion engines.	Concept of harmful emission from	NA	This response is an existing concept focusing on the



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Yes, it impacts the development of Carbon – Neutral city because collection services are managed by combustion engines vehicles which release high CO <sub>2</sub> emissions.		vehicles engine combustion		harmful emission of gases from automobiles.
<b>2.Influence of recovery services-</b> Yes, it impacts the Development of a Carbon-Neutral City because its recovery services processes release CO <sub>2</sub> and without proper source segregation, recovery services will keep harming the environment.	Improper source of segregation. Recovery services.	NA	Concept of environmental design based on recovery services.	It is an emerging concept that focuses on development by means of eco-friendly methods.
<b>3.Innovative transformation approach-</b> Yes, I do, implementing an innovative transformation approach for sure will have an impact on the Carbon-Neutral city approach if it will consider replacing the current methodology by renewable resources.	Replacement of current methodology. Renewable resource management.	Concept of renewable resources	NA	Emerging concept on impacts of the environment with renewable resources
<b>4.Significance of innovative transformation approach –</b> Yes, I believe that the innovative transformation approach on Carbon Neutral City will have a positive impact, but it will solve a small portion of the main issue and will not finish it completely, it will be only a benchmark for other industries to follow this success story.	Recovery process. Economical beneficiaries.	Concept of recovery services and impact on carbon emission.	NA	Mainly focusing on saving the environment with recovery services from toxic impacts.
<b>5.Impact of other factors on carbon neutral city-</b> A lot of other factors impact the Carbon-Neutral city goal like transportation, power industries, industrial activities. etc .....	Transportation industries, power industries and industrial activities.	NA	Concept of other factors like transportation and industrial combustion	This response is an emerging concept on other factors affecting environment
<b>RESPONDENT NO: 7</b>				

<b>Generic data:</b>				
Gender: Male Age: 29 Educational Qualification: BSc in environmental science Organizational tenure (in years): 7 Civil Status: Single				
<b>Responses:</b>	<b>Key themes</b>	<b>Existing concept</b>	<b>Emerging concept</b>	<b>Comment</b>
<b>Specific data:</b>  <b>1.Impact of domestic waste collection-</b>  Yes, domestic waste collection impacts the Development of a Carbon-Neutral City because it is operated by vehicles and equipment's consume fossil fuels and Co2 release is high because of the collection operations.	Fossil fuel combustion. Carbon emissions.  Collection operations.	Concept of segregation of waste.	NA	This response is an existing concept that focuses on the impacts of carbon emissions and fossil fuel combustion.
<b>2.Influence of recovery services-</b>  It impacts the Development of a Carbon-Neutral City because its processes are run by electricity which comes from diesel generators.	Production of electricity from diesel generators. Negative carbon neutral target	Concept of non-ecofriendly machinery.	NA	Existing concept that focuses on the alternate methods that are eco-friendly.
<b>3.Innovative transformation approach-</b>  Yes, I do perceive that implementing an innovative transformation approach will have an impact on the Carbon-Neutral city approach only if it will be considering lifecycle assessment once applying the transformation.	Lifecycle assessment.  Sustainable growth.	NA	Concept of sustainable growth.	It is an emerging concept that focuses on sustainable development.
<b>4.Significance of innovative transformation approach –</b>  Yes, I perceive that the innovative transformation approach on Carbon Neutral City will have a positive impact, even it would be a small impact but better than nothing and continue in the same mechanism.	Mechanism of innovative transformation.	NA	Concept of eco-friendly techniques.	This response highlights the need of innovation in reducing environmental damages.

<p><b>5.Impact of other factors on carbon neutral city-</b></p> <p>All human and industrial activities playing a huge impact on the carbon neutral city approach. All these activities are releasing CO<sub>2</sub> and GHG into the atmosphere and polluting the environment.</p>	<p>Carbon emission. Green-house gas emission.</p>	<p>Concept of industrial pollutants.</p>	<p>NA</p>	<p>This response highlights the impact of industrial pollutants on the environment.</p>
<p><b>RESPONDENT NO: 8</b></p>				
<p><b>Generic data:</b></p> <p>Gender: Male Age: 42 Educational Qualification: BSc in mechanical engineering Organizational tenure (in years): 11 Civil Status: Married</p>				
<p><b>Responses:</b></p>	<p><b>Key themes</b></p>	<p><b>Existing concept</b></p>	<p><b>Emerging concept</b></p>	<p><b>Comment</b></p>
<p><b>Specific data:</b></p> <p><b>1.Impact of domestic waste collection-</b></p> <p>Yes, domestic waste collection impacts the Development of a Carbon-Neutral City because all vehicles and equipment's are operated by fossil fuels.</p>	<p>Fossil fuel combustion. Carbon emissions.</p>	<p>NA</p>	<p>Concept of alternate transportation and equipment.</p>	<p>It is an emerging concept that focuses on usage of eco-friendly techniques.</p>
<p><b>2.Influence of recovery services-</b></p> <p>It impacts the Development of a Carbon-Neutral City because it uses power generated by diesel generators.</p>	<p>Diesel generators. Carbon emissions.</p>	<p>NA</p>	<p>Concept of reduction of air pollution.</p>	<p>This response focuses on the negative impacts of carbon emission.</p>
<p><b>3.Innovative transformation approach-</b></p> <p>Yes, I perceive that implementing an innovative transformation approach will have an impact on the Carbon-Neutral city approach if it keeps into consideration the renewable resources engagement to reduce CO<sub>2</sub> release to the atmosphere.</p>	<p>Renewable resources. Recovery process. Economical beneficiaries.</p>	<p>Concept of renewable energy.</p>	<p>NA</p>	<p>It is an existing concept that highlights the benefits of renewable resources.</p>

<p><b>4.Significance of innovative transformation approach –</b></p> <p>Yes, I perceive that the innovative transformation approach on Carbon Neutral City will have a positive impact, because reduction of each CO2 ton will save the environment.</p>	<p>Carbon emission.</p> <p>Enhance sustainability.</p>	<p>NA</p>	<p>Concept of sustainable energy.</p>	<p>It is an emerging concept of sustainable growth.</p>
<p><b>5.Impact of other factors on carbon neutral city-</b></p> <p>Yes, all equipment's, vehicles, machinery, power industries, manufacturing industries are a major factor that play a role on releasing CO2 into atmosphere and impacting the Carbon-Neutral city negatively.</p>	<p>Sustainable development.</p> <p>Industrial combustion.</p> <p>Automobiles gas emissions.</p>	<p>NA</p>	<p>Concept of reducing environmental damage.</p>	<p>It is an emerging concept of innovation in environmental development.</p>
<p><b>RESPONDENT NO: 9</b></p>				
<p><b>Generic data:</b></p> <p>Gender: Male  Age: 55  Educational Qualification: PhD in Environmental Science  Organizational tenure (in years): 5  Civil Status: Married</p>				
<p><b>Responses:</b></p>	<p><b>Key themes</b></p>	<p><b>Existing concept</b></p>	<p><b>Emerging concept</b></p>	<p><b>Comment</b></p>
<p><b>Specific data:</b></p> <p><b>1.Impact of domestic waste collection-</b></p> <p>Yes, domestic waste collection impacts the Development of a Carbon-Neutral City because more than 95% of the activities related to collection processes are using fossil fuels.</p>	<p>Fossil fuel combustion and composition.</p> <p>Carbon and industrial emissions.</p>	<p>NA</p>	<p>Concept of environmental design.</p>	<p>It is an emerging concept that focuses on development by means of eco-friendly methods.</p>
<p><b>2.Influence of recovery services-</b></p> <p>It impacts the Development of a Carbon-Neutral City because all recovery processes use fossil fuels in its processes and release CO2 into atmosphere.</p>	<p>Fossil fuel combustion.</p> <p>Global warming.</p>	<p>NA</p>	<p>Concept of green building.</p>	<p>This response highlights the cause of global warming.</p>

<p><b>3. Innovative transformation approach-</b></p> <p>Yes, implementing an innovative transformation approach will have an impact on the Carbon-Neutral city approach if the main goal of this approach is using the renewable resources to save the environment instead of fossil fuels.</p>	<p>Ozone layer depletion.</p> <p>Renewable resources.</p>	NA	<p>Concept of future energy development.</p>	<p>It is an emerging concept that focuses on the cause of ozone layer depletion.</p>
<p><b>4. Significance of innovative transformation approach –</b></p> <p>Yes, an innovative transformation approach on Carbon Neutral City will have a positive impact, because it will reduce the carbon and GHG emissions.</p>	<p>Green-house gas emissions.</p> <p>Carbon emissions.</p>	<p>Concept of green building.</p>	NA	<p>This response focuses on the concept of green building.</p>
<p><b>5. Impact of other factors on carbon neutral city-</b></p> <p>Yes, all industrial activities using fossil fuels are releasing CO<sub>2</sub> and GHG to the atmosphere.</p>	<p>Sustainability.</p> <p>Innovative waste management methods.</p>		<p>Concept of environmental technologies.</p>	<p>This response highlights the requirement of eco-friendly technologies.</p>
<b>RESPONDENT NO: 10</b>				
<p><b>Generic data:</b></p> <p>Gender: Female  Age: 32  Educational Qualification: MSc in Sustainability  Organizational tenure (in years): 6  Civil Status: Married</p>				
<b>Responses:</b>	<b>Key themes</b>	<b>Existing concept</b>	<b>Emerging concept</b>	<b>Comment</b>
<p><b>Specific data:</b></p> <p><b>1. Impact of domestic waste collection-</b></p> <p>Yes, domestic waste collection impacts the Development of a Carbon-Neutral City because fossil fuels are the main drivers for the vehicles and equipment's used to collect the waste.</p>	<p>Fossil fuel combustion.</p> <p>Carbon emissions.</p> <p>Waste segregation.</p>	<p>Concept of proper disposal of waste.</p>	NA	<p>It is existing concept that focuses on the importance of waste segregation.</p>

<p><b>2.Influence of recovery services-</b></p> <p>It impacts the Development of a Carbon-Neutral City because fossil fuels are the main drivers to generate electricity used in the sorting facilities.</p>	<p>Production of electricity from diesel generators. Waste segregation. Negative carbon neutral target</p>	<p>NA</p>	<p>Concept of energy conservation.</p>	<p>It is an emerging concept highlighting the importance of energy conservation.</p>
<p><b>3.Innovative transformation approach-</b></p> <p>Yes, implementing an innovative transformation approach will have an impact on the Carbon-Neutral city approach in case lifecycle impact assessment is considered in the whole innovation transformation steps.</p>	<p>Assessment of lifecycles.  Advanced eco-friendly technologies.</p>	<p>NA</p>	<p>Concept of eco-friendly development.</p>	<p>This response focuses on the need for a development that is environmentally safe.</p>
<p><b>4.Significance of innovative transformation approach –</b></p> <p>Yes, an innovative transformation approach on Carbon Neutral City will have a positive impact because implementing it considering Lifecycle impact assessment will reduce GHG and CO2 release to the environment.</p>	<p>Sustainable development.  Environment beneficial.</p>	<p>NA</p>	<p>Concept of conservation ethic.</p>	<p>This response focuses on the need for focusing on the environment while developing technologies.</p>
<p><b>5.Impact of other factors on carbon neutral city-</b></p> <p>Yes, all industries, facilities, transportation activities and even human activities are main factors have an impact on the Carbon neutral City.</p>	<p>Industrial emissions.  Air pollutants due to transportation and human activities.</p>	<p>Concept of innovative sustainable growth.</p>	<p>NA</p>	<p>It is existing concept that focuses on the importance of waste segregation.</p>

### 5.0.1 Summary of the Research Analysis

With the help of the qualitative data analysis method the collected data has under gone a deep insight on the study by interpreting the patterns and themes in the form of texts, as well as the ways these concepts and responses assist the of answer the research questions at hand. The qualitative research instrument used for this study is the questionnaire. The main purpose of

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this questionnaire was to gather the information from the respondent's views on innovative Transformation of Domestic Solid Waste Collection and Recovery Services.

Based on the questionnaire survey of 10 cadets from different educational qualification and organizational tenure, majority of them believe domestic waste collection impacts the Development of a Carbon-Neutral City because it is a daily activity that require huge number of vehicles to collect the waste from the whole city and then send it to landfills or recovery facilities. Also, Carbon and GHG emissions release are high because it is all operated by internal combustion mechanism. Most of them also responded saying that domestic waste collection impacts the Development of a Carbon-Neutral City because fossil fuels are the main drivers for the vehicles and equipment's used to collect the waste.

The point of view of the respondents on the impact of recovery services on the development of carbon neutral city that recovery services might impact the Development of a Carbon-Neutral City because the collected waste will be processed in sorting the facilities which is operated by electricity and if the electricity is generated by diesel generators and not alternative resources then it will release carbon and GHG emissions which have a negative impact on the carbon neutrality. Most of the respondents also perceived that domestic waste collection or Recovery services need to be implemented through an innovative transformation approach to have a positive impact on the Carbon Neutral City.

An innovative transformation approach on Carbon Neutral City will have a positive impact because implementing it considering Lifecycle impact assessment will reduce GHG and CO<sub>2</sub> release to the environment.

The result of the survey also provided some empirical data on the impact of the Carbon Neutral City based on other factors apart from domestic waste collection or Recovery services. Most the respondents had the same opinion that many other factors impact the Carbon-Neutral city

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goal all activities related to industry, manufacturing, transportation including fossil fuel resulting from industrial activities will have a negative impact on the carbon –neutral city / cities goal which is a global concern nowadays.

#### **5.1 Summary**

In the chapter the views, perspectives and opinions of the respondents on carbon neutrality through innovative transformation were discussed. According to the questionnaire survey of responses collected from 10 respondents collected from different educational qualification and organizational tenure, majority of them believe domestic waste collection impacts the Development of a Carbon-Neutral City because it is a daily activity that require huge number of vehicles to collect the waste from the whole city and then send it to landfills or recovery facilities.

The point of view of the respondents on the impact of recovery services on the development of carbon neutral city that recovery services might impact the Development of a Carbon-Neutral City because the collected waste will be processed in sorting the facilities which is operated by electricity and if the electricity is generated by diesel generators and not alternative resources then it will release carbon and GHG emissions which have a negative impact on the carbon neutrality. The result of the survey also provided some factual data on the impact of the Carbon Neutral City based on other factors apart from domestic waste collection or Recovery services. The respondents had the same belief that many other factors impact the Carbon-Neutral city aim of all activities related to industry, manufacturing, transportation including fossil fuel resulting from industrial activities. According to the analyzed data the respondents have a positive attitude towards maintain a carbon –neutral city which is a global concern nowadays.



### 5.3 Test of Hypotheses Using the Conceptual Model

The conceptual model adopted for this research study is tested which clearly signifies the key elements based on the system of interest along with the hypothesized relationships. These hypothesized variables have a positive relationship with the co-relating hypotheses that are derived based on the quantitative data and qualitative data.

	Hypotheses variable 1	Hypotheses variable 2	Description
1	H1. Domestic waste collection is positively related to innovative transformation	H2. Recovery services is positively related to innovative transformation.	Both H1 and H2 are positively related to innovative transformation which results in a positive relationship between innovation, transformation and carbon neutral city.
2	H1. Waste management process is significantly related to the toxic carbon emission	H2. Climate change is significantly related to the toxic carbon emission	Both H1 and H2 are positively related to when it comes to producing carbon-based particles into the air through irresponsible waste management that directly effects the climate change.
3	H1. Recycling process is significantly related to air pollution	H2. Garbage deposition significantly related to air pollution	Both H1 and H2 are related to the process of recycling that helps to keep the environment clean and ecologically balanced by minimizing waste deposition and consequent pollution.
4	H1. Waste prevention methods are is significantly related to the green-house gas emission	H2. Recycled products are significantly related to the green-house gas emission	Both H1 and H2 are positively related to waste prevention by reducing the production and increase the

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			production of recycled products that requires less energy resulting in lower emission of GHG's.
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## CHAPTER SIX

### Interpretation and Discussion, Conclusion and Future Research Direction

#### **6.1 Summary of the Chapter**

This chapter captures the high-level conclusion and discussion derived from the analysis as well as findings from Chapter 5. The parameters derived from Chapter 5 on the Domestic waste collection has a limited impact on the Development of a Carbon-Neutral City, its contribution is not much compared to other industrial activities, but each single kilo of CO<sub>2</sub> could make a difference for the long term towards climate change. The factors related to the innovative transformation approach which has an impact on the Carbon-Neutral city approach based on the lifecycle assessment is also analyzed in the whole innovation transformation steps. Certainly, other factors apart from carbon like all equipment's, vehicles, machinery, power industries, manufacturing industries which are the major factors that play a role on releasing CO<sub>2</sub> into atmosphere and impacting the Carbon- Neutral city negatively are some of the key findings from Chapter 5.

Lastly some of the major findings like developing transformational capabilities requires the utility of the digital transformation capabilities will be discussed. Particularly, automating the standard process of collecting solid waste using a structured mechanism is critical to gain process efficiencies. Along with the emphasis of the Beeah's vision, the project will now incorporate digital elements to increase the project efficiency and reduce costs. Some of the significant future directions are also mentioned below followed by the final conclusion of the research study.

## 6.2 The Implication of a Carbon-Neutral City

The below shown table shows the implication of the Carbon Neutral City with the help of the key variables and parameters of measurements. These variables and parameters implications are studied and mentioned under the findings.

No	Variables and parameters of measurements	Findings
1	Natural based recovery process	Recovery services impact the Development of a Carbon-Neutral City because the collected waste will be processed in a sorting facility which is operated by electricity and if the electricity is generated by diesel generators not alternative resources will release carbon and GHG emissions which have a negative impact on the carbon neutrality.
2	Impact of innovative transformation towards carbon neutral city	Innovative transformation in both services will have an impact on the Carbon Neutral City, replacing the current technologies / transportation mechanisms by environmentally friendly technologies will definitely reduce the carbon emissions and save ozone layer.
3	Impact of Decarbonization	Improving the energy efficiency policies can help reduce CO <sub>2</sub> emissions significantly, especially when the global energy generation is not environmentally friendly.
4	Domestic waste collection and recovery services	The domestic waste and recovery services are positively related to innovative transformation which results in a positive relationship between innovation, transformation and carbon neutral city.

5	Impact of fossil fuel in the carbon city	Sustainable management of fossil fuels emphasizing on the carbon emission and source segregation.
6	Other factors affecting carbon neutral city	All equipment's, vehicles, machinery, power industries, manufacturing industries are major factors that play a role on releasing CO2 into atmosphere and impacting the Carbon-Neutral city negatively.

#### 6.4 Conclusion: Major Findings

This study investigated the need for unconventional thinking in creating a carbon-neutral city by 2025: Innovative Transformation of Domestic Solid Waste Collection and Recovery Services. Most of the interviews indicated that developing transformational capabilities requires the utility of the digital transformation capabilities. Particularly, automating the standard process of collecting solid waste using a structured mechanism is critical to gain process efficiencies. This is a strategic process requires the integration of both software application and hardware. This means the Sharjah Municipality needs to connect every household's waste collection mechanism through a standard automation process. Ideally, the Sharjah Municipality could offer mechanical waste collection bins (papers/tins/metals) integrated with sensors. Once the bins get filled, the sensors automatically send a signal to the municipality to collect it. This process enables to gain two key benefits (a) it regulates and streamlines the process to waste collections and (b) gain process efficiencies. Also, both the process collectively maximizes the effectiveness of the garbage collection process while minimizing the cost of operations associated.

In line with Bee'ah's vision, the project will now incorporate digital elements to increase the project efficiency and reduce costs. While the initial meeting will be conducted physically to allow for all enquiries to be answered and demonstration to be given to the tenants, all

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succeeding communications and meetings with tenants will be done digitally. Also, a dashboard accessed by management to monitor the project's progress.

The key findings of the waste study based on the Sharjah municipality from high-rise buildings, the waste coming out from chutes is normally very dry that comprises of very high percentage of recyclables. These wastes that emerge from the ramps could be dangerous and have a detrimental effect on the city's carbon neutrality. The production of these wastes can be eliminated or minimized with some kind of control on these activities. The control could be in the form like increasing the level of inspection in the highly prone areas and imposing fines accordingly. One of the other effective way of minimizing the production of the waste are spreading awareness to the people on the impact of these waste in the environment. Different media channels can be used to spread awareness to the people and establish more campaigns by encouraging everyone to follow the norms of proper disposal of waste.

The adoption of a pilot project on the conventional strategy advised by other researchers on the Innovative Transformation of Domestic Solid Waste Collection and Recovery Services in Sharjah aiming towards a carbon neutral city.

Some of the effective ways to improvise the segregated waste collection are discussed below. One compactor will be assigned to collect the bins and it will take two trips to collect the waste from the households using the quickest path with the help of the google map software

The representatives are should dispatch the stickers for the new collection timings and hang it on the entrance to be appeared. The availability of the other compactor should be checked or make necessary arrangements accordingly. Also, the contractors must receive these materials separately to check the quality and to report for the project progress as it's the main goal to separate the high-rise waste and the street waste bins.

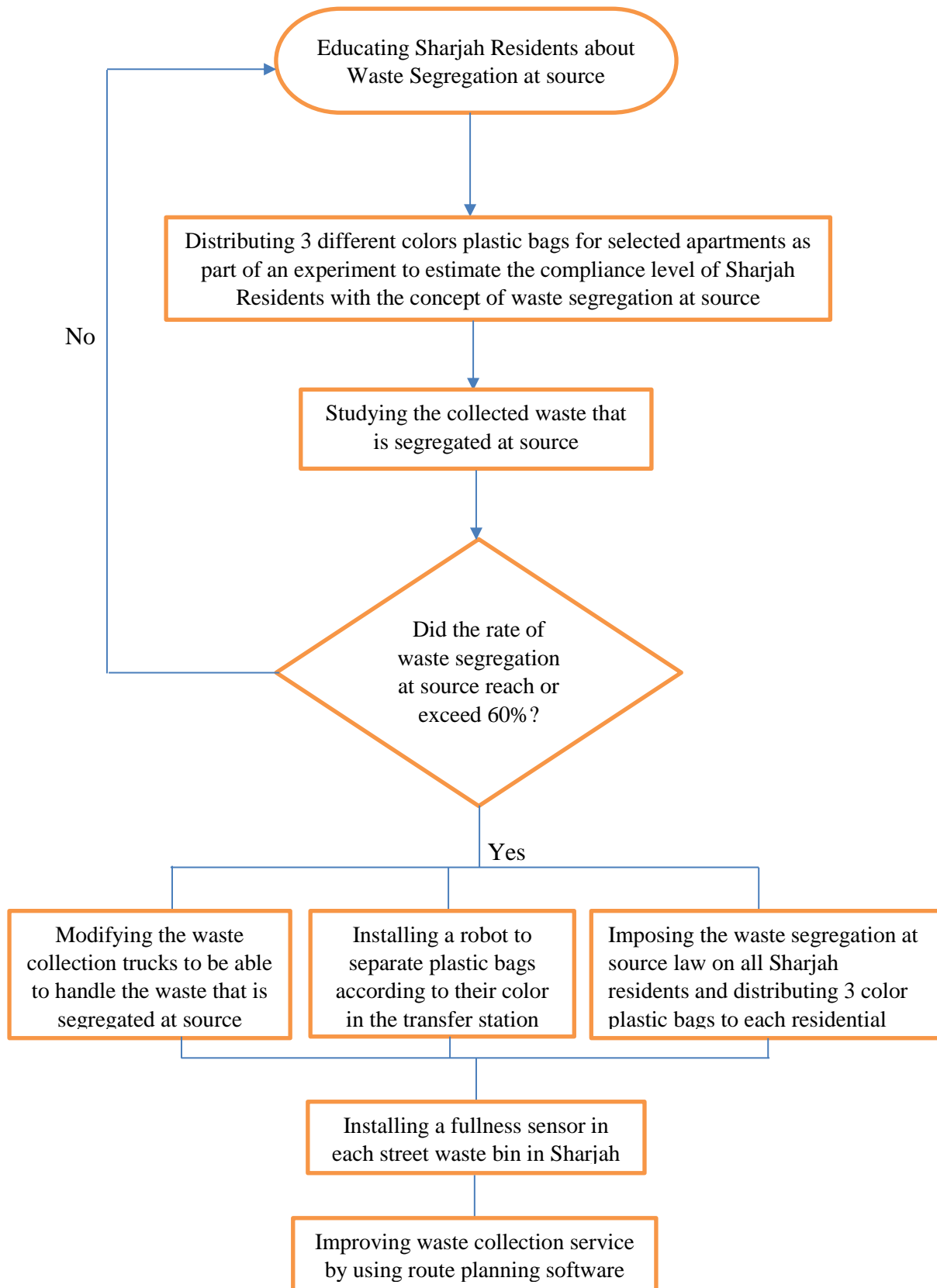
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According to the lines of the Beeah's vision, the Sharjah municipality will now incorporate digital elements to increase the project efficiency and reduce costs. While the initial meeting will be conducted physically to allow for all enquiries to be answered and demonstration to be given to the tenants, all succeeding communications and meetings with tenants will be done digitally. Also, a dashboard accessed by management to monitor the project's progress.

A Marketing team will also design an updated brochure in 4 languages (Arabic, English, Urdu and Hindi) that will be physically distributed to the participating tenants in the initial visit. After that concludes, a digital brochure will be distributed in order to digitize the operations in line with the digital switch in the project.

A new video to be shot showing the project activities including snapshots the awareness sessions through video call applications, the compactor during collecting the waste under the buildings, offloading the waste in MRF to be done in a professional way to be posted in our social media.

The steps of the project will be as shown in the following flowchart.





## **6.7 Conclusion**

The purpose of this experimental study is to evaluate the impact of a major step that will significantly contribute to the transformation of Sharjah into a carbon-neutral city by the year 2025. The study was focused to determine the rates of various waste categories in residential buildings mainly by processing the prospective possibilities for basic waste reduction, and calculate the reduction in carbon or green-house gas emissions that may be accomplished through each potential chances. Carbon emissions are considered to be a useful statistic for multiple number of reasons mainly the climate change that is a pressing issue that must be addressed, carbon emissions are strong signs of a system's environmental effect, and these impacts enable simple contrast with other existing systems. Furthermore, the impact of waste management being a contributing factor for a carbon neutral city is varied and unknown as it can give a total view of the source or pitch of greenhouse gas emissions. Waste management for the utilization of garbage as a resource – might have significant environmental advantages that aren't frequently defined, as the study was focused on waste management possibilities for a carbon neutral city.

Carbon has a disposal cost in a waste management method. As a result, it is frequently more cost-effective to completely prevent emissions. Therefore conservation, efficiency, and carbon recycling will be rewarded. Apart from the initiatives to cut emissions by controlling large-scale energy systems, the most important factor of waste management does not need hierarchical interrelation and administration. Despite the huge amount of money spent by the government agencies and private enterprises on innovative energy technology targeted at lowering emissions, emissions keep going up for a variety of reasons especially in the household sector. This becomes a totally different concept for carbon dioxide capture in the air. Every individual attempt to catch and discard of garbage, no matter how small, will always lead the people in the right path.

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It is clear that the waste management methods that still need to be implemented in order to achieve the reduction targets set forth in the Paris Climate Agreement do not encompass the whole population of a country. With the help of the examples from other countries, carbon reduction measures for the waste industry and work that may be done in place discussed. Sharjah must keep a close eye on and be aware of global trends as it formulates its future strategies. Many research on low-carbon cities were based on this study.

### **6.8 Future Research Directions**

Several prospective study areas linked to waste management understanding regarding carbon neutrality are mentioned in this research study. Some of the most significant methods for future research directions are deployment of a systems framework of approach towards carbon neutrality along with the transitioning to an enhanced sustainable management, and managing regulatory work. Carbon neutrality, carbon information, and carbon accounting should have the main highlight over the field of stake holders on research and development from all over the world, spanning industries, and academic fields. This creates several chances for various players to assist in the transformation of cities to carbon neutrality. Using appropriate methodologies, cities and their stakeholders could collaborate more easily, resulting in a speedier change.

Certain digital partnerships particularly like the ones that use digital technologies like Artificial intelligence, cloud computing, data analytics and block chains should track and engage on the impact of social and environmental implications of the human footprint on the Planet. It is then conceivable to build a better future that is not just carbon neutral but also more sustainable for the earth and the living beings by acting on the knowledge of human effects.

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With the help of the developing technological transformation the electronic appliances have grown omnipresent that can be applied in the field of waste collection and segregation. The introduction of Internet of Things (IOT) with machine learning algorithms for visual recognition of the object's idea based on the approach to trash management and classification can be implemented. Trashnet is a dataset that is used to evaluate the insight of approaches for waste classification based on the objects in order to determine the place the specified trash belongs and separate it accordingly. Some of the other innovative technological ways are by setting artificial capabilities to trace the waste collection. Artificial Intelligence technologies can facilitate the pace of the entire waste management value chain, including all aspects of smart recycling and waste disposal.

Implementing other special software related to the route tracking solutions can help to track and trace the collection in order to estimate the collection and the quantity to be recycled based on the availability of the resources.

Finally, it is also important to spread awareness among the households to separate waste and keep it ready through which they can manually click the sensor to alert the municipality or the sensor will automatically send the message to the Sharjah municipality department. The Involvement of artificial intelligence (AI) and human support marked by efficiency, speed, and precision; can undoubtedly unleash the future of waste management.

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**Appendices:**

**Aluminium:** It is a light silvery white metal. It is a chemical element aluminum (Al), also written aluminum, belongs to the major Group 13 "IIIa, or boron group" of the periodic table.

**HDPE:** A sort of frequently manufactured plastic with a relatively high density that is created from ethylene and is mostly used for pipes, plastic bottles, and the substitution of wood.

**Wood:** Wood is a porous and fibrous structural substance in the stems and roots of trees which are also found in the waste.

**OCC:** All corrugated cardboard cartons are covered by OCC. Corrugated boxes are ones that include three layers of paper, two liners, and a corrugated, or wavy, layer sandwiched between them as its main components.

**PPC:** Concrete made of cement, fine aggregate (sand), and coarse aggregate but without steel is known as plain cement concrete.

**PPb (Polypropylene Block Copolymer) :** Co-monomer units are placed in blocks (i.e., in a regular pattern) and include between 5% and 15% ethylene in block copolymers of polypropylene.

**PP Sacks:** Woven polypropylene bags, often known as poly bags or pp bags, are employed for a variety of products, such as nuts, maize, and bird seed.

**Steel:** When compared to other kinds of iron, steel is an alloy formed of iron with a few tenths of a percent of carbon to increase its strength and fracture resistance.

**Paper:** A thin sheet of material called paper is created by physically or chemically processing cellulose fibers obtained from wood, rags, grasses, or other vegetable sources in water.

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**PET Polyethylene terephthalate:** It is a transparent, robust, and lightweight plastic, is frequently used to package meals and drinks, particularly convenience-sized soft drinks, juices, and water.

**Black Film:** Electrical needs are fulfilled by black conductive film. It is comprised of a single layer of carbon-loaded polyethylene, and since it doesn't contaminate components, its conductivity is not dependent on humidity.

**Mixed Film:** Surface roughness has a major impact on the performance of the contact in the operating condition (regime) of mixed lubrication.

**Textile:** The term "textile" refers to a wide range of fiber-based products, such as fibers, yarns, filaments, threads, and other fabric kinds.