SUSTAINABLE SMART CITY DESIGN IN KSA BASED ON A NATIONWIDE SURVEY OF PEOPLES' AWARENESS FROM A WASTE MANAGEMENT PERSPECTIVE

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Abstract

Waste management has been an issue around the world since the birth of Humans. In the beginning, we use to dispose of waste using different methods like disposing or throwing waste in water or disposing of them in soil. But now as the population is growing it is very difficult to actually manage the waste and save the environment as well. So we need to implement some dynamic solution which not only focuses on the issue of waste management but will also help us in creating better policies for the future of the planet. Many countries are tying their best to figure out these issues of waste management and sustainability. Among these countries, Saudi Arabia which is one of the major countries in the Middles east area is facing some issues regarding waste management. Saudi Arabia has a vision for 2030 in which they are focusing more on Smart cities using the Internet of things and AI. This vision also reflects their goals to focus more on sustainability and for that they want their waste to be managed as much as they can so they can easily decrease the adverse effects on the planet. In this paper we have discusses how countries used the manage waste in the past and the present which is supported by related work. Furthermore, we have also discussed the plan for a new smart city in Saudi Arabia which will use Artificial Intelligence and the Internet of Things to not only manage the waste but will also monitor the type of waste people are disposing of and how to make a better plan for management. So we have done several surveys and at the end, we will be showing results and will discuss how in future we will be dealing with this problem. Apart from these, we will also discuss the future challenges and suggestions which we can use in Saudi Arabia and the whole world to keep this planet as much cleanly as possible.

Chapter 1 Introduction

Waste management has been a major concern for the world even before the start of the industrial revolution. In the past, people used to dispose of waste in the soil or water but in those days, there was not so much population thus the amount of waste was also less compared to today. As time passed on new and innovative methods of waste management were used. But today due to the industrial revolution there are a lot of hazardous chemicals which are there in the form of waste and we cannot dispose of them easily. So, with time, we need to improve the ways through which we manage our waste. So, in this paper, we will first start with how the world used to manage waste in the past and its evolution.

We will be using references from different studies and on their basis; we will make the basis of our future waste management plan. We will also be discussing how the waste is managed at present and what special we are doing presently for the sustainability and reusability of waste. At this time, the world is in dire need to move toward more sustainability and reusability. Currently, many countries have implemented strict rules to save the environment from environmental pollution, as the United Arab Emirates has banned the use of plastic bags. And following this trend, many countries have started doing different measures to stop environmental pollution.

Currently in this paper what we will do is we will first discuss overall what we can do for the world to minimize environmental pollution due to the hazards then we will apply it to a certain area for the sake of having it as a case study. So, the country we have chosen for this is Saudi Arabia. As we all know Saudi Arabia is the hub of many industries and especially industries related to mining and crude oil. Because of that, they have a major challenge in disposing of the waste or reusing it.

So, we will study their challenges and then will propose a solution for them. After this, we will share our results and will conclude the results with suggestions and future work.

Proposed Solution:

- Using Blockchain and IOT devices to store the data related to waste management with each ledger to be located at all the disposal places so everything is updated whenever the waste is to be needed to pick up and tracked as well.
- The system will be secure so no data can be tempered, and these devices will be installed on each commercial and residential property.
- We can track and impose fines on the individuals/ companies violating it.
- Also in future, we can replace humans with robots that can do this work automatically without any human interaction to dispose of radioactive wastes as radiation can have long-lasting damage to humans.

Method for conducting research:

- We will interview different industries and waste management companies about the process they are following along with the challenges they face.
- The interview will be in the form of questionnaires, surveys or in-person interviews.
- After this, we will analyze the data through AI and will propose what measures we can take while taking into consideration our proposed solutions as well for the management of waste and to promote sustainability.

Keywords: Sustainability; Clean environment; Artificial Intelligence(AI); Smart City Construction and demolition (C&D) waste · Municipal solid waste (MSW) · Waste recycling · Landfill sites · Sustainable construction material municipal solid waste (MSW); 3R-WTE; solid waste management; sustainability evaluation; waste-to-energy (WTE); Saudi Arabia.

Chapter 2 Related works

In this section of the paper, we will discuss different previous works for waste management done in different countries of the world and then will also discuss that previously how waste was used to be managed before the industrial revolution, after it and presently. Effective waste management is a problem everywhere. Many nations have seen a paradigm shift in their waste management policy that has them focusing on recycling, energy harvesting, and improving treatment and disposal methods and procedures, thereby perceiving garbage to be a recyclable source. Waste generation in various EU nations has reduced from 527 kg per person per year in 2002 to 475 kg per person in 2014, a 10% decrease.

Various public measures launched since 2007 helped to support this decline. As a result, during the same period, the contribution of waste to greenhouse gas (GHG) emissions dropped by almost 35% (from 223.6 in 2002 to 144.4 million CO2 equivalents in 2014).

In 2015, the proportion dropped. The overall CO2 emission has decreased by around 339 million tons of CO2eq between 1990 and 2014 as a result of a more stringent management strategy with the future emission targets of 375 Mt CO2 established for the year 2040, of which 55 million tons were attributed to waste management efforts. The anticipated 12% increase in GHGs from trash is four times higher in poor nations. However, the EU waste prevention strategy appears to neglect factors that contribute to trash formation, such as consumption, and instead relies on conventional waste management objectives to stop waste from being produced in the first place.

The European Union expects its member states to adhere to its solid waste management standards and directives by the year 2020. This includes sorting waste on a larger scale, valorizing at least 50% of household waste and 70% of construction waste, disposing of less than 35% of biodegradable waste, and recycling at least 55% of packaging waste. The development of waste management strategies and the establishment of the necessary infrastructure for environmentally sound waste management are also top priorities. As a result, this framework was forced into the national policies and rules of many nations in the Euro-Mediterranean region. About 250 kg/person/year are produced in North African nations, which is 50% less than what is produced in European nations.

About 50% of household garbage is biodegradable at the Mediterranean level. Waste production across nations is comparatively equal, averaging between 0.7 and 1 kg per person per day in urban areas and 0.3 to 0.6 kg per person per day in rural regions. Together with Egypt for the urban area and Algeria for the rural region, Jordan produces the most garbage both in the urban and rural settings. In 2004, Tunisia produced 183 kg of municipal solid garbage per person per day.

"Discarded (and untreated) materials from healthcare operations on people or animals that have the potential to transfer infectious pathogens to humans," according to the World Health Organization, is what is meant by "health care waste" (World Health Organization, 2004). Dental health care service units produce a range of wastes that may be divided into sharp, pharmaceutical, hazardous, non-hazardous, and biohazardous wastes. Infectious waste, materials, equipment, sharp items, heavy metals, paper, cardboard, glass, gloves, needles, x-ray films, dental amalgam, and bloody tissues are only a few examples of these wastes.

The daily production of solid dental wastes per patient or treatment was evaluated in several studies. The average produced wastes for two consecutive months were 398.3 and 194.7 g/procedure/day in Turkey when the solid dental wastes from eight different university specialty clinics were studied. Research in Greece measured the trash generated by 20 dental clinics and found an average unit output rate of 53.3 g/patient/day.

It can be difficult for healthcare professionals to deal with these different wastes since they could include harmful and infectious elements that cannot be dumped into the environment. Dental waste components also affect how it is collected, recycled, and disposed of. Any dental organization must properly segregate and dispose of their trash, as infectious and sharp wastes must be gathered separately in a puncture-resistant container much as radioactive waste must be isolated from other wastes. Any departure might put the dentist, the general public, and the environment in danger by causing the disposal process to produce poisons and infectious pathogens.

These wastes might wind up in municipal garbage if they are handled carelessly. Transmission of potentially fatal infectious illnesses like HIV and hepatitis might result from this. Heavy metals and radioactive elements may contribute to their potential for detrimental environmental effects.

Dental waste management is a relatively recent environmental concern that has attracted a lot of attention in recent years and has been the topic of a lot of research in various nations. Previous research suggested that dental professionals' knowledge, attitudes, and behaviors surrounding the management of dental waste are problematic.

Qualitative interviews with practitioners in New Zealand revealed a lack of concern over the dumping of contaminated waste into general garbage, with the lack of appropriate laws to encourage many practitioners to follow regulations. According to cross-sectional research carried out in Palestine over five months in 2007, the majority of dental waste was disposed of in the regular trash. According to this study, oral healthcare professionals were not following the recommended biological waste disposal technique. Most biomedical wastes were misclassified, according to a Brazilian study that examined the microbiological composition of dental solid waste and its sensitivity to antibiotics as produced by three dental health services.

About 90% of dental workplaces and facilities placed their infectious waste with interior garbage, according to a cross-sectional survey that included 595 private and public dentistry offices and clinics at Shiraz University, Iran, while only 60% of centers used a conventional approach for sharps transfer. Only 28% of practitioners in Lebanon segregated sharp waste in a suitable container, and only 7% of dentists reported treating infectious waste before disposal. Additionally, about two-thirds of the surveyed dental practitioners didn't follow local guidelines, and 50% didn't take the proper precautions when managing dental waste.

Additionally, the majority of participants in this survey (90%) noted the absence of formal waste management processes. Similar findings from research carried out in Bangkok showed that few dentists followed all waste disposal requirements, with a large percentage of trash being deposited into household waste streams, indicating the need to suggest a change in the practitioners' behavior. There is a clear need for training programmes for all levels of dentistry unit employees, from dentists and dental assistants down to waste handlers and maintenance and incinerator operation staff, as a result of the serious dental waste management issues that have been identified in several nations. There have been several studies undertaken across the world to evaluate the mindsets of clinical staff about trash, but none of them was carried out in Saudi Arabia.

This absence of data is concerning when coupled with the haziness of the rules and procedures governing the disposal of dental waste. To assess the issue, it is necessary to analyse the degree of knowledge and practices among oral health care professionals in connection to dental waste management. The primary goal of this study was to determine the degree of dental waste management knowledge and behavior among oral health care providers.

A microcontroller and a communication protocol will be installed in ordinary items in the future, according to the Internet of Things (IoT) communication paradigm [1]. The smart city, which may be characterized as a city with smart technology, smart people, and smart collaboration, is one well-known IoT product [2]. IoT is expected to transparently and seamlessly integrate a wide range of heterogeneous end systems while granting open access to specific data subsets for the creation of several digital services [3]. Smart waste management is one of the main issues in the smart city.

The efficacy of waste management systems is significantly influenced by the communication distance between the garbage collection location and the waste collecting center. The long-distance communication required for the waste management system can be met by already existing communication technologies, such as LoRa and SigFox, which operate on low-power, wide-area networks (LPWAN), while compromising the pace of data transfer. The pace of research [4–8] in the area of wireless communication in IoT has also increased. In contrast, faster data transfer speeds are offered by communication technologies like Bluetooth, Wi-Fi, and Zigbee, although they are constrained by their data transmission ranges.

Waste management is an expensive process since it requires a lot of effort and resources. The establishment of the recyclable bin and the introduction of the 3Rs campaign are examples of steps the authorities have done to enhance waste management systems (recycle, reuse and reduce). Only 31.8% of the 384 participants in research on public awareness of recycling activities in Kota Bharu, Kelantan, Malaysia, participated in recycling [9]. This demonstrates both the ineffectiveness of earlier endeavors and the necessity for the creation of an intelligent waste management system to replace the current infrastructures. The current waste management system has been improved thanks to developments in IoT. Real-time monitoring, which is not possible with the current waste management system, is made possible by the deployment of sensors in the trash can and IoT connectivity.

The sensors may be used to gather data such as fill level, temperature, humidity, and any other essential information. The storage and processing of these data can subsequently be done on the cloud. The processed data may then be utilized to research and identify the shortcomings of the current waste management system, hence increasing the system's overall effectiveness.

One step toward creating a smart city is an IoT application in the trash can. Deep learning has also offered cutting-edge technologies for thoroughly comprehending human actions [10]. The categorization of garbage can now be done more quickly and accurately thanks to advances in deep learning and image processing techniques. Before doing trash separation, it is essential to classify the garbage. Unique characteristics may be extracted from the picture using a deep learning technique like a convolutional neural network, which then accurately classifies the features into each class [11].Machine learning applications employ the deep learning package Tensor flow, which is open-source. It can recognize voice [2], classify images [3], identify objects [14], classify text [5], and more. The infrastructure for waste management systems may be enhanced using deep learning intelligence and IoT, which connects millions of smart devices. A summary of the difficulties in establishing sustainable waste management may be found in [6]. Due to inadequate infrastructure and technology, landfilling has been unable to keep up with the rate of garbage creation [7,8].

The success of garbage recycling implementation has also been hampered by the lack of a recycling market [19]. Because waste reduction is an expensive process, industry professionals have been reluctant to use effective waste management approaches [7,9]. In addition, inadequate rules put in place by the government have permitted practitioners to use their waste management methods [19,20]. The significance of creating a regulated waste management system based on the predetermined waste management hierarchy is not understood by industry practitioners [19,20]. The current approaches and infrastructures are covered in [21]. The current infrastructures are expensive to operate and provide only mediocre accuracy [2].

[5] Proposes a second IoT-based smart bin. There are three compartments included, and each has a different purpose: An IR sensor and metal detector make up the first compartment. An IR sensor and a moisture sensor are included in the second container to distinguish between dry and wet garbage. The last compartment is separated into three separate bins for the collection of different types of garbage. For data transfer to a particular server, the system establishes a WiFi connection. A revolving table with three bins—dry, wet, and metal—makes up the storage area. Depending on the kind of garbage that was discovered in the prior compartment, it rotates. A critical component of a smart bin that may be installed in a distant area is its transmission range, which is limited by Wi-usage Fi's as a communication channel.

In [6], a third IoT-based solid waste management system is suggested. This system uses a DHT22 temperature sensor, MQ-135 gas sensor, IR sensor, passive infrared, PIR sensor, and load cell to monitor temperature and humidity, presence of dangerous gas, amount of garbage, user presence, and weight of rubbish, respectively. Data are delivered to a gateway via LoRa connectivity and then forwarded to a cloud for cloud monitoring. The system requires a total of five garbage bins to manage five distinct sorts of waste, and each bin has its own set of sensors, which eventually raises the system's overall cost. In [7], a fourth IoT-based system is suggested. The amount of waste in the bin is monitored by this system using an ultrasonic sensor. Additionally, the observed data are sent via the LoRa connection. The suggested technology just keeps track of how much trash is in the container.

To regulate power usage, the author highlighted power management using elements like a counter and a switching regulator. [28] Suggests an automated system for sorting recyclable materials. Four different types of sensors are installed in the recycling bin: inductive sensors for plastic, capacitive sensors for metal, photoelectric sensors for paper, and proximity sensors for the motor position.

Three different types of sensors that are attached to an Arduino Uno are in operation when the trash is put into the recycle bin to determine the sort of material. Following completion of the detection, the direct current motor will rotate the circular plate containing the waste to the compartment for the appropriate substance. The recyclable material is subsequently pushed into the separating bin by a pusher. The suggested method depends on several sensors, which might raise the recycling bin's maintenance and production costs. Energy efficiency, communication capabilities, and information sharing across expanded coverage are necessary for an IoT-based system to be deployed [3].In [4], an embedded system based on the IoT is presented. Data transfer to the server is carried out on a platform that uses GSM communication technology.

Web-based Android applications are created to communicate with a web server and transmit data from sensors monitoring the state of the trash can, the quantity of trash inside, and the time till trash pickup. To effectively manage garbage collection tactics, the data are analyzed using a graph theory optimization algorithm to determine the shortest path to the bin. A very cost-effective method to lower a waste management system's operating expenses is provided by graph theory optimization.

In [3], an intelligent waste separator is suggested. The system uses Euclidean distance to classify garbage based on the first two Hu's Invariant Moments (HIM) [34] and the k-Nearest Neighbors (k-NN) [35] algorithm. Using the k-NN method with k = 3, the suggested system can attain an efficiency of 98.33%. The suggested system can accurately identify various forms of garbage, but because it bases its waste detection on the shape of the waste, it is unable to recognize deformed waste that has been disposed of.Deep neural network garbage sorting research is conducted in [3]. For training and testing, deep convolutional neural network architectures including ResNet, MobileNet, Inception-v4, DenseNet, and Xception are employed.

The training dataset consists of 2527 waste photos, which include paper, glass, plastic, metal, cardboard, and rubbish. Adam [37] and Adadelta [8] are two distinct optimization techniques that were employed. Based on the findings,

DenseNet-121 produces 95% test accuracy when done using transfer learning with specified weight, whereas Inception-v4 produces excellent results above the other architectures, with 90% test accuracy when trained without any pre-learned weights. RecycleNet, a novel model that this study also suggests and which is tailored for the categorization of a few kinds of recyclable objects, this model can decrease a 121-layered network's 7 million parameters to around 3 million, and it can achieve 81% test accuracy with a little dataset.

[11] Proposes a smart bin system based on machine learning, image processing, and IoT. The convolutional neural network (CNN) used by this system allows it to recognize and classify garbage into many categories, including metal, glass, paper, and plastic. To train the network, a total of 400 to 500 photos with four distinct classes are employed.

Keras is used to implement the CNN in TensorFlow. There are eight tiers in the network. 50 epochs are employed, with a train/validation split of 350–400/50–100 per class. The Raspberry Pi micro-image controller's processing software allows the system to categories and identifies garbage with an accuracy of about 84%. In [9], a smart trash can utilizing LoRa technology is suggested. WiFi, Bluetooth, and cellular networks are used to establish wireless communication; however, these bands have significant issues with noise, interference, network slowness, interruption, and inefficiency. These issues are said to be resolved by LoRa technology by having a separate network. LoRa allows for low-power, greater than 10 km, long-range communication.

It is appropriate for public network operators servicing a large number of users since it can manage high capacity or millions of messages per base station. The suggested system comprises sensors for measuring waste volume, a cloud platform, a LoRa gateway, a remote diagnostic system, and other components. Different components, including GPS, cameras, motors, and sensors, are interfaced to complete the procedure. Sensors monitor rubbish accumulation and identify overflowing. By storing the data in the cloud platform, a LoRa gateway transfer's information about the trash can to a nearby vehicle that is a smart dustbin.

The information-receiving smart trash can will go to the bin where it will be replaced. Using LoRa, communication is carried out. Research on LoRa, an LPWAN protocol for low power wide area networks, is given in [40]. To transmit signals between the node and the gateway, LoRa uses a star architecture. Scalable bandwidths of 125 kHz, 250 kHz, or 500 kHz may be used with it [1]. The chirp spread spectrum enables high sensitivity, durability, and resistance to doppler shift. Due to its low power requirements, it may be deployed for an average of five to 10 years.

Numerous uses for LoRa may be discovered in industries including smart metering, smart homes, smart cities, and smart environments. The comparison of several communication protocols is shown in Table 1. Similar methods are utilized in [2], however, Zigbee and GPRS are the communication protocols employed.

Table 1 Comparison between Communication Protocol

Characteristics	**Bluetooth**	**ZigBee**	**Wi-Fi**	**Lora**
Max. end-devices	255 (2 Billion in BLE)	More than 64000	Depends on the number of IP addresses	More than 5000
Peak Current Consumption	30 mA	30 mA	100 mA	17mA
Range	10 m	10 to 100 m	100 m	More than 15 km
Data Rate	1 Mbps	250 kbps	11 Mbps and 54 Mbps	290 bps to 50 Kbps
Relative Cost	Low	Low	Medium	Low
Topology	Star	Star and Mesh	Star and Point-to-point	Star
Transmission Technique	Frequency Hopping Spread Spectrum	Direct Spread Spectrum Sequence	Orthogonal Frequency Division Multiplexing	Chirp Spread Spectrum

Optimization of solid waste delivering sustainable goals in Jeddah, Saudi Arabia.

Saudi Arabia's fast urbanization, population expansion, and industrialization have all contributed to rising pollution and waste levels. Solid waste disposal for governments and municipal agencies is increasingly difficult every day.

With a population of around 29 million people, Saudi Arabia generates more than 15 million tons of solid trash yearly. The average amount of garbage produced daily per individual is between 1.5 and 1.8 kilograms. Since over 75% of the population lives in urban areas, the government must act immediately to improve the nation's garbage recycling and management situation.

Three of the main cities, Riyadh, Jeddah, and Dammam, produce more than seven million tons of solid trash yearly, demonstrating the severity of the challenge facing the local government. The design Expert programmer was used in this study to optimize process parameters during the collection of municipal solid waste (MSW) from the city of Jeddah. To optimize the many process parameters on the total cost, design trials and numerical optimization are both very successful. To handle municipal solid waste promptly and ecologically friendly for Saudi Vision 2030, the country urgently needs an agile waste management system.

Municipal solid waste (MSW) output has increased in India due to population growth, and economic expansion that has spurred urbanization, and altered public living standards1. Waste production is now predicted to be between 64 and 72 million tons, and by the year 20312, it is expected to reach about 125 million tons. MSW3 is often the result of the collection of business and residential garbage from publicly generated sources. Paper and paper products, food, textiles, wood waste, and entirely non-biodegradable products like leather, rubber, metal, and glass are all included in MSW in general. The integrated management approach and the idea of waste are illustrated in Fig. 1. A bad style of life and a lack of environmental awareness are influenced by the continuous and thoughtless disposal of urban solid waste6. Additionally, inadequate transportation infrastructure and inefficient trash collection procedures are mostly to blame for the accumulation of MSW around the city. Unscientific MSW monitoring and disposal are to blame for several issues related to environmental pollution and issues with human health and wellbeing. The characterization, correct collection and storage plans, waste transport methods, and ultimate dumping must all be determined to handle MSW professionally, and effectively, for improved and secure lifestyles, and sustainable development.

Numerous investigations have identified variables influencing the parts of the waste management system. The size of the household, the degree of education, and the monthly income all affect how much garbage is produced.

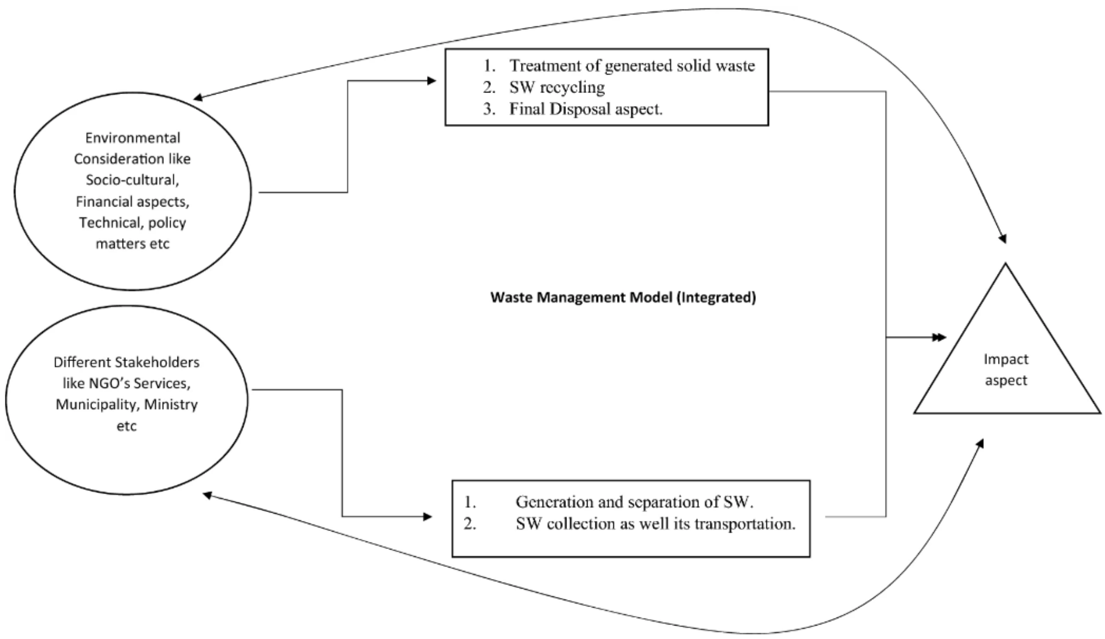


Figure 1 Management of solid waste using integrated management mode

The positive sponsorship and commitment of a real estate firm, the function of neighborhood residential councils in fostering civic engagement, and a recycling service cost based on trash volume or weight all have an impact on household perspectives toward waste separation. Gender, peer pressure, the amount of land a home occupies, where it is located, and participation in an environmental organization are all factors in household trash usage and separation behavior.

In poor nations, waste disposal is still generally ad hoc and uncontrolled. In the Kingdom of Saudi Arabia, MSW collection services deal with an increasing number of issues, including the expanding population, variances in customary conditions, and a lack of understanding of the impacts of solid waste on the environment.

To enhance MSW management, which would ultimately increase environmental security, this article also recommends suitable management strategies. It reviews the current MSW in Jeddah. Solid waste management was one of the key concerns the League of Arab States embraced in its goals for 2008. The league requests that scholars create national-level initiatives on solid waste management for the Arab area. A comprehensive plan for managing garbage and hazardous materials should also be implemented. Residents are at risk since MSW play a crucial part in environmental contamination. The rate and quantity, type, source, and location of waste created must all be known in detail to manage solid waste (such as processed, collected, disposed of, and recycled) effectively18. This paper illustrates the necessity for an in-depth investigation to evaluate the status quo approach to problem consciousness and reaction in biomedical wastes4,18 in light of the COVID-19 pandemic.

We need to open up the discussion on potential changes to current procedures for collecting, managing, and classifying biological waste from clinics and isolation facilities housing positive or suspected COVID-19 patients. The most recent device changes may be required and should be taken into consideration2, even though the most recent practices, such as the

retention periods, can greatly lower the dangers to workers involved in the management of hazardous wastes. Additionally, there is an urgent need for information on the occurrence and detection of SARS-CoV-2 in biomedical waste to understand related transmission processes.
And to clarify appropriate risk estimation and management techniques for the biomedical industry. According to the most recent research on a potential airborne COVID-19 transmission, which also includes SARS-CoV, this might be a future method for the spread of the illness. An excellent opportunity to reestablish SARS-usefulness CoV-2's as the source of a statistic is presented by the facility to separate it from medical waste. Given the chance, human expenditure, and economic impact of COVID-19, such inquiry should proceed with zeal7. Additionally, special safety precautions and the requirement to maintain information security can provide a challenge. This kind of information is not available in the Saudi Arabian city of Jeddah24.
There are several ongoing case studies on the contribution of the local and private sectors to solid waste management in developing nations. A robust waste system and an agile waste management system are essential for Saudi Arabia to efficiently and sustainably manage its urban solid waste.
The software was used to minimize the cost per trip for this study's experimental design, taking process characteristics into account. Therefore, it is crucial to assess the current methods and potential developments for the collection, storage, and disposal of solid waste. In this work, the optimization of process parameters during the collection of MSW from Jeddah city was done using design expert software.
The many process parameters on the total cost may be optimized with the use of design trials and numerical optimization. This research took into account the MSW produced in Saudi Arabia, which has a high potential to be turned into riches. Therefore, future management methods for MSW have also been considered while taking into account the existing

environmental condition and the energy outlook. This research took into account the MSW produced in Saudi Arabia, which has a high potential to be turned into riches.

The literature on performance evaluation of multi-criteria decision-making (MCDM) systems is still scarcer than that of other infrastructure services. A thorough analysis of the literature on the performance assessment of MSW systems using various models was required to support this. Here is a small summary of different research that is connected. Recently, numerous MCDM applications for waste management were systematically analyzed. The analysis reveals that the majority of studies covered the issues of site selection, social and environmental effect analyses of different waste management technologies and the choice of waste processing plant types.

Mendes et al. have implemented waste management programs in areas of Portugal where there is a significant seasonal tourist presence and used a straightforward weighted sum approach to assess their effectiveness. Based on a straightforward cross-comparison, 39 municipal trash systems in Portugal were taken into account. The driver pressure-state impact-response model uses 18 performance metrics to improve waste management programmer performance (PI). Each PI's output (response) was evaluated using a straightforward addition. By passing legislation that supported autonomous curbside recycling of recyclables and residual garbage, the European Union (EU) took involved in the waste industry. Additionally, while the EU has turned its attention from garbage disposal to recycling and reuse, low-income nations all over the world have been

Concentrating on extending service reach. Given the scarcity of resources affecting the public sector and the tightening budget constraints imposed by EU agreements, municipalities can pursue one of three strategies to raise funds necessary to meet higher quality standards:

1. Boost tariffs and taxes.

2. Increase debt by taking out more loans from banks and private investors
3. Boost productivity.

The first option is extremely unpopular and conflicts with parliamentarians' need to win re-election; in addition, it can only be pursued with the support of local municipal governments and the concession agreements that govern garbage facilities on a local level. In a number of these studies, the performance of a certain component was assessed utilising a collection of several PIs for regional and worldwide comparisons using the raw data considered from numerous towns. Guerrini et al. employed non-parametrical approaches with an emphasis on important data metrics to assess the performance of 40 municipalities in Verona, Italy. To increase economic productivity and efficiency, 30 enterprises in Nigeria have introduced non-government sector contributions to solid waste management. Huang et al. evaluated the performance of 307 MSWM systems in Taiwan using just five critical metrics. Using cost-income analysis, Lohri et al. evaluated the MSWM systems' financial sustainability in Ethiopia. The production of electronic garbage in Brazil was recently calculated by Abbondanza et also, there is a lot of literature available, but their main focus is on the present issues of the world and even the literature which is relevant to Saudi Arabia is very wide open with no focus on the main issue rather than most of the studies are on the general waste management and how we can use different methods to optimize them. In this paper what we are going to do is to make a plan which is inclined with the KSA 2030 green mission. So, we are not only optimizing waste management, but we are also focusing on how we can decrease the greenhouse effect as much as possible. In the next section of the paper, we will discuss the current issues of waste management and the other GCC countries which are also like KSA.

Chapter 3 Survey and Research on Waste Management problem in KSA

The Kingdom of Saudi Arabia (KSA) has rapidly urbanized over the past 30 years as a result of high birth rates, immigration, and rural migration to urban areas. The demand for basic infrastructure to serve housing and transportation demands have expanded as a result of this large-scale migration into urban areas. According to government and corporate investment in the area, it is anticipated that the EP will accommodate a significant number of additional inhabitants as urbanization trends advance. The KSA will thus soon have to deal with the effects this will have on the area's production of building and demolition debris (C&D). In the Kingdom of Saudi Arabia, construction and demolition waste (C&D) is regarded as a significant contributor to the formation of solid trash.

The minimization of C&D is a significant priority because of its severe effects, including resource depletion, degradation of land pollution related to noise, air, and dust, and hazardous waste discharge. The Gulf Cooperation Countries (GCC) routinely creates more garbage per person than the top 10% of countries worldwide. GCC produces 120 million tons of garbage yearly, of which

55% comes from construction and demolition (C&D), 20% from municipal solid waste (MSW), 18% from industry, and 7% from hazardous waste. The Kingdom of Saudi Arabia (KSA), like the other GCC countries, produces enormous volumes of MSW, C&D trash, and industrial waste. To identify the elements that has a significant impact on the sustainable management of C&D waste in the nation.

This study will look at 81 construction businesses in the Eastern Province of the Kingdom of Saudi Arabia. Only 39.5% of the enterprises under investigation had a project-specific pollution control strategy. Additionally, it was iscovered that only 13.6% of C&D trash gets recycled and utilized annually, with the remaining 86.4% of C&D waste ultimately ending up in landfills. The majority of the C&D trash produced in the nation is a promising supply of sand, metals, and other recyclable building materials. In addition to meeting the KSA's needs for the manufacture of metal and gravel, this would also address the problem of waste disposal and result in significant economic gains.

The numerous elements that could influence the nation's construction waste management practices must be highlighted to achieve the objective of sustainable construction waste management. The Gulf Cooperation Countries (GCC) routinely ranks among the top 10% of the world in terms of garbage generation per capita [1]. Construction and demolition (C&D) trash are thought to make up 120 million tons of the total garbage produced yearly in the GCC, or 55% of the entire amount of rubbish that is collected [2]. Municipal (20%), industrial (18%), and hazardous (7%) wastes make up the remaining waste [1]. In Abu Dhabi, the United Arab Emirates (UAE), 75% of the total garbage produced in 2010 was C&D waste [3]. Similar to this, Dubai's municipal government recorded 6.64 million tons of C&D trash alone in 2012, or 68.7% of all waste. In Kuwait, between two and two and a half thousand tons of C&D trash was produced per day in 2010 [4].

The majority of garbage that is collected in the GCC, including C&D waste, finally ends up in landfills, dumps, or on the outskirts of major cities. Additionally, the landfills lack collecting systems for leachate and gases and are neither hygienic nor designed landfills [5, 6].

As a result, issues such as waste sludge, stench, and greenhouse gas (GHG) emissions are commonplace close to landfills [7,8,9]. In the GCC, the amount of land needed to build new landfills grows dramatically each year [10]. To address the challenges of climate change, environmental preservation, and sustainability, the GCC nations are implementing several new waste management rules [11, 12]. Investment in trash recycling is one of these tactics, like Vision [13] in the Kingdom of Saudi Arabia (KSA). And programs for trash reduction, facilities for waste-to-energy (WTE), and composting of organic waste [13].

Local governments in the GCC are in charge of garbage management, however, in some of the GCC countries, private corporations are also involved in rubbish collection and sorting [1]. Despite the established organizational structure for waste management at the local level, the majority of the GCC nations' recycling markets are insufficient, which interferes with its operation [1]. The lack of public-private partnerships (PPP) is another reason why waste management strategies for C&D waste are not being implemented properly [10].

As a result, it is essential to encourage municipalities and other public sectors in the GCC region to reuse and recycle C&D waste as a source of value-added products (VAP), a solution to the region's current waste disposal issues, as well as something that will have enormously positive effects on the economy and the environment [1, 6].

Similar to other GCC nations, the KSA has experienced rapid urbanization, industrial development, and population growth. As a result, the generation of industrial and C&D waste as

well as municipal solid waste (MSW) has increased significantly, reaching 15 million tons annually at an average rate of 1.4 kg per person [5, 7]. Such a wide range of waste kinds calls for various indigenous techniques and solutions for resource recovery and recycling [14,15,16,17].

For instance, building an integrated C&D waste management strategy for KSA and other GCC nations involves an agreement among the major players, such as construction firms and governments, to dispose of C&D trash sustainably in the country [1, 18]. There isn't research available in the GCC area that focuses on data from one stakeholder group, construction businesses, and the variables that might affect how they handle C&D waste. Thus, this article attempts to investigate the variables influencing KSA's sustainable construction waste management for the first time. To reach clear findings and provide strategies for attaining sustainability in the C&D waste sector not only in the KSA but also in the GCC area, 81 construction businesses in the Eastern Province of the Kingdom of Saudi Arabia were examined as case studies.

Additionally, the region's present waste management techniques lag below internationally adopted best practices for environmental sustainability. In the past ten years, several academics and engineers have published widely on the viability and effective management of C&D waste. They concluded that waste management awareness, (ii) waste management rules and methods, (iii) sustainable building technologies, and (iv) waste management R&D are essential components for successful C&D management. For instance, the introduction of a rising landfill charge in the United Kingdom in 1996 led to a general decline in the amount of garbage being diverted to landfills, which has continued to this day. Following the adoption of its landfill ordinance in 2009,

Germany saw a similar trend, although this type of progressive levy needs to be strictly enforced to avoid accidentally encouraging unlawful dumping.

According to estimates, hundreds of thousands of tons of rubbish were illegally placed in landfills in Germany as a result of particular features (progressive taxes and a landfill ban) in the Landfill Ordinance that raised landfilling rates above what stakeholders could afford. Similar to Spain, where the legislation showed that all construction-related authorities must follow protocols and take essential measures to reduce C&D waste production and handle it properly, The effective exploitation and recycling of C&D waste for new building goods has also been explored in earlier research. Concrete and masonry may be made from C&D waste that has been recycled and reused. Road engineers, for instance, have advocated recovered C&D waste as an acceptable road base material in a select few nations. Nearly 90% of the C&D handled after recycling is reportedly made up mostly of masonry and concrete.

The government's job is to stress the use of processed C&D waste as a raw material for new building sites to get it implanted. Only a few studies have looked at choosing the best location and quantity of facilities, including recycling factories. According to the studied literature, the Saudi Arabian kingdom's building and demolition waste stream has not yet been the subject of a thorough investigation. The purpose of this research is to outline the present obstacles to managing C&D debris effectively as well as to offer a roadmap and a solution in light of current regulations and the production of C&D debris. A range of stakeholders, including national and local authorities, enterprises, and families, will be impacted by the implementation of an effective C&D management program in the Kingdom of Saudi Arabia. The possible secondary and tertiary effects

That C&D production may have on the environment's deterioration and people's health only serve to exacerbate this.

Therefore, before any national or regional waste management strategies are implemented, the waste streams from building and demolition must be properly recognized. To better comprehend and then characterize each rule, more than 200 surveys of current laws controlling C&D generation in the KSA were undertaken to utilize interviews and emails with pertinent governmental and technical personnel. C&D management techniques are currently used in the KSA.

Finally, potential routes by which environmentally sound construction and demolition waste management practice can be imported for use within Saudi Arabia's distinct geographical and cultural climate were discussed. Were then outlined and discussed concerning how they were affected by applicable regulatory policy. Since there has been a lot of study on waste management, we now need to talk about the areas on which we should concentrate to address all of the waste management-related issues in Saudi Arabia. Therefore, to do that, we must first go over all of the difficulties with trash and garbage in the KSA and other Middle Eastern nations.

Saudi Arabia has one of the highest rates of garbage-generating output in the world, with Riyadh having the highest rates at more than 1.5 kg/day per person, with an average of 13,300 tons of rubbish arriving at landfills daily [1]. So, when the word "waste" is mentioned, the first thing that comes to mind is the used items that are primarily trash, such as plastic, glass, paper, and food. People usually tend to throw these items away because they believe they serve no purpose and that this is the best course of action, but waste can also be a source of income. The majority of a product's life cycle does not finish in a landfill; instead, recycling refers to the process of turning a product into another one after it has been used. Instead of recycling, this research will concentrate on using contemporary constructed landfills, recovering trash, and recycling waste, which encompasses a wide range of waste use methods.

Municipal solid waste (MSW) generation is expected to increase significantly by the end of 2030, from its current level of 2.01 billion tons per year [1] to 2.59 billion tons. By the end of 2025, the rate of MSW generation is expected to have increased to 1.24 kg/capita/day from 1.2 kg/capita/day in 2012 due to the levels of global urbanization expansion and the population at a considerably greater pace [2]. It will be extremely difficult for authorities to create client waste management regulations that can handle the rise in MSW creation given these statistics. Governments must address the MSW buildup since failing to do so would harm the nation's economy, ecology, and public health.

Population development in the Kingdom of Saudi Arabia (KSA) has forced the nation to increase its housing and infrastructure stock, thereby leading to a buildup of construction and demolition debris (C&D) that has the potential to encourage ecologically friendly waste management techniques. It is vital to comprehend C&D generation in the KSA before applying best practices in the area. The existing difficulties with handling C&D waste in Saudi Arabia's Eastern Province were examined in this study. In addition, it offered a plan and a method for managing C&D debris in light of current laws and the production of C&D waste. Through interviews with pertinent political and technical personnel and the distribution of more than 200 questionnaires to academic, governmental, and business stakeholders, a study of the laws currently governing C&D was carried out. To estimate the volume of C&D moving through the Eastern Province of the Kingdom, data from a landfill was gathered, and building sites were scrutinized to learn more about how trash producers were getting rid of C&D. Major issues were identified based on an assessment of C&D waste generation, regulation, and management policies.

These issues included: I a lack of institutional collaboration (across the academic, governmental, and private sectors); (ii) ineffective strategic policies for C&D management and recycling; (iii) limited coordination between C&D regulators and generators; (iv) a lack of motivation, awareness, and incentives to manage C&D; and (v) the absence of an enforceable law for (vi) Inadequate infrastructure for waste disposal, a lack of treatment facilities, and (vii) A lack of an appropriate strategy for the sustainable management of landfills. By taking into account three key elements, primarily economic, (ii) regulatory, and (iii) technological considerations, C&D management may be properly categorized. The main themes consist of "encouraging C&D waste recycling" and the use of recycled materials in the building sector, "enforcing laws to stop unlawful dumping," and "landfill disposal and recycling fees for waste generators" are some examples.

Within the context of this study, several other issues are also suggested and examined. Finally, a roadmap outlining alternative options for C&D management was presented, outlining possible routes via which environmentally sound construction and demolition waste management methods might be imported for usage within Saudi Arabia's particular geographical and cultural context.

Local governments in the GCC are in charge of garbage management, however, in some of the GCC countries, private corporations are also involved in rubbish collection and sorting [1]. Despite the established organizational structure for waste management at the local level, the majority of the GCC nations' recycling markets are insufficient, which interferes with its operation [1].

The lack of public-private partnerships (PPP) is another reason why waste management strategies for C&D waste are not being implemented properly [10].

As a result, it is essential to encourage municipalities and other public sectors in the GCC region to reuse and recycle C&D waste as a source of value-added products (VAP), a solution to the region's current waste disposal issues, as well as something that will have enormously positive effects on the economy and the environment [1, 6].

Waste into Biodiesel assessment in KSA

Overuse of natural resources has raised worries about anthropogenic climate change and the availability of food, water, and energy worldwide. This has prompted an effort to investigate environmentally friendly and renewable fuels. As a result, biodiesel has become a viable fuel for the future, particularly as a replacement for fossil fuels in the transportation industry.

Transesterification, a method used to create biodiesel from diverse plant or animal-based biological feedstocks, produces the fatty acid methyl esters that makeup biodiesel. More than 350 oil-bearing crops have been discovered globally as potential biodiesel feedstocks. As a result, biodiesel has been produced experimentally using several oil sources.

Figure 2 Waste to 77777Biodiesel In KSA (Ouda, 2018)

These include virgin oil feedstocks such as rapeseed, soybean, sunflower, palm, mustard, jojoba, tung, rubber, cotton seed, neem, Nahor, Karanja, jatropha, Pongamia, and rice bran oils. Additionally, oils made from tallow, lard, yellow grease, chicken fat, and by-products of fish oil and flaxseed oils' fatty acids are employed (Leung et al., 2010). Additionally, in the past ten years, oils from algae and microalgae have been used with improved yields and lower costs. The four main types of feedstock are, generally, categorized as waste or recycled oil, animal fats, edible vegetable oil, and non-edible vegetable oil.

Table 2 A comparisons of properties of petro diesel with biodiesel produced from various waste sources/feedstocks

Characteristics	**Units**	**Petro diesel**	**Waste fish oil**	**Waste poultry fat**	**Waste cooking oil (WCO)**	**Tallow from beef and mutton**
Viscosity at 40 °C	mm^2/s	3	5	4.5	4.7	6.4
Cetane number	–	51 (Euro 3, 4, 5)	51	61	50	59
Sulphur contents	ppm	350 (Euro 3) 50 (Euro 4) 10 (Euro 5)	–	–	Range	0.2
Density at 40 °C	kg/m3	0.82	0.86	0.87	0.87	0.86
Heating value: high heating value (HHV) and low heating value (LHV)	MJ/kg	LHV = 43 HHV = 47	41.5	61	40	40
Acid value	mg KOH/g	–	1.2	0.3	2	0.6
Cloud point	(°C)	−5	−5	−6	20	−4
Flash point	(°C)	50	–	–	86	–
Pour point	(°C)	–	4	−6	16	−5
Short-chain unsaturated fatty acids (C:14-C:18)	%	–	30–60	65–80	40–80	35–65
Short-chain saturated fatty	%	–	15–30	20–35	20–45	40–60

acids (C:14-C:18)						
Long-chain unsaturated fatty acids (≥C:20)	%	–	25–40	0–(−2)	0–1	0–0.5

The selection of the feedstock for biodiesel production primarily depends on environmental factors, agricultural practices, the availability and characteristics of the soil, and geographic locations, which vary from country to country. For example, palm oil predominates in Malaysia due to favorable soil conditions, whereas soybean oil predominates in the United States (US) due to weather conditions as well as utility value. When calculating the income and overall cost of producing biodiesel, the feedstock utilized is a crucial factor.

The accessibility of low-cost feedstocks for biodiesel synthesis has been a persistent problem since Rudolf Diesel's first engine was operated on peanut oil in 1893. The choice of raw material is thought to account for up to 75% of the cost of producing biodiesel. Therefore, numerous unique ways are being investigated to lower the total cost of biodiesel synthesis, including the utilization of diverse non-food feedstocks, novel heterogeneous solid-based catalysts, and carbon-supported feedstocks. Due to process economics, technological difficulties, and regulatory restrictions, the commercial production of biodiesel is still in its infancy. About 12% of the world's supplies of edible vegetable oil were used to make biodiesel in 2012, which has an impact on global food, animal feed, and edible oil costs, particularly in poorer nations. As a result, producing biodiesel from food feedstocks such as edible oils costs 1.5 to 3 times more than producing regular diesel and accounts for 60 to 80 per cent of the entire cost of production. The base-stock, labor facility, methanol, catalyst, seasonal variations in feedstock supply, geographic region, and total production cost of biodiesel are all factors.

However, the public's concern over food shortages and poverty is rising in developing nations as a result of biodiesel production from food sources. Compared to both Petro diesel and conventional feedstock-based biodiesel, biodiesel made from non-food sources like sewage sludge, waste cooking oil (WCO), microalgae, animal fat wastes, and non-edible oil seeds like Jatropha, Pongamia, Neem, Camelina, and Soapberries has received a lot of attention due to its favorable energy balance and economic and environmental values.

Additionally, many of the non-food sources listed above are categorized as wastes and would offer significant economic and environmental benefits if utilized to produce biodiesel. Such non-food feedstocks produce high-quality biodiesel that may be utilized in diesel engines either straight away or after being blended with petroleum fuel. Rapid population expansion, urbanization, and industrial activity in the Kingdom of Saudi Arabia (KSA) and the Gulf area have led to high energy needs as well as the production of municipal and industrial waste. With an expected 8% annual growth rate, KSA's present power-producing capacity of roughly 55 GW is expected to reach 120 GW by 2032.

The only uses for more than 50% of the power are domestic ones, such as air conditioning. More than 15 million tons of municipal solid waste (MSW) are produced in KSA each year; after partial recycling (up to 15%), this material is disposed of in landfills or dumpsites without energy recovery. Lack of waste to energy (WTE) or effective recycling programs causes a huge environmental and economic loss that is added to the economy and public of the country. The KSA government recently unveiled its new Vision 2030 strategy, which aims to establish a circular economy in the nation by producing renewable energy from domestic sources such as garbage and the sun, wind, and geothermal energy.

Similar to other GCC nations, the KSA has experienced rapid urbanization, industrial development, and population growth. As a result, the generation of industrial and C&D waste as well as municipal solid waste (MSW) has increased significantly, reaching 15 million tons annually at an average rate of 1.4 kg per person [5, 7]. Different indigenous recycling resource recovery methodologies and solutions are required for such a variety of waste kinds [14–17].

For instance, building an integrated C&D waste management strategy for KSA and other GCC nations involves an agreement among the major players, such as construction firms and governments, to dispose of C&D trash sustainably in the country [1, 18]. We've examined every problem with Saudi Arabia's present waste management system, so now we'll focus on the biggest ones before coming up with a plan for a brand-new smart city that will utilize AI to address every one of these problems. These are the primary issues:

- Improper waste management is a key contributor to the present situation.
- KSA considers the issue as high priority to address the issue with all possible means and actions
- Research study helps to build a Sustainable way to achieve the KSA's Vision 2030

Research Questions

Also, there are different questions that our research has answered and we will explain these all questions. As you know we are not making a sustainable waste management system to only help the government easily manage waste. But our main goal from the start of this research is to have a good and sustainable environment for the planet and the people living in it. So there are three things we need to take care we want to make sure that the planet is clean and we have a sustainable strategy so the next generations can have the same clean environment which we have now. Due to pollution every day the Ozone layer is depleting and we are having different kinds of new diseases which we never saw before. Let's have the answer to the research questions which we are essential for this research:

How to protect the health of the population?

For having good pollution what we need is a cleaner environment which is pure. A Heathy environment depends on different things like the air quality, the quality of drinking water and the food we eat. So due to waste like if we have a lot of garbage and rather than dispose of it we burn it then it will deteriorate the air and humans will have difficulty in breathing. So it will very dangerous for the help of people. Furthermore, if we are wasting chemicals and different hazards in the water then if people drink think water they will again face severe health issues. In the paper [4] several hundred people in Syria had faced stomach infections due to the contaminated water they drank which was coming from factory wastage. Furthermore due to the bad quality of air different eye diseases and infections are growing and it is very difficult to live near an area which has plants and factories in it. Also as when this water grows in the soil then the vegetables and fruits also become less healthy. The sea population is also getting affected by plastic waste and their number is drastically decreasing over time.

Above we have mentioned all the threats and implications faced by the population and how to solve them. It is difficult to fully eliminate the waste from the system but we can do plenty of measures which will not only safeguard the population but will also keep the environment clean. So what we can do it to first take all industries that are generating air pollution out of the populated area or even if they want to emit CO_2 into the environment then they should pay the tax on Carbon emissions this tax should be so huge that they would rather choose a different path. Then we need to make sure less plastic is used and replace it with recyclable material for all kinds of waste. Also, the waste water should have retreated so it can be reused as cleaning water after the purification.

How to promote the quality of the environment?

If we follow the above steps then we can easily promote the quality of the environment when we will have less air pollution then it will be easier for people to break and the quality of air will be better. Also, we need to ban the use of any kind of plastic and replace it with any kind of recyclable or reusable material so that whenever anyone wants to use a bag or plastic then they can use the material. Plastic is not only bad for humans but it makes marine life worse. So we should raise awareness through different campaigns to not use plastic. Still, if people want to use plastic then the price should be so high that either they use it less or avoid it.

How to create sustainable support for economic progress?

Well, a cleaner environment has economic benefits as well for the government. As they will need fewer resources to clean the environment it will be cheaper for them to manage the waste. And due to the use of more recyclable materials in every field of life then the cost of producing new materials will decrease and the government can use this money to support the life of people. They can spend this money on infrastructure, education and the health sector. Government can also spend the saved money on the environment by using and implanting more and more trees. These trees will not only increase the level of oxygen in the environment but will also make it cooler so people need to use less Air conditioning and less fuel will be used to generate it. Apart from that for the sustainable support of the economy the government should use less fuel and go on to sustainable solutions for the generation of energy like Hydropower and solar. As there is plenty of sunlight in Saudi as compared to Europe the government should less rely on fossil fuels and focus more on solar energy to fulfill their needs of energy.

Chapter 4 New-Era Smart City

As the problems caused by waste and other pollutants that are polluting the environment have already been thoroughly discussed in earlier sections, we will now discuss a new way to manage this waste and will develop a plan for a new smart city that will assist us in carrying out the Saudi Arabian government's 2030 plan. "Vision 2030 is based on three main tenets: a strong economy, a lively society, and an ambitious country. The Council of Economic and Development Affairs, which is led by Deputy Crown Prince Mohammed bin Salman, established the historic vision.

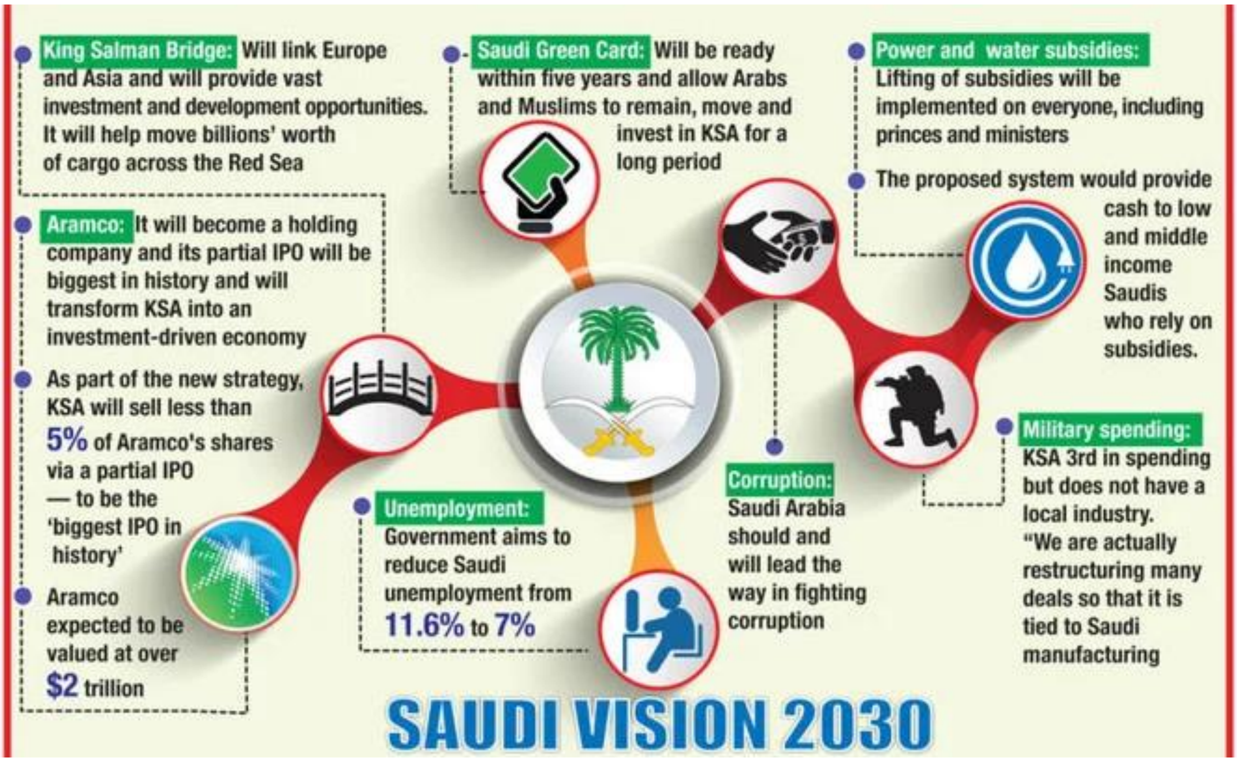


Figure 3 Saudi Vision 2030

(Alqahtani, 2022)

To ensure that every piece of garbage is monitored, we will employ the Internet of Things and AI. AI will also be heavily utilized in the machines that will sort out which waste can be recycled and which cannot. However, to create a smart city, we must first make all households intelligent and link trash cans to the cloud. Therefore, the owner will receive information anytime there is enough garbage in the bins at the dwellings that he has to dispose of the waste, and this notification will also be transmitted to the government system.

As a result, the government can simply determine which persons are frequently disposing of rubbish. There would also be a notice for consumers who use plastic bags and other less reusable things. And, when the garbage arrives at the disposal place, the AI computers will assess what type of waste is supplied by which residence, and the government will either reward or penalize persons who pollute the environment by using non-resuable3 bags and other items.

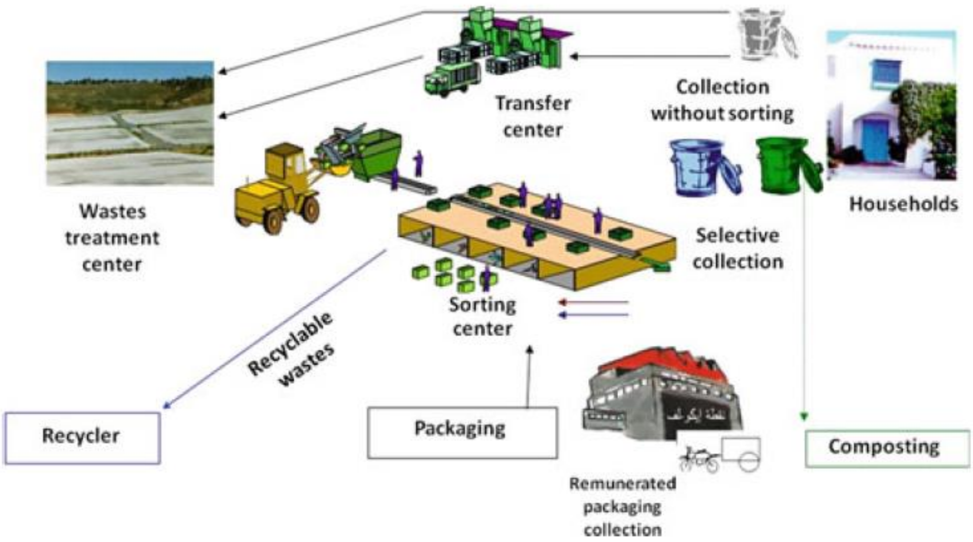


Figure 4 General waste management flow

. (Ji, 2020)

Households are the main source of waste, producing 1.5 kg of waste per person each day. All sorts of waste are tossed together in trash bags without being separated on the way to the landfill. To solve this problem, specially designed trash bins inside the home should be introduced. The bin sections are organic waste with a green bag, plastic waste with a blue bag, glass waste with an orange bag, and paper waste with a brown bag. After that, people place the trash bags in the trash bins that are located in the streets. However, the waste is now mixed, and the separation process will cost a lot of money in the separation plants.

For easier separation in the separation plant, these various bags could be thrown in separate municipal trash bins, or they could be thrown together in the trash container and then separated using a specialised auto-sorting machine that detects the color of each bag and then sorts them by their colors. Using innovative technologies to separate garbage according to its precise weight and transparency is another option.

According to the graphic below, the system turns on when the IR detects a material being placed on the system tray. The glass and metal sensors then start working when the weight sensor is engaged to determine the weight of the garbage. If a metal sensor identifies the garbage as metal, a servo motor will move it to bin 3. (Which is dedicated to metals). An identical course of action will be conducted and the garbage will be disposed of in bin 4 if the glass sensor detects glass. If neither sensor detects anything, the LASER and LDR are turned on. If the LASER passes through garbage, it is deemed transparent and sent to bin 2 instead. If the LASER doesn't work, the object is labelled as paper and put in Bin 1.

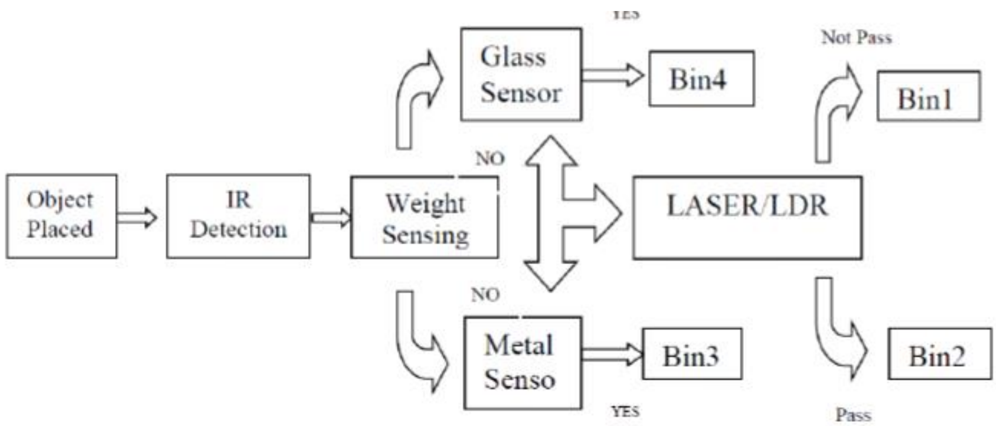


Figure 5 Process of Sorting

In Riyadh, trash is collected every day by following a route that has been specifically designed for waste collection in each neighborhood. This traditional method is time-consuming because drivers must pass by each trash can every day, and it is also expensive because many of the trash cans are empty when they have been collected, forcing drivers and cleaners to stop and empty them.

New technology has been developed to place a sensor inside each trash can to measure the amount of waste inside and determine whether or not to collect it. This system functions like a network and displays each can's location as well as its remaining capacity. It is connected to the waste collection truck as shown in the figure below and creates a special route for waste collection. Additionally, these trash cans will be linked to the cloud so that they can alert the owner and the government that the bins from these residences need to be disposed of.

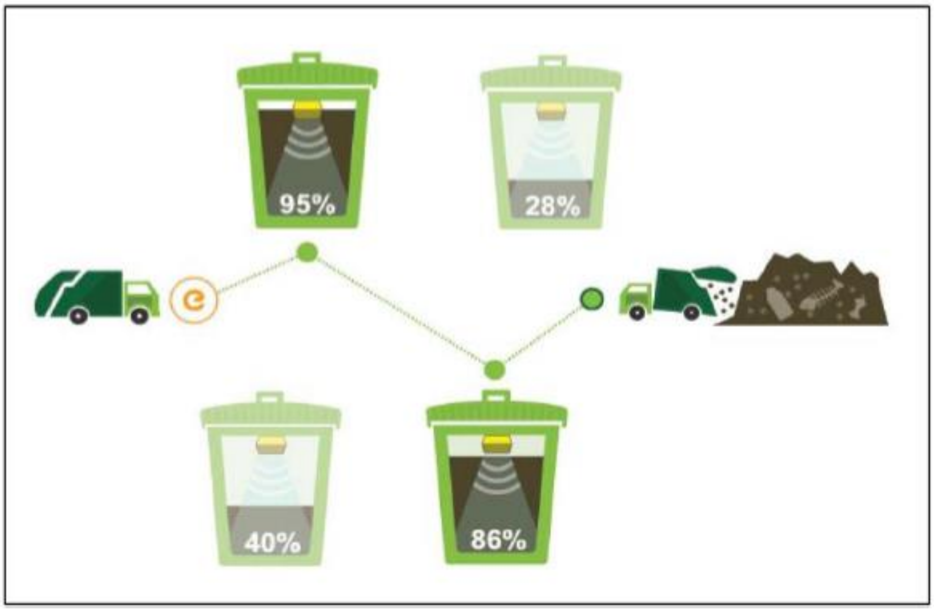


Figure 6 Technology to check the level of waste in bins *(I., 2019)*

Another way to collect waste is to set up an underground system that is specifically made for waste storage and collection in neighborhoods, as shown in figures 4 and 5.

Trash cans for each type of waste (organic, recyclable, etc.) are connected to this system, which uses air pressure to transport the waste to the collection plant or station. However, this method might function better in urban areas. The design of the garbage collection network will be viable, but it will be expensive in Riyadh since the population density there is low compared to other neighborhoods.

Figure 7 Integrated waste collection system *(Blaisi, 2019)*

Figure 8 Smart Collection System *(Blaisi, 2019)*

The waste's trip from the garbage cans to the treatment and recycling facilities or landfills is referred to as the transportation phase. Traditional. When the garbage is collected and transported straight to the landfills, the previous step and this phase are integrated. The transportation step will be less difficult and time-consuming after employing the clever solutions discussed in the collection phase, which will immediately influence the operating cost for transporting the garbage to either recycling plants or landfills. One method of transportation involves moving the waste containers that are kept in each neighborhood's collection facility. Each container is moved separately depending on the type of waste it contains; for instance, containers for recyclable materials are taken straight to the recycling facility, while containers for non-recyclable materials are taken straight to the landfill or the incinerator.

Traditional. Only 1% of the garbage in Riyadh is recycled, and approximately 6% of it is burned in an incinerator, which releases a lot of CO2 gas and other harmful greenhouse gases and gives off an unpleasant smell. Smart. Nearly 40% of the garbage in Riyadh, or around 2,000,000 tons annually, is recyclable, according to waste data. Glass, plastic, metals, papers, and textiles are among the recyclable materials that have the following information: Recycled aluminum costs on average of $1322 per ton, PET recycled plastic costs on average of $333 per ton, recycled paper costs on average $32 per ton, and recycled glass costs on average between $85. and $155. per ton.

Due to the high rate of food consumption, nearly 51% of the waste in Riyadh is organic waste, which is disposed of in landfills with no benefit. There are a few methods for treating organic waste, including combustion, in which organic waste and non-recyclable waste are burned to produce energy as shown in figure 6, and composting, in which organic waste is transformed into fertilizer for use in agriculture.

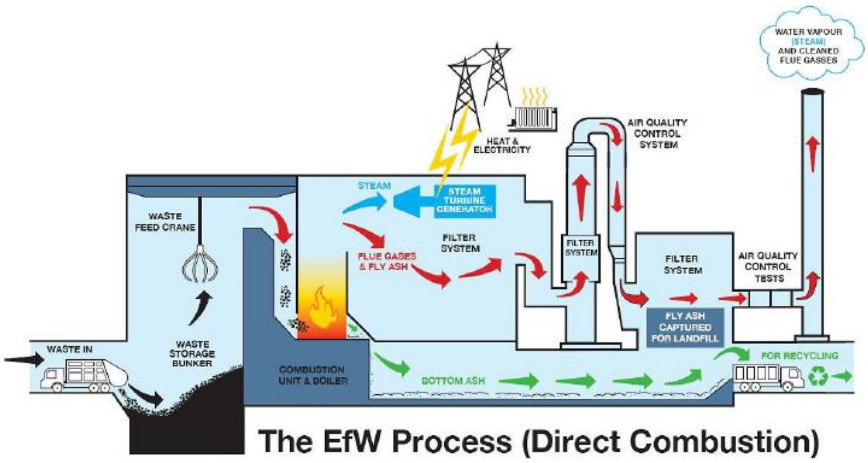


Figure 9 Combustion process of waste to produce energy

(Waste Management in Tunisia—What Could the Past Bring to the Future?, 2020)

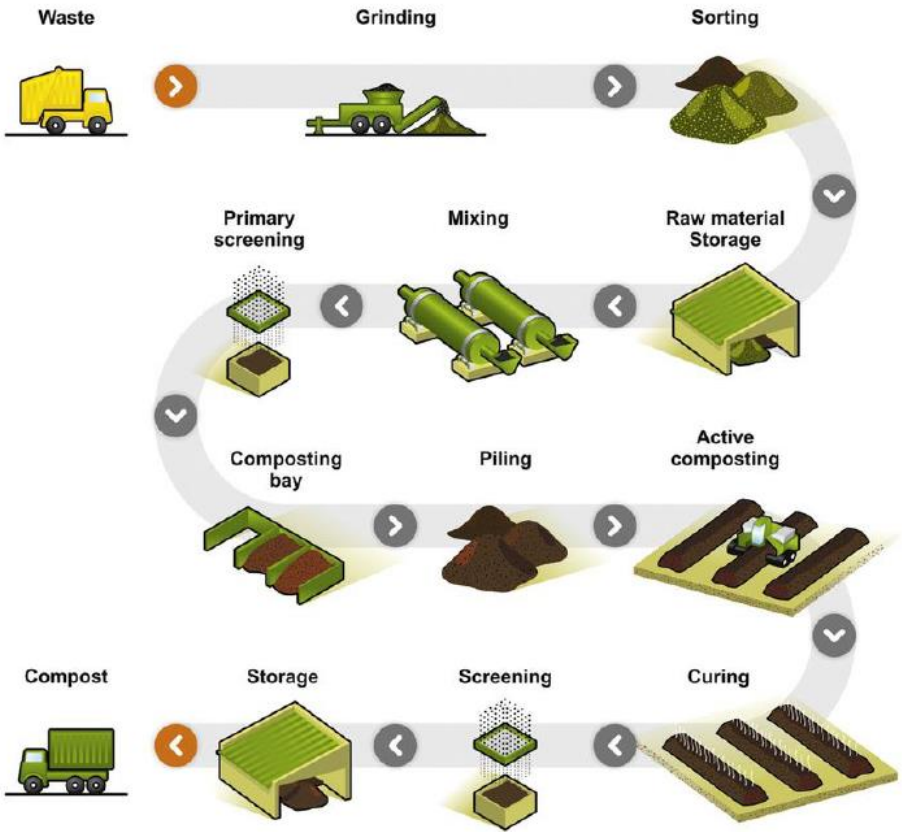


Figure 10 Composting process to produce fertilizers by soil Farmer Company

(Waste Management in Tunisia—What Could the Past Bring to the Future?, 2020)

Traditional. In Riyadh, landfills account for over 93% of garbage disposal and occupy an amount of land that is equivalent to 8,000,000 square meters. Every day, more than 16,000 tons of rubbish is brought to this dump. The garbage is shaped into cells with a cover of 30 cm between each cell and a specified trapezoid cross-section (100m*3m) that is almost 170m long. This kind of waste disposal causes certain environmental issues, such as untreated leachate, which might seep into the groundwater and contaminate it because of its highly harmful effects, and the gas (Methane) created by the organic waste's natural decomposition process, which causes stench.

Recently, the idea of engineered landfills, like the one in figure 8, has entered the waste management system. These landfills concentrate on the environmental impact of the waste and how to reduce it, as well as on how to take advantage of the final stage of the waste management system, which could be obtained by using the gas produced by the decomposition of the organic waste.A specially constructed network of pipelines collects the gas (methane) from the various strata of the landfills and transports it to the generators, which use the gas to generate energy. To ensure that the leachate does not mix with the groundwater, these constructed landfills treat it by collecting it from the bottom of the dump and sending it to a treatment facility.

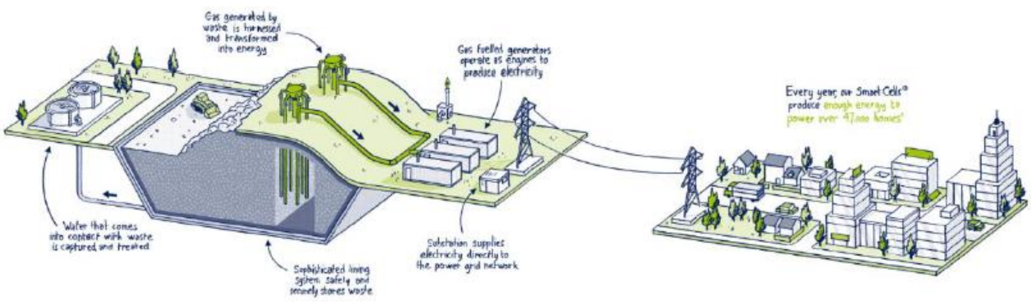


Figure 11 Engineered landfill to produce gas for energy and reduce environmental impact

(Anjum Muzammil, 2016)

So, we have discussed in detail how we can use smart technology AI, and the internet of things to manage waste. We will not only manage the waste but will also make sure that a smart city is formed by using different smart technologies.

Chapter 5 Discussion

For a proper waste management system which is optimized and in line with Vision 2030. We need to have in mind a lot of aspects as there can be a lot of issues which we need to keep in mind. Like on each step we need to plan because if there is negligence on any step then we need to design a whole new system. There can be challenges in cleaning the baskets as well as their sensors might stop working or be covered by dust. So, we must have a proper plan for their maintenance as well. Also, we need to raise awareness among the people that how they can use more and more reusable stuff. For that, we need to take strict action to have a renewable policy and anyone who doesn't follow it should be fined.

Evolution Criteria

<u>Cost of Implementation</u>

The cost of implementing a solution depends upon several factors like availability of technology, the infrastructure required, skills necessary, etc. This is an important criterion before selecting any solution. The capital expenditure and operational expenses should make sense against the benefits to the finances and environment combined.

<u>Time required for implementation</u>

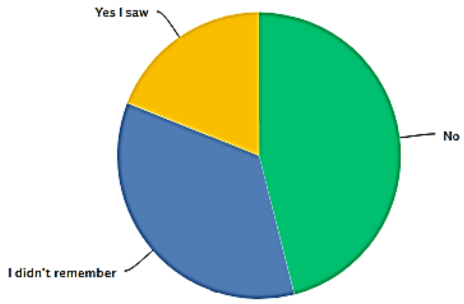
Few solutions are more time taking than others to implement. The solutions that take too long in the implementation stage normally defy the purpose—looking into the approximate time required for the selected solutions to be set in place.

Time and resources saving

The effective use of time and other resources is the main result demanded from waste management systems. Most likely, the option that uses the least time will be chosen. Several factors, including high operating expenses, adverse weather, outdated technology, and others, might make certain solutions impractical. Each solution will be tested against these criteria.

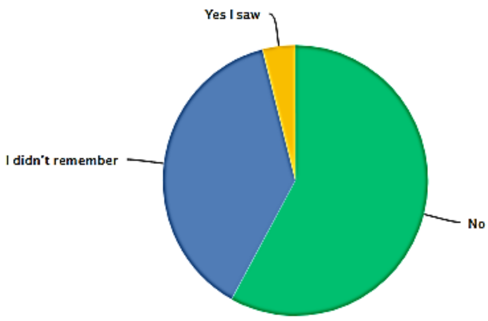
Results

Also, I will share with you the results from the survey and implementation:



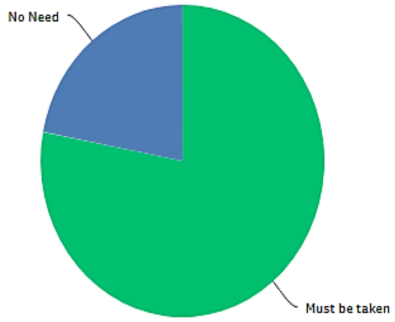
ANSWER CHOICES	RESPONSES
No	46.00%
I didn't remember	35.00%
Yes I saw	19.00%
TOTAL	

Figure 11 Application of technologies (1)



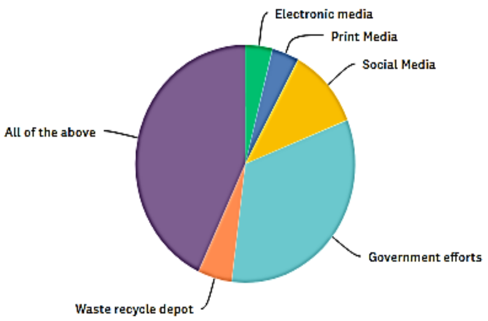
ANSWER CHOICES	RESPONSES
No	58.00%
I didn't remember	38.00%
Yes I saw	4.00%
TOTAL	

Figure 12 Application of technologies (2)



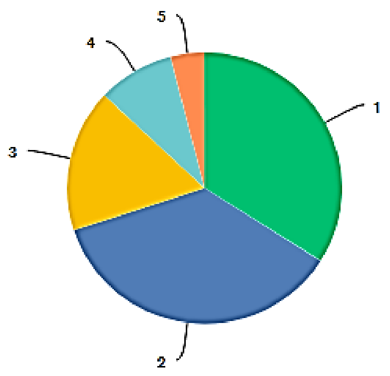
ANSWER CHOICES	RESPONSES
Must be taken	78.00%
No Need	22.00%
TOTAL	

Figure 13 Initiatives



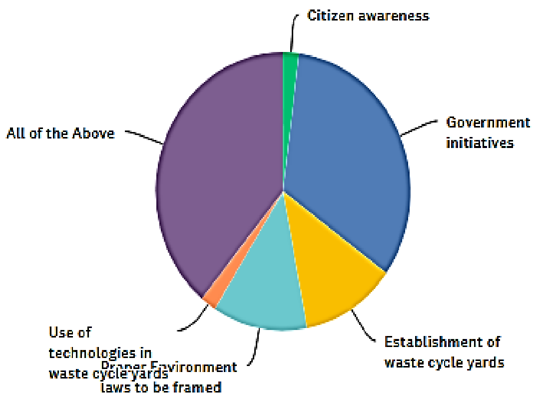
ANSWER CHOICES	RESPONSES
Electronic media	4.00%
Print Media	4.00%
Social Media	11.00%
Government efforts	33.00%
Waste recycle depot	5.00%
All of the above	43.00%
TOTAL	

Figure 14 Role of Media



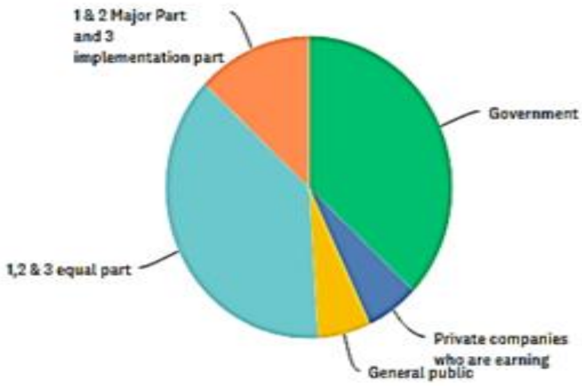
ANSWER CHOICES	RESPONSES
1	34.00%
2	36.00%
3	17.00%
4	9.00%
5	4.00%
TOTAL	

Figure 15 Government Effort



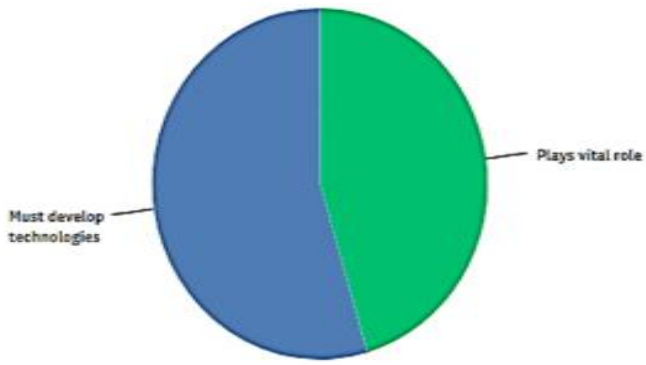
ANSWER CHOICES	RESPONSES
Citizen awareness	2.00%
Government initiatives	33.00%
Establishment of waste cycle yards	12.00%
Proper Environment laws to be framed	12.00%
Use of technologies in waste cycle yards	2.00%
All of the Above	39.00%
TOTAL	

Figure 16 Awareness Initiatives



ANSWER CHOICES	RESPONSES
Government	37.00%
Private companies who are earning	6.00%
General public	6.00%
1,2 & 3 equal part	38.00%
1 & 2 Major Part and 3 implementation part	13.00%
TOTAL	

Figure 17 Initiatives Opinion



ANSWER CHOICES	RESPONSES
Plays vital role	45.45%
Must develop technologies	54.55%
TOTAL	

Figure 19 Present and future role of technology

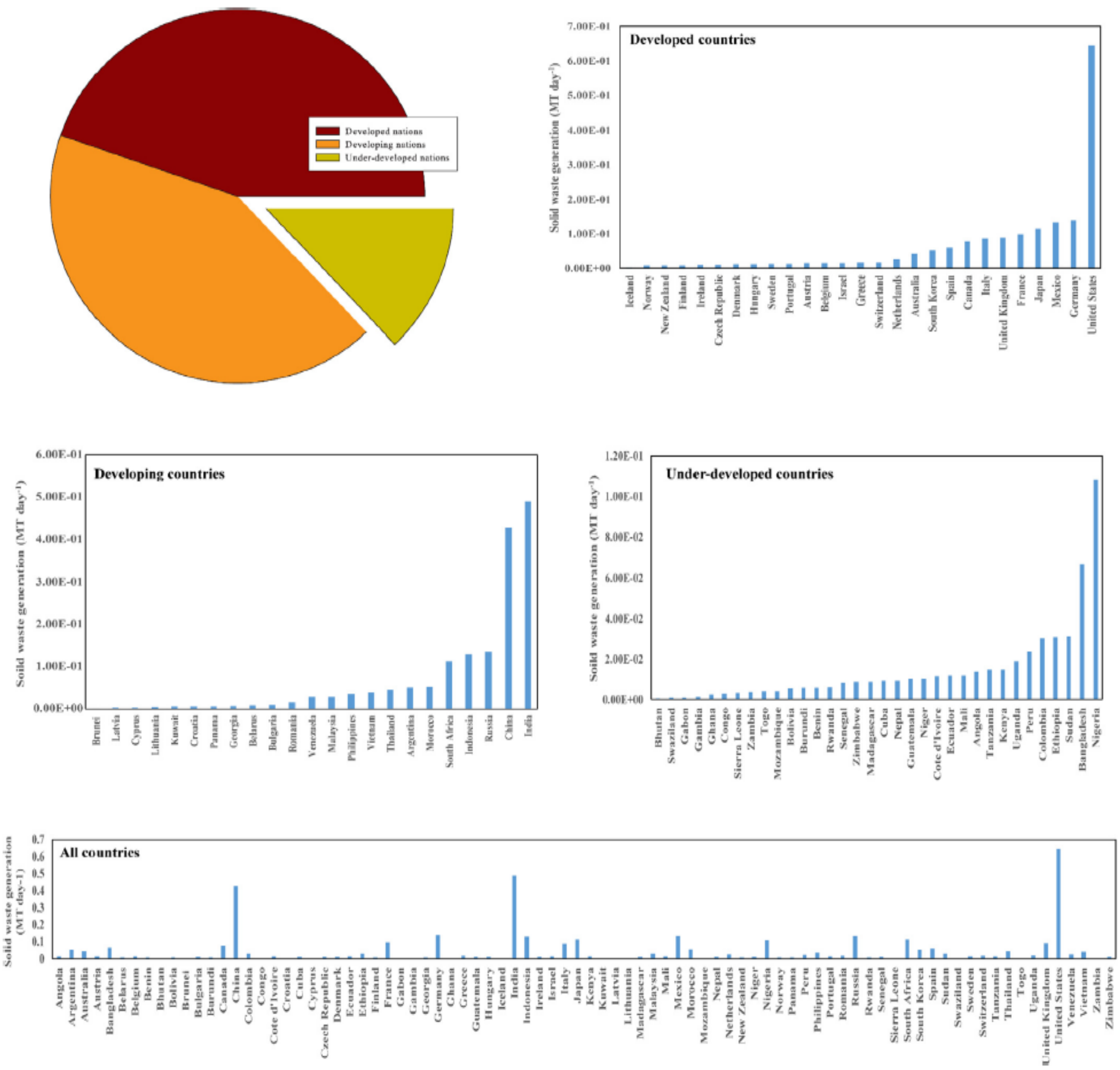


Figure 18 Waste generation in developed, developing, and under-developed countries

Order	Regions	Countries included	Countries not included	Urban population (millions)	Waste generation per capita (kg capita^{-1} day^{-1})			Reference
					Lower boundary	Upper boundary	Mean	
1	Africa (AFR)	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe	Algeria, Djibouti, Egypt, Equatorial Guinea, Guinea-Bissau, Libya, Mali, Mauritania, Mauritius, Morocco, Somalia, South Sudan, Tunisia	261	0.09	3	1.55	Hoornweg and Bhada-Tata (2012)
2	East Asia and Pacific (EAP)	Brunei Darussalam, Cambodia, China, Fiji, Hong Kong, Indonesia, Lao PDR, Macao, Malaysia, Marshall Islands, Mongolia, Myanmar, Philippines, Singapore, Solomon Islands, Thailand, Tonga, Vanuatu, Vietnam	Australia, Bangladesh, Bhutan, British Indian Ocean Territory, India, Japan, Maldives, North Korea, Pakistan, Papua New Guinea, Sri Lanka, South Korea, Taiwan, Timor-Leste	777	0.22	4.3	2.26	
3	Eastern Europe and Central Asia (ECA)	Albania, Armenia, Belarus, Bulgaria, Croatia, Cyprus, Estonia, Georgia, Latvia, Lithuania, Macedonia, Poland, Romania, Russia, Serbia, Slovenia, Tajikistan, Turkey, Turkmenistan	Czech Republic, Hungary, Kazakhstan, Kyrgyzstan, Moldova, Slovakia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan	227	0.68	1.81	1.25	
4	Latin America and the Caribbean (LAC)	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela	Nil	400	0.49	5.5	3	
5	Middle East and North Africa (MENA)	Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank and Gaza	Libya, Sudan, West Sahara, Yemen	162	0.16	5.7	2.93	
6	Organization for the economic co-operation and development (OECD)	Andorra, Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States	Chile, Estonia, Israel, Latvia, Lithuania, Mexico, Poland, Slovenia, Turkey	729	0.85	2.13	1.49	
7	South Asia (SAR)	Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka	Afghanistan	426	0.32	2.8	1.56	

Figure 19 Summary of the per capita waste generation worldwide

Chapter 6 Conclusion

To sum up, Riyadh's existing waste management system has four significant issues, which are as follows: a route for collection as detailed in this review, solid waste output significantly differs by nation, and the composition of solid waste is strongly correlated with economic level. All currently used solid waste management systems were evaluated in this research. This research also highlighted the value of using various low-cost management approaches, such as composting and vermicomposting. This study looked closely at a range of economic evaluation methodologies for a scenario including solid waste management. In light of the foregoing, it is clear that solid waste management paths should be assessed based on their long-term economic viability; doing so would enable managers to successfully manage solid wastes of ever-increasing volume with more flexibility. The concepts like investment in the solid waste sector could also be regarded as a positive step towards sustainable waste management worldwide. On the other hand, incentives, as well as taxes/levies, may be imposed by the Governments and local bodies depending on the socio-economic strata, although the success of this polluters-pay concept is yet questionable, exposed bins, lack of data collection, and material sorting.

Following a thorough investigation into previous success stories from cities including Barcelona, Philadelphia, New York, and others, several solutions were gathered, the solutions were assessed from various angles, and three scenarios—a pneumatic chute, IoT-enabled waste bins, and IoT Enabled waste bins in conjunction with off-site sorting plants—were selected.

If there is sufficient funding, it is advised to develop an IoT Enabled Solution with Off-Site Sorting; otherwise, it is advised to first implement IoT Enabled Bins before implementing the Off-Site Sorting Plan. It is crucial to recognize the obstacles Riyadh would have while putting these scenarios into action, including the initial investment, infrastructural interruption, the availability of technology resources, and community engagement.

Challenges and Suggestions:

These are the challenges and suggestions that we need to keep in mind to make a successful system.

1. The initial investment: Any system implemented country-wide or even in a major city will require millions of SAR investment. The project must be approved by the Ministry of Finance and be embedded in the year's budget.
2. The infrastructure: solutions like pneumatic chutes might require dismantling public or even private properties and infrastructure. Implementing in a developed city will require regroups planning and approvals before the start of actual work. It can pose some great challenges operationally. It can even disrupt traffic flows at a time.
3. The technological resources: to implement and maintain an IoT-based solution, training local resources for maintenance will be required. Investment in technology will be inevitable, and the cost of servers, networking, etc., will be high.
4. Community engagement: any system can fail if the community doesn't do its part. The masses must be educated to play their part in waste management as they are the source.
5. Waste generation: Unexpectedly quickly, waste production is rising. Both countries with a higher population density and less developed nations share this. For instance, garbage production in India is at a crisis point, particularly in metropolitan areas. The main reason why people dispose of their trash improperly is a lack of environmental knowledge among the general public. The situation is not necessarily better in wealthy nations. High living standards and per capita income are linked to high

refusal rates, which produce enormous amounts of garbage. The duration of "trash in bins or on the roadside" is prolonged in impoverished and remote nations like Nigeria due to a lack of garbage disposal facilities. In these situations, installing in-house recycling technology and educating the populace to make less trash must be the most effective methods for reducing waste.

6. Waste collection: Waste disposal by the side of the road or in other public areas is a widespread practice in many nations. In this situation, garbage is collected by street sweeping, which is problematic in and of itself because most of these workers are inexperienced rag-pickers. The regularity of sweeping and garbage towing is closely tied to a nation's economic situation. For instance, sweeping frequency varied between Guwahati, India, and Tokyo, Japan, being once daily in Guwahati and twice weekly in Tokyo. Extended trash retention in public spaces should be considered a health threat.

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