Smart Solid Waste Management Solution
Case Study: East Mansoura District

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Abstract

Recently, the transformation of existing cities into smart cities has become an urgent necessity to solve urban problems by linking the dimensions of sustainability with information and communication technology to enhance the quality of life. The current research problem lies in the rapid increase in urban population growth, the increase in resource consumption over the past few decades, and the increase in migration rates from the countryside and neighboring villages to urban cities, which lead to an increase in the problem of solid waste management. Conventional waste management systems are not equipped to handle the excess waste generated by a growing population. To help bridge the gap, societies need to adopt smart waste management solutions that increase efficiency and reduce collection costs. Hence, transforming the solid waste management system into a Smart solid waste management system has become an urgent need for solid waste collection and treatment to achieve the Sustainable Development Goals (SDGs), especially in developing countries. Therefore, the study adopts examining the performance of East Mansoura city as a case study in the field of solid waste collection and treatment. To achieve the objective of this study, the key performance indicators for smart sustainable cities KPIs for SSC that were developed by the ITU and related to the collection and treatment of solid waste were adopted to measure and evaluate the current situation for the selected case study. Finally, an action plan was proposed to transform the waste management system in East Mansoura into a smart waste management system.

Keywords: Smart Cities; Smart solid waste; Solid Waste Collection; Solid Waste treatment

1. Introduction

Increasing migration from rural to urban areas is a challenge for countries. The most predicted urban growth will occur in developing countries. Consequently, these countries will face numerous difficulties in satisfying the needs of their expanding urban populations. [1] Thus, experts predict that by 2050, nearly 70% of the world's population will live in metropolitan regions. [2] As a result of growing urbanization and urban population, cities are responsible for emerging environmental issues such as solid waste management. [3]

The issue of environmental protection is gaining more attention as a result of numerous significant laws and rulings pertaining to the Egyptian environment, the most significant of which is Law No. 4 of 1994, a comprehensive law for Egypt's environment, and the amendments made to the previous law in March 2007. In accordance with international guidelines that state that the right to a clean

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environment is at the core of a citizen's fundamental rights, Article 59 specifies that conserving the environment is a national duty and that the law governs the steps that must be taken to maintain the environment. [4] Egypt's population and nation face major health and environmental issues as a result of improper waste disposal. Both the government and civil society are now paying more attention to this problem and potential remedies. Recycling efforts are ongoing and expanding across the nation however, most of these actors are unofficial or private, and government actions are required to administer these systems effectively and supply them with sufficient funding. [5]

The research problem: The research problem lies in the increase in solid waste generated in East Mansoura district with the absence of smart solid waste management, which led to an increase in the environmental problem in the city.

The research goal: The research aims to solve the solid waste management problems in East Mansoura district which is considered an administrative district of Mansoura. The city can benefit from smart solid waste technology to find solutions to solid waste problems.:

The research questions: How can the smart solid waste management solution solve the solid waste problem in East Mansoura district?

2. Methodology:

In this research, a consequence methodology was followed to achieve the goal, and it is represented in figure 1.

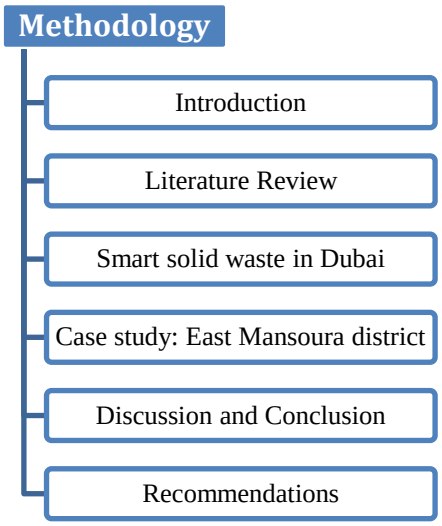

Figure 1: Methodology of the paper

3. Literature Review:

A. Smart Cities:

The term originated from the "Smart Growth" movement, which promotes new urban planning policies, around the end of the 1990s. [6]. The term "smart city" spread as an "urban labeling" phenomenon in the early years of the new century. [7]. The term was taken up in the mid-2000s by some technology companies such as IBM, Siemens, and Cisco to integrate information systems into listed city infrastructure and services such as buildings, transport systems, infrastructure electricity, water and sanitation, security, health, and utilities. [6]

ITU and the United Nations Economic Commission for Europe (UNECE) (2015) have described smart sustainable cities as innovative cities that use ICTs and other means to achieve a very quality of life, efficiency of urban operation and services, and competitiveness while making sure that it meets the needs of present and future generations with respect to economic, environmental, and social and cultural aspects.

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The transformation of smart cities requires an integrated framework based on the city's existing social, economic, organizational, and competitive assets. The development and functioning of a strategic framework contribute to an efficient allocation of resources and effective urban planning.[8] So, smart cities can be defined as cities that connect the physical infrastructure, the social infrastructure, and the business infrastructure with the information-technology infrastructure to effectiveness the collective intelligence of the city to improve quality of life, the efficiency of urban operations and services, and competitiveness through ensuring the needs of present and future generations.

B. Egypt's vision 2030: (The Ninth Pillar: environment):

The Arab Republic of Egypt has adopted Egypt Vision 2030,*1 which was launched on February 2016 by the Egyptian government and inspired by the ancient Egyptian civilization. [9]

The ninth pillar of Egypt's vision 2030 is an environment that is integrated with all economic sectors in order to preserve natural resources, promote their efficient use and investment, and protect the rights of future generations. A clean, safe, and healthy environment contributes to the diversification of production resources and economic activities, so enhancing competitiveness, creating new jobs, eradicating poverty, and attaining social justice. Egypt's Vision 2030 aims to maintain the balance of ecosystems and biodiversity and sustainable management of them through the development of a waste management system. One of the objectives of the sustainable development strategy and Egypt's Vision 2030 is to reduce pollution and integrated waste management while maximizing the utilization of natural resources through smart waste management which supports environmental, economic, and social development to provide a clean, healthy, and safe environment.

Egypt's Vision 2030 aims to raise the efficiency of waste collection and transportation operations to reach 80%, by 2030, and raise recycling efficiency to 25%, in order to achieve the goals of the sustainable development strategy. [9]

C. The vision of Mansoura: (Environment sector):

Mansoura is a city in the Delta region that is situated in the Dakahlia Governorate and in a semi-central location. [10] Mansoura's vision for 2007–2027 is based on an analysis of the city's current situation in terms of its strengths and development opportunities, particularly emphasizing the city's competitiveness and community involvement.

The city established aims to assist realize this vision. In the environmental sector, the Objective is done through:

- Making Mansoura a clean, pollution-free, and environmentally safe city.
- Solving a solid waste problem.
- Solve the problem of demolition waste.

D. Smart solid waste management:

Smart waste management is an innovative approach to handling and collecting waste. [11] Although the production of waste is increasing, especially in developing countries, thanks to the modern technical system known as the "Internet of Things"; Many waste management companies are installing an ultrasonic sensor to measure the level of fullness in a container and periodically send data through 2G/3G or LP-WAN networks to a remote internet platform, where the data is processed and forecasts are made. Upon reaching the surface level, the waves are reflected back to the sensor with a reading similar to the echolocation process. The container sensor can also measure temperature, GPS coordinates, and angular directions to locate the container. Characteristics also include waste collection history, status in terms of overloading, response time, fire incidents, alarms, and errors in recording processes. The advantages of the smart waste collection system are: [12]

- Enables waste management companies to increase their operational efficiency by up to 50%
- This achieves a lower environmental footprint and therefore a cleaner environment.

*1 "By 2030, the new Egypt will achieve a competitive, balanced, diversified and knowledge-based economy, characterized by justice, social integration and participation, with a balanced and diversified ecosystem, benefiting from its strategic location and human capital to achieve sustainable development for a better life to all Egyptians"

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- Users can also come up with a disposable insight into waste collection performance, efficiency, waste generation, and load times to help them understand their operations and point out areas for improvement.
- Reducing the volume of collection vehicle movements and waste collection operations, which leads to savings in fuel, labor, and fleet management costs.
- Contribute to the decision-making process based on smart data, reduce carbon dioxide emissions and noise levels, maintain clean public places, and get rid of the increased loads in waste containers.
- Minimizing the risks to waste collection personnel during waste collection and handling
- Combined waste with solar panels helps measure fullness and waste pressure and effectively increases container capacity up to 8-6 times. The container that was used to accommodate only 100 liters of garbage has suddenly become a capacity of 800 liters, which allows the most congested areas of traffic to reduce the number of waste collection times and to overcome the problem of increased loads of waste containers.
- The solar energy is stored in non-rechargeable batteries which enable the compressor to operate through a standalone system without any external wires.

4. Smart solid waste in Dubai

Dubai Municipality continues to meet and exceed the demands of society for high-quality, efficient and, effective waste management services. [13] The strategic vision of the Dubai Municipality is to achieve the ultimate goal of 'zero waste to landfill'. By 2021, the emirate must divert 75% of its garbage from landfills. There are programs to motivate locals to engage in recycling efforts for a more environmentally friendly future. [14] They used the garbage-collecting methods depicted in figure 2. Dubai provides 100% regular solid trash collection services.

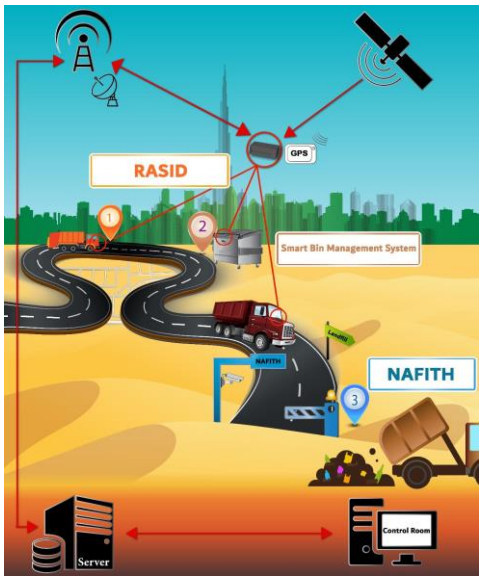

Figure 2: Smart solid waste management systems

A. Dubai Smart solid waste collecting techniques

1) Bigbelly Waste Containers

Bigbelly is a garbage receptacle (bin) that runs entirely on solar energy as seen in figure 3. Bigbelly has a compaction capability, allowing it to contain six to eight times as much trash as the typical street bin. When the garbage fills the bin to a particular level, the volume sensors embedded in the bin start the compaction process. Each Bigbelly station has a geotag, which enables CLEAN (Management Software) to track the effectiveness of the bins based on where they are. When the bins get close to being full, the sensor also alerts headquarters. The bigbelly increases the efficiency of the Dubai Municipality fleet by significantly increasing collection at once, using less fuel because of fewer journeys, and minimizing labor and equipment exploitation. [13]

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Figure 3: Bigbelly waste container

Dubai is one of the most recent cities to implement Bigbelly's world-leading smart waste and recycling management technology. The Bigbelly system features a completely contained design to remove waste, sustainable technology that decreases Dubai's environmental footpint, and a recycling stream for quick waste separation on-the-go. The Waste Management Department of Dubai Municipality has deployed 100 eco-friendly smart containers for waste storage along both sides of Sheikh Zayed Road as a first step to promote waste separation and boost the effectiveness of recycling programs in the area. Additionally, the revolutionary containers include two separate holes, one for general waste and the other for recyclable materials such as glass, packaging, plastic, paper, etc. [15] They are also distributed in the commercial centers as shown in figure 4.

Figure 4: Segregation in commercial centers

2) Vehicle Tracking System (RASID)

RASID's is a tool to monitor, report and eliminate trespassers. It has flexibility, strength, stability, and continuous uninterrupted performance. [13] With the installation of a GPS tracking system, Smart Gate, and RFID, the Dubai Municipality intends to severely reduce the amount of waste that is disposed of in landfills and ensure that enterprises adopt a variety of recycling options. The department has mandated that all waste transport companies install GPS tracking systems in their vehicles so that authorities may monitor their travels and determine how much waste is being transferred to landfills [14]. Figure 5 shows Rashid- waste management map available in website of government of Dubai.

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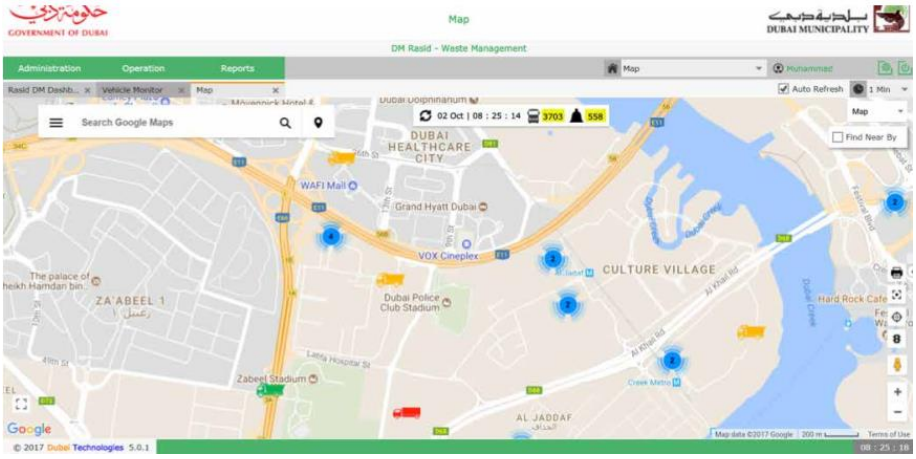

Figure 5: Rashid- waste management map

3) Smart Gate System (Nafith)

At landfill sites run by the Dubai Municipality, the Smart Gate System (Nafith) is a completely automated access management system. Vehicle admission to sites is controlled using integrated software, Automatic Number Plate Recognition (ANPR), and Radio Frequency Identification technology (RFID). The effort will shorten the time required for vehicle entrance, which will cut emissions and boost efficiency. Human error will also be completely eliminated because all information will be automated [13].

4) Underground Waste Compactors

An innovative solution to the problem of trash disposal in crowded and active public spaces is the subsurface garbage collecting system as shown in figure 6. The technique recovers important area that would otherwise be taken up by communal dumpsters with just one giant bin buried under the surface. The system contains a compacting mechanism that increases storage capacity, gets rid of smells, shields the equipment from vandalism, and improves the aesthetics of the region. The underground waste compactors were installed in various strategic locations all around Dubai [13].

Figure 6: Underground Waste Compactors

B. Dubai Smart solid waste treatment techniques.

1) Smart Sustainability Oasis

The smart sustainability oasis is Dubai's innovative recycling center. It is a solar-powered, self-sufficient recycling facility with integrated sensors and CCTV cameras that connect directly to

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headquarters as shown in figure 7. With 13 centers strategically placed in the city, as shown in figure 8, The Dubai Municipality seeks to encourage the public to utilize these facilities for recycling as opposed to discarding recyclables. It is expected that this initiative will enhance recycling in the Emirate, hence decreasing the amount of waste disposed of in landfills [13]. The first center to be opened was a smart recycling center at Al Manara Center, while the second was placed in Karama. The whole project is green. The recycling stations have been made from recycled containers and are outfitted with numerous cutting-edge technologies, such as solar panels that conserve energy and smart relaying sensors embedded in the recycling bins. When the bins are nearly full, the responsible waste management company collects the recyclables from the recycling centers [14].

Figure 7: Smart recycling center in Dubai

Figure 8: Smart recycling center places in Dubai

5. Case study: East Mansoura district

The city of Mansoura is the capital of Dakahlia Governorate. It is one of the most important urban gatherings dense with health services in Egypt in general and the Delta region in particular. The city of Mansoura provides an example of a medium-sized Egyptian city that suffer from many urban problems. Solid waste management is one of these problems which are similar to most cities throughout the Republic, and therefore the absence of a sustainable urban environment. The city of Mansoura consists of two district which are East Mansoura district, and West Mansoura district. Figure 9 shows the map of East Mansoura district and the Main streets in the district.

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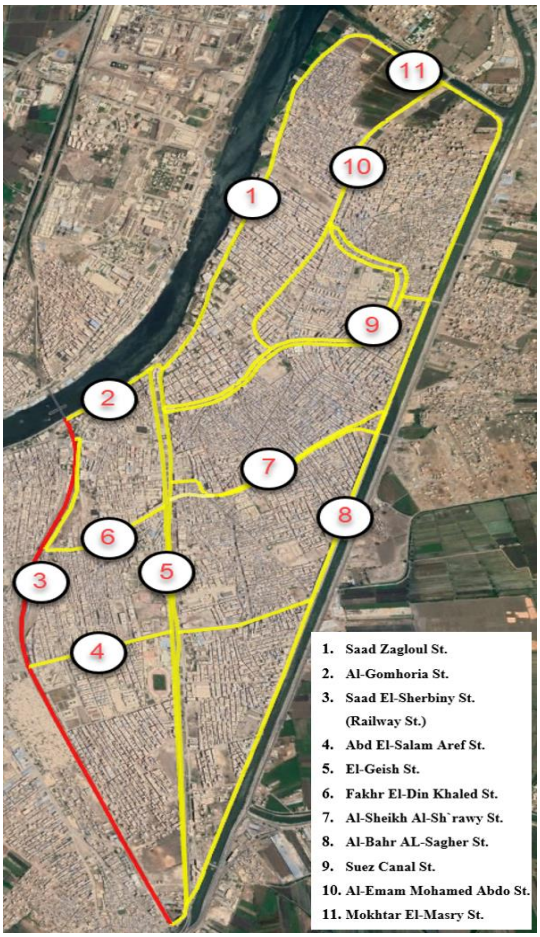

Figure 9: Main streets in East Mansoura district

A. Solid Waste Collection (SWC) in east Mansoura district.

Solid waste management is one of the most important problems facing environmental management in the district. Its danger derives from:

- The huge volume of waste and its increase year after year.
- The increase in the practices of random dumping of solid waste on roads or on both sides of canals and drains. As shown in figure 10.
- The absence of alternative solutions and acceptable management of solid waste.

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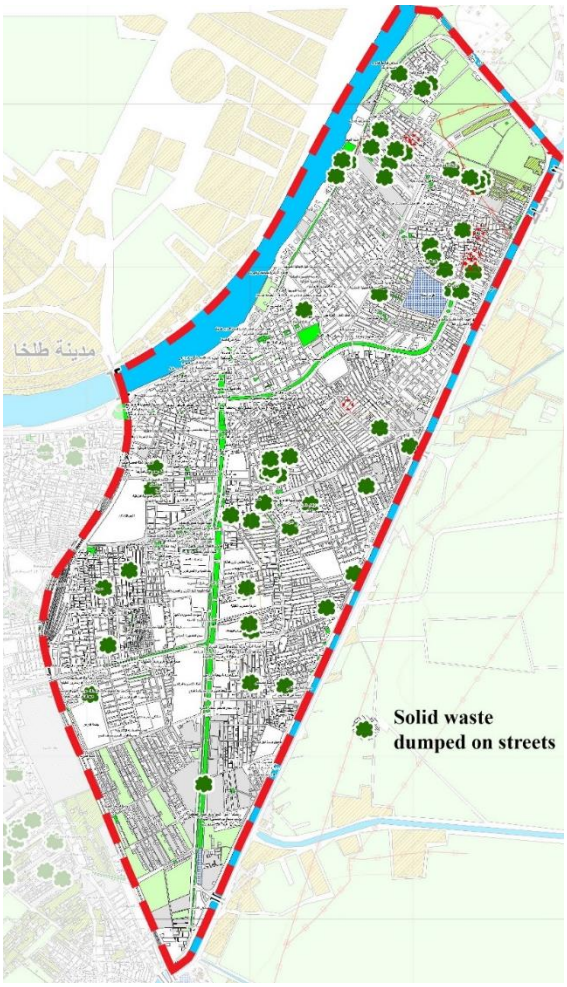

Figure 10: Solid waste dumping on streets

The local administration collects the waste from the garbage bins distributed in the main areas, from the streets, public squares, shops, and stores then dispose of it in the Sandoub garbage dump, in which the height of the garbage reaches more than 40 meters on an area of 8 acres of the finest agricultural land. [16]

The most important obstacles to providing this service are:

- The lack of employment due to low wages.
- The lack of necessary equipment or the end of its lifespan.
- The lack of financial support and reluctance to invest in solid waste management.
- Lack of environmental awareness of the population.
- Lack of cooperation of the people with the municipality in keeping the streets clean.
- The inability of poor citizens to pay for participation in the waste collection project.
- The lack interest in the garbage collectors in slums areas, where the waste does not constitute a resource for recyclable materials.
- The spread of demolition and construction waste on roads and vacant lands and on the Mansourieh Canal, due to the high cost of transportation outside, as the nearest dump is about 60 km away from Mansoura city. Since these wastes are not household waste, they cannot be transported to the Sandoub dump in Mansoura. As shown in figure 11.

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Figure 11: The spread of demolition and construction waste on roads

$$SWC = \frac{Number\ of\ city\ households\ that\ are\ served\ by\ solid\ waste\ collection}{Total\ number\ of\ city\ households} \times 100 \quad (1)$$

$$SWC = \frac{31512}{62705} \times 100 = 50.25\%$$

By measuring the current citation East Mansoura district in solid waste collection indicator using KPIs for SSC, it was found that the percentage of households that are served by solid waste collection reached 50.25%, while the rest of the households dispose of waste by throwing it in the streets or burning it. So, it is recommended to provide a solid waste collection service for all households and transform the solid waste collection system into a smart solid waste collection system. Figure 12 presented a proposed smart solid waste collection system map of East Mansoura district.

As a result of studying the current situation of the district, it was found that:

- There are no garbage dumps, solid waste recycling factories, solid waste incinerators, and sanitary landfills with the meaning and technical and environmental standards due to the absence of a desert back and the surrounding of the Nile River and agricultural lands with the urban mass.
- A sanitary landfill is under construction in Kalabshaw in Belqas, which will serve the entire governorate.
- There is one cleaning company in the district with one equipment, the efforts of the localities serve the district with 24 equipments, and the cleaning associations serve it with 2 equipments, which is not enough to serve the entire district.

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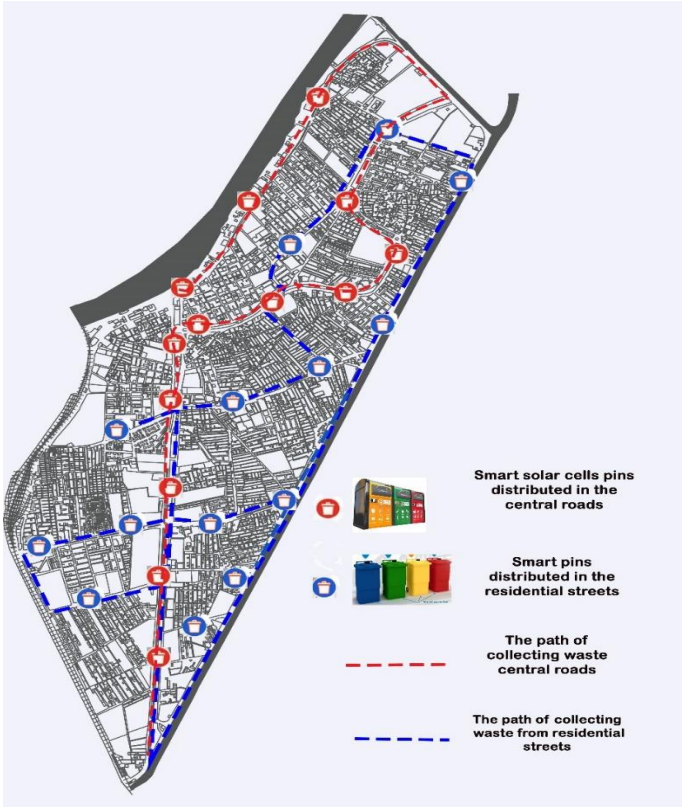

Figure 12: Proposed smart solid waste system map of East Mansoura district

B. Solid Waste Treatment (SWT)

Solid waste is sorted by garbage collectors and they separate paper, cardboard, plastic, metal, glass, and fabrics to sell them. Part of the waste is recycled in Sandob recycling factories, which contain two production lines, but these factories do not accommodate the amount of garbage produced, which leads to:

- The accumulation of garbage in the landfill.
- The presence of stray animals and insects.
- The outbreak of self-fire and air pollution.

$$SWT = \frac{Total\ amount\ of\ solid\ waste\ that\ is\ (disposed\ to\ landfills, incinerated, burnt\ in\ an\ open\ area, disposed\ in\ an\ open\ dump, other, recycled)\ (ton)}{Total\ amount\ of\ solid\ waste\ produced\ (ton)} \times 100 \quad (2)$$

Table 1: Measuring solid waste treatment method in East Mansoura district using KPIs for SSC

Solid Waste Treatment method	The percentage of solid waste
Disposed to landfills	65.92 ÷87.55× 100= 75.3 %
Incinerated	no data available
Burnt in an open area	3.1518÷87.55× 100= 3.6 %
Disposed in an open dump	17.12 ÷87.55× 100= 19.55 %
Recycled	1.36 ÷87.55× 100= 1.55 %

By measuring the current citation East Mansoura district in solid waste treatment indicator using KPIs for SSC as shown in table 1, it was found that the district suffers from random waste disposal, as well as solid waste collection and recycling operations, and a large number of scrapers. Recycling is carried out in unofficial and unlicensed places. Figure 13 shows an analysis of the measurement results of Solid Waste Treatment Indicators. Therefore, it is recommended that the city develop its recycling

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capacity and solid waste collecting techniques and transform the solid waste treatment system into a smart solid waste treatment system.

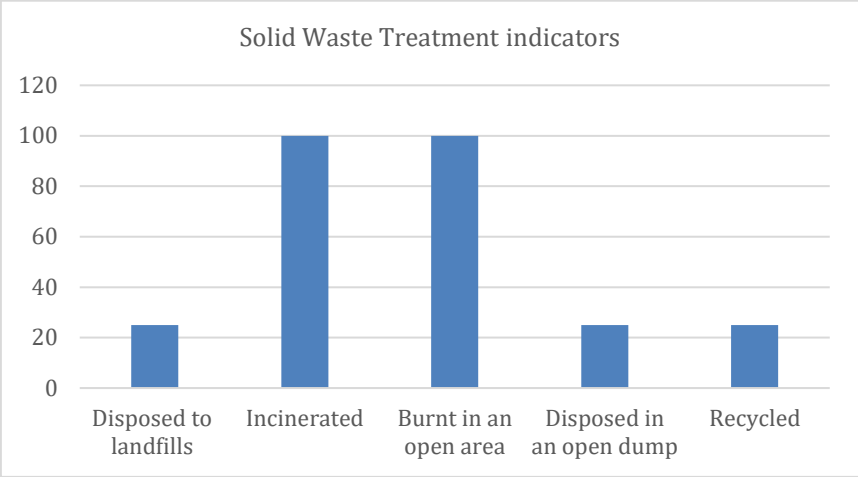

Figure 3: Analysis of the measurement results of Solid Waste Treatment indicators

6. Discussion and Conclusion

By examining the current situation of East Mansoura district city in solid waste collection and solid waste collection treatment and measuring it using KPIs for SSC. the study identified that the district has shortcomings in solid waste collection and solid waste treatment systems so, the study proposes the following action plans as shown in Table 2:

Table 2: Proposed action plan

Category	Indicator	Result		Proposed action plan
Waste	Solid Waste Collection	50.25%		• Increasing the percentage of households served by solid waste collection to be transferred to public landfills, and then transferred to sanitary landfills. • Appling smart solid waste collection system in the district.
	Solid Waste Treatment	landfills	75.3 %	• Increase the number of associations and hygiene companies in the governorate through the efforts of officials, self-efforts, and the provision of the required resources. • Recycling solid waste generated waste at structured facilities. • Increasing investments in recycling infrastructure, techniques, and equipment. • Increased public recycling participation awareness • Providing sufficient means of solid waste transportation to landfills. • Modifications made to waste collection and separation technology to facilitate recycling. • Evaluating recycling markets and determining solid waste pricing levels. • Instruction in the use of smart recycling processes that incorporate information and communication technologies, as well as the creation of a sustainable waste management system. • Enhancing the district's ability to recycle.
		Incinerated	0 %	
		Burnt in an open area	3.6 %	
		open dump	19.55 %	
		Recycled	1.55 %	

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7. Recommendations

To enable the action plan to be applicable to the case study and, therefore, to all cities of the Arab Republic of Egypt, the study recommends the following:

Solid waste collection:

- Increasing the percentage of households served by solid waste collection to be transferred to public landfills, and then transferred to sanitary landfills.
- Appling smart solid waste collection system in the district.

Solid Waste Treatment:

- Increase the number of associations and hygiene companies in the governorate through the efforts of officials, self-efforts, and the provision of the required resources.
- Recycling solid waste generated waste at structured facilities.
- Increasing investments in recycling infrastructure, techniques, and equipment.
- Increased public recycling participation awareness
- Providing sufficient means of solid waste transportation to landfills.
- Modifications made to waste collection and separation technology to facilitate recycling.
- Evaluating recycling markets and determining solid waste pricing levels.
- Instruction in the use of smart recycling processes that incorporate information and communication technologies, as well as the creation of a sustainable waste management system.
- Enhancing the district's ability to recycle.

8. General Recommendations

- The utilization of smart city applications to solve all urban problems in developing countries' cities.
- Involvement of the public and private sectors, as well as all relevant decision-makers in the governorate and the nation, to promote a successful transformation.
- Directions of researchers in the field of SSC on how to utilize their trends and ideas for community service.

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- **Conflicts of Interest:** "The authors declare no conflict of interest."

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