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Artificial Intelligence-Based Waste Management Prototype Model for Egyptian Urban Neighborhoods

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ABSTRACT: Industrialization has led to many of the city's current environmental problems, Waste management is one of the primary problems that the world faces regardless of whether the case is of a developed or developing country. The key issue of waste management is that the waste bins in public places get overflowed well in advance before the commencement of the next collection process. As the Fourth Industrial Revolution gathers pace, innovations are becoming faster, more efficient, and more widely accessible than ever before.

As the world was being developed, with cities being smarter through the IOT, smart grids, etc., we find ourselves living with the general AI which potentially can meet the intelligence of the human brain. We can restore our environment through a holistic equilibrium of a framework, harnessing this fourth revolution "AI" to save cities. This Thesis aims to understand the use of machine learning and Internet of Things, and find its application for the most potential areas and ultimately replace human interaction from urban neighborhoods to achieve an optimal quality of life. A case study on Kafr Abdou Neighborhood, Alexandria is conducted on the implementation of this technological approach and its synergies on waste management to a designed real time integrated model for waste management model.

KEYWORDS: Urban waste management, Artificial intelligent, Internet of things, machine learning, real-time.

I. INTRODUCTION

With the rise of the population density, waste management becomes a key factor to the urban quality of life. Given the frequency of integrating new technologies into our daily lives, waste management systems gain the potential of great improvement. Many of the present environmental problems in our urban built environment are the result of industrialization.

Climate change, hazardous levels of air pollution, poisons in rivers and soils, wastes spilling on land and in the ocean, biodiversity loss, and deforestation are all linked to industrialization [1]. Through an understanding and imagination of the world's progress over the last 10 decades in comparison to thousands of years in the past, which could also be measured in terms of global Industrialization revolutions.

Currently, waste stream collection in and around cities contributes to high levels of air pollution due to ineffective collection processes: container placement, decision-making, collection duration, sorting, and segregation; all of which have a detrimental impact on the health of millions of people all over the world. Such environmental conditioning has a direct and qualitative effect on the efficacy of the urban fabric in terms of comfort, health, and vehicular circulation. Furthermore, since the world's population grows at a rapid rate. The use of resources for material goods is increasing at an exponential rate. As a result, we must urgently reconsider how we dispose of and collect waste in metropolitan areas.

This paper will attempt to propose a smart waste collection model for waste management and offer analytical insights applicable for this model, for the neighborhood of Kafr Abdou which is a prototypical Alexandrian neighborhood. Meaning that should this model prove effective on Kafr Abdou, the same will apply to most of the Alexandrian urban fabric.

II. METHODOLOGY

To achieve the study aim and objectives, methodology of the paper will rely on inductive and deductive reasoning for collecting and managing the data of the waste stream on the urban scale and artificial intelligence applications.

- Study and analyze the obstacles that will face the future of the city, aligning with the current status of the urban waste management problems.

- Carry an extensive literature review on the waste management situation faced by the city, the opportunity of harnessing future technology of Artificial intelligence - AI to face these obstacles and problems.
- Comparative analytical examples; the research used the analytical methodology to analyze different relevant examples to emphasize the principles needed to develop urban spaces in the point of managing smart urban waste stream data.
- Follows examples which are implemented by other countries to face the threats and offers an explanation of the use of AI Technology that serve thesis vision.
- Highlights the limitations and challenges that, considering most applicative opportunities to a theoretical framework, a smart urban waste collection process faces to put the outcomes on classifications and predictions.
- Apply a real-time, integrated, adaptive computerized smart urban waste management hierarchical model for urban NH - KAFR ABDO based on computer vision of artificial intelligence to the optimal decision taken for human wellbeing.

The research used the field methodology to apply the derived principles and guidelines for urban waste management in Kafr Abdou, Alexandria, Egypt as an application for the literature review and analysis.

III. DISCUSSION ON GENERAL WASTE MANAGEMEN

Waste is well managed when management is fully and sustainably planned to prevent, limit and minimize physical and managed impacts on health, environment, economy and aesthetics. All while also involving technical knowledge, within a legal framework, sufficient financial resources, and equipment and facility infrastructure, and taking into account the participation of the public and other stakeholders, as well as the socio-cultural aspects of local people [2] [3] [4] [5].

Solid waste management is an important, but often ignored aspect of developing cities and urban spaces which are sustainable [6]. Upper-income countries generate the most urban solid waste (USW), amounting to 46% of total output, followed by low-middle-income countries accounting for 29%, high-middle-income countries with about 19%, and low-income countries with 6%.[7]. By 2050, as many of the population will live in cities as there were people in the entire globe in 2000, posing new waste disposal issues. Citizens and businesses will very certainly have to take on more responsibility for waste creation and disposal, particularly in terms of collocation process and waste separation [7].

According to Hoornweg and Bhada-Tata (2012), The amount of solid waste generated increases in direct proportion to the rate of economic development and urbanization. Residents of cities create almost two times as much waste as those in rural areas. There are positive correlations between per capita waste generated, development, and income in cities all over the world [8]. Higher-income nations create more than a third of global waste, more than double their population proportion. However, in low-income nations, the volume of waste has risen at a higher rate than in high-income countries.

Waste collection is an important step on the way to proper recovery or disposal. In many situations, the effectiveness of ecologically sound waste management is determined by how the collection process is arranged [9]. In cities, servicing is usually insufficient, with more than half of the waste generated going uncollected and huge sections of cities receiving no regular care. Local governments are typically responsible for providing solid waste management services, and a common and basic deficiency is governments' inability to guarantee that sufficient finances are available to provide an adequate level of service [4]. Waste collection is the point of interaction between waste generators and the waste management system, and it is critical that this connection be well handled if the system is to be functional [10]. The manner in which waste materials are collected (and then sorted) affects which waste management choices are available, including whether value-added procedures such as material recycling, biological treatment, or fuel combustion are economically and environmentally viable. [10].

Therefore, It is also essential to obtain data on waste management in order to understand how much solid waste is generated, and sort the wastes accordingly. This would help local governments to choose suitable management strategies and prepare for future urban needs. To battle the exponential growth in waste, land use influence on the waste collection must be acknowledged and considered. As the observations and studies show, the static system for waste management is inefficient, and policies must consider dynamic strategies.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 3, Issue 1, pp: 215-227 www.ijemh.com

IV. DISCUSSION ON THE EMPLOYMENT OF AI AND IOT

Waste management issues in smart cities mainly focus on designing new sensor-based Internet of Things (IoT) technology and optimizing the route of waste collection trucks to minimize transportation costs, operation, energy consumption and pollution emissions from traffic. In this chapter, the importance of value recovery from waste bins and the collocation process which is related to urban waste management (UWM) is highlighted. An optimization model based on urban waste management and technology to optimize the planning of waste collection operations by several studies (figure 1). The value of the collected waste is modeled as an uncertainty parameter to reflect the uncertain value that can be recovered from each bin due to the uncertain condition and quality of the waste. The concept of smart urban spaces is offering new opportunities for handling waste management practices. The chapter offers novel venues for incorporating the value recovery element into waste collection in urban planning and development of new data acquisition technologies that permit municipalities and decision makers to monitor the recyclables embedded in particular waste bins [14].

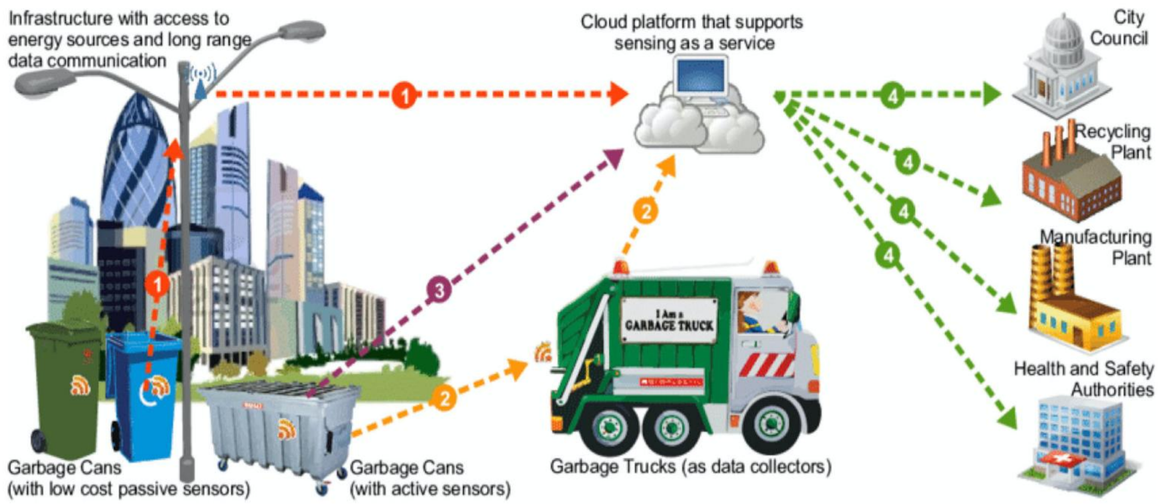

Fig 1: Internet of things-based smart waste management process [14].

As is previously mentioned, the rate of waste generation is increasing rapidly due to improving living standards, rapid urbanization and advanced economies; considering the general advancement of civilized society [11]. Effective waste management becomes very important to improve citizens' quality of life and minimize negative impacts on the environment. Waste management practices cover a variety of activities extending from waste collection, and waste separation to waste recovery and recycling. Many waste collection and recovery systems have been developed to efficiently manage a variation of types of waste. Information and communication technologies (ICT) offer fundamental benefits in solving waste management problems when integrated into the systems which are already in existing condition. A significant example would be the dynamic collection of waste made available by the capabilities offered by AI and IOT.

In recent years, waste collection was treated statically, but, as our understanding evolved, today dynamic solutions have been enabled by the production of newly developed sensors, as well as actuators and IoT technologies [12], where the bins can be equipped with plenty of IoT components and sensors such as capacity sensors, weight sensors, temperature sensors, humidity sensors, chemical sensors, pressure sensors and actuators [13]. This chapter will discuss literature review on optimization models to improve the recovery of waste collected in smart urban spaces. And how it developed a waste recovery function and an allocation model to simultaneously maximize waste recovery and minimize transport costs.

Deep learning and Internet of Things (IoT) respectively seek an intelligent solution for real-time data classification and monitoring. The proposed model is expected to provide an insightful method for classifying and sorting digestible and indigestible waste using complex neural networks (CNNs), a well-known learning technique. The

International Journal of Engineering, Management and Humanities (IJEMH)
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diagram also showcases an architectural design of smart waste bins using a microcontroller with multiple sensors. The proposed method uses IoT and Bluetooth connectivity for data monitoring. IoT enables real-time data monitoring from anywhere, while Bluetooth makes it easy to monitor data at close distances via an Android app.

Therefore, Cloud technology is an efficient means of communicating between certain platforms as well as objects. With the application of sensors and cameras, big data, valuable information can be stored and then later utilized. An online platform (dashboard) with its cloud-based capacity can offer potential methods of utilizing this data, via machine learning algorithms and such, to enhance the waste management process in an efficient manner. With such tools and considerations, the waste collection process would be able to dynamically account for the changes in the urban situation as well as be able to accurately make predictions and help decision making. This would enhance the efficiency of the collection process and provide data for an evolving process.

V. KAFR ABDOU CASE STUDY ANALYSIS

Kafr Abdou being considered as a mixed-use neighborhood located in Abo- El Nwater, Sharq District, Alexandria, Egypt; makes it a good opportunity to explore and study the different types of waste streams inside it through the different activities and diversity of land use. Abo Nwater population 25,269 with land area 1,137,500-meter square which includes high and low rise buildings, heritage sites, etc. [15].

Figure 2 illustrates the study area's geographical limits on a map which is situated with its north as Abu Quir Street, bordering south is the Railway line, its western front as Victor Emanouil street, and east is Mohamed Farid Street (Wingat Street). Its statistical overview can be summarized as follows:

- Study Area Population is 87% of Abo Nwater population which is equal to 21, 985.00 capita.
- Study zone land area is 75 % of Abo Nwater land area which is equal to 910,000 m2.

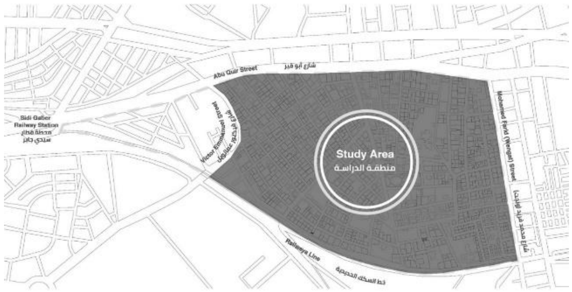

Fig 2: Map illustrating the study zone and its geographical limits

Kafr Abdou is a typical example of a mixed-use neighborhood, it has all kinds of interactions within its boundaries and shares similar urban characteristics to a typical Alexandria neighborhood, like narrow streets and formal and informal strategies for waste management. Gathering families from all ends of the economic income spectrum, from villas to highrise buildings to low-income households. These relate to reasons which can be summed up in the following points:

- Kafr Abdou possesses similarities of problems and waste management which are shared between typical Alexandrian neighborhoods, which makes it a prototypical subject.
- Kafr Abdou is a mixed-use neighborhood which influences the proposed considerations to be holistic.
- Studying and conducting observations of Kafr Abdou was a practical endeavor.
- The ambition for sustainability is driven and encouraged by the community of Kafr Abdou.
- Kafr Abdou has significant heritage and cultural backgrounds.
- There isn't enough available data regarding urban status and waste streams.

This case study highlights not only the urban planning aspect of the Kafr Abdou neighborhood but also the urban form, urban fabric, and synergies with waste management. After observation, it is found that there is an inefficient waste management system in the neighborhood and that it suffers from overflowing bins and imprecise collection habits.

Waste Stream Status in Egypt, Alexandria, and Kafr Abdou

In Egypt, urban solid waste management is considered to be continually challenging. An estimate of the population is about 102 million, as the Central Agency for Public Mobilization and Statistics (CAPMAS) calculates. It is also calculated that the municipal waste generation unit is within 0.4-1.0kg/capita day; around 21 million tons of

MSW (USW) and 60 million tons of solid wastes (urban, rural, industrial, agricultural, etc.) is generated yearly in Egypt, following 2014. With the statistical analysis, it is found that only 43% is handled by formal collection and 11% is operated by informal collection, leaving 46% of the MSW uncollected. This is an undesirable situation as far as the residential communities are concerned, as it is a dangerous condition for their health and the environment. This all comes to show that the MSWM system in Egypt is showcasing signs of inefficiency of operational capacities [16].

The traditional waste management in Egypt consists of a hierarchy of three. The first is the Ministry of Environment, then the Waste Management Regulatory Authority (WMRA), and then the National Solid Waste Management Program (NSWMP). The implementation of the strategies and programs are under the responsibility of the government between the environmental management unit and the SWM Unit to the contractors that implement these programs. The activity on these NSWMP programs and strategies began between 2013 - 2017 and they're under heavy governance; it is even expected that by 2030 the urban solid waste management will be collected by a 90% efficiency rate as it is stated by the Ministry of Environment's annual report of 2020.

In the case of Kafr Abdou, and despite being known as an elite and exclusive neighborhood, it suffers from inefficient waste management as is the case with most of Alexandria's residential neighborhoods. One of the residents' main problems about Kafr Abdou is the excess of waste and the lack of a proper waste management system to facilitate the waste collection process. Some of the elements that contributes to the inefficiency of the current waste management system are:

- Waste collecting vehicles find it difficult to navigate the narrow streets of Kafr Abdou.
- The lack of waste bins resulted in people going, by themselves, far distances to dispose of waste to the nearest waste bin in the main streets or asking local doormen to collect the waste daily with an agreed upon fees, which caused some doormen to demand higher prices or work on their own agreement.
- There are not enough waste drop-off or collection points for the neighborhood
- The existence of waste scavengers "Nappasheen", who cause a mess in waste collection points which leads to environmental problems and impacts the quality of life inside the neighborhood.

There are limited collection points attributed to the Kafr Abdou neighborhood, all of which are on the bordering lines. As for the collection routes, there are only two routes crossing inside the boundaries of Kafr Abdou. The problem highlighted is that the formal waste collection routes are very limited and much of the urban fabric is isolated from these formal collection points and their routes. This results in the appearance of messy informal strategies, in waste collection where the formal systems had failed to fix or reach. The two main systems, illustrated in figure 3, are the current collection systems, with formal through the government and informal through civil societies.

According to the study area observation, and tracking the waste stream inside Kafr Abdou, the diagram in figure 3 shows the collection model of the current status. Whereas the main dynamic problems in Kafr Abdou are outlined as the following:

- Informal systems of civil society are usually activated.
- Weak communication between authorities and neighborhood data (no real-time status).
- Current Waste stream is out of date based on human decisions (ad hoc approach).
- Lack of real status analysis and insights to face the waste collection, current and future.
- Failures with waste collection times, pick up times, and durations, related to street types and size (Traffic time - Route plans).
- Failure of determination of waste bins size and volume.
- Lack of any type of waste sorting and initial waste segregation related to neighborhood.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 3, Issue 1, pp: 215-227 www.ijemh.com

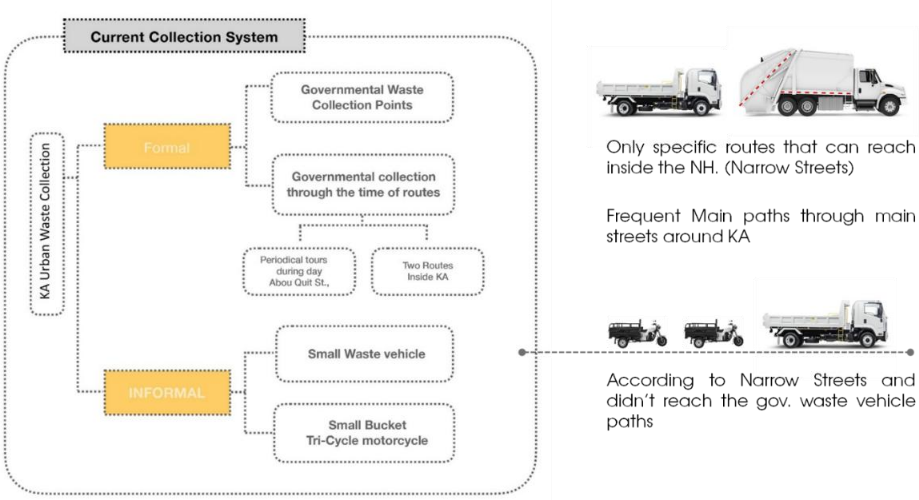

Fig 4: Waste Stream Map Illustration

General Urban Analysis of the Study Area

This part shows maps with filtered levels of information that deliver a basic idea of the urbanization system and its relation with urban waste management of the neighborhood, through an understanding of the spatial relationships of built-up areas It is important to provide analytical maps concerning the study area, in order to assess urban relations to the waste stream data. These analytical maps are urban studies conducted for a good overview of the study area and to help with understanding the field situation better. Understanding these and relating them to the big data is a critical step in conceptualizing the framework for efficient waste management. The main analytic study maps are the following:

- Waste Stream Map
- Traffic and Transportation Map
- Population Density Map
- Building Heights Map
- Land Use Map

Waste stream Map

Understanding the waste stream and its relation to the urban fabric of Kafr Abdou is perhaps one of the most essential aspects of this study. It is imperative to have a good understanding of the collection routes and waste collection points, as they are the main influences on the waste collection process. Following rigorous investigation and observation, a clear outline of the situation was prepared in the illustrations. As one can see from figure 4, there are 7 main fixed formal collection points which pertain to the main roads of Kafr Abdo. Three along Abo Quir St. bordering Kafr Abdo, three along Mohamed Farid St. and one on the street adjacent to the railway line inside Kafr Abdou boundaries, which is the one that can be seen in figure 5.

As is shown in the picture of figure 5, poor collection resulted in an unclean condition of the street and curb, and polluted the surrounding atmosphere, a direct impact on the urban quality of life.

Fig 5: Railway line fixed collection point

The orange points illustrated represent the pavement collection points (Waste on ground as shown in figure 6, which are the result of waste transferers' -usually doormen- designated general location (street intersections), placing the waste along the formal collection route of the waste collecting vehicles. These points are often unsanitary and repulsive as they sometimes leave dirt marks on the pavement, negatively affecting the urban quality of life. The gray lines represent the usual route of the formal waste collecting vehicles of the government, whereas the dotted blue lines represent detours upon the request of the residents in the area or complaints. The rest of the streets are generally too narrow that the formal waste

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 3, Issue 1, pp: 215-227 www.ijemh.com

collection vehicles find it difficult to navigate and seldom do they cross them as per observation.

Fig 6: Pavement collection point

Fig 7: Bucket Tricycle picking waste

Generally, when the collection vehicles are inefficient, informal waste collection options get to work. Where informal vehicles such as pickup trucks and Bucket Tricycles where waste pickers collect the waste from inside the buildings and transfer them outside the neighborhood to the collection stations as seen Figure 7. These waste pickers are known for their uncivil mannerisms when dealing with other residents which negatively impact the urban quality. These informal waste collection times range from 2 to 3 times per day, depending on the requests, whereas Formal collection times are typically twice per day on the main streets bordering Kafr Abdo and once per day within the neighborhood of Kafr Abdo.

Traffic and Transportation Map

The traffic map would help with knowing both the general pathways routes of the citizens and the streets for the waste collecting vehicles (Formal / Informal). Aspects like knowing when congestions occur and where to account for the timing and navigation of collecting vehicles and the appropriate bin placement. As is shown in figure 8, there are a lot of narrow streets which are difficult for waste collection vehicles to navigate. The more accessible streets are the ones connected with Abo Quir St. and main streets as represented by the orange lines.

This results in poor waste collection due to many areas not being within the proximity of these formal collection processes. Leaving much space for informal ad-hoc management which is known to be inefficient due to its lack of sustainable operations of the informal systems. In addition, Route planning can be solved by google algorithm for traffic control systems which can solve the shortest path to reach the destination point without any traffic congestion.

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Volume 3, Issue 1, pp: 215-227 www.ijemh.com

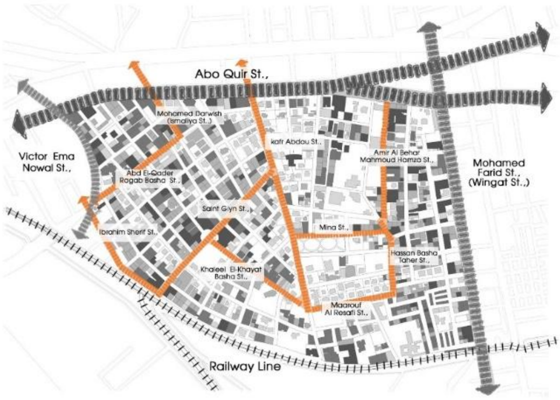

Fig 8: Traffic and Paths map in relation to waste collection routes in KA

Population Density Map

The urban population density is an important aspect in knowing how the urban metabolism progresses, with areas more active than others, areas that are going to generate more waste, and areas that will likely have more traffic congestion with high density and narrow streets. Knowing the details of the density of the urban fabric will help in accounting for these insights in relation to the waste management. As one can see in figure 9, the density of the population within the neighborhood of Kafr Abdou seems to be concentrated on the borders at the main streets - With 30% of the population density ranging from 6500 - 8000- where more waste is generated in proportion to population density as previously explained in chapter two. It is important to have more collection points in these areas of high population density.

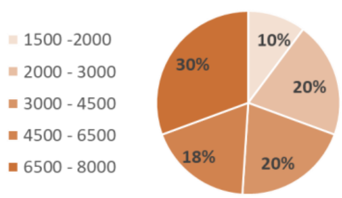

Fig 9: Population Density Map & Proportion Pie Chart

Building Heights Map

Building heights are an important aspect to urban analysis, they not only show the population densities in relation to the solid and void and the urban planning, but also show how the urban form has progressed by showing the progress between the building of high-rise buildings in comparison to low rise buildings. This can help with understanding the comparative residential incomes and how they relate to their urban surroundings.

The ratios between building heights in the study area are shown in Figure 10, where it can be seen that low rise buildings with 1-3 floors occupy about 25% of the built land in the neighborhood. High rise buildings with 12+ floors on the other hand occupy only 14%, which shows the degree of differences.

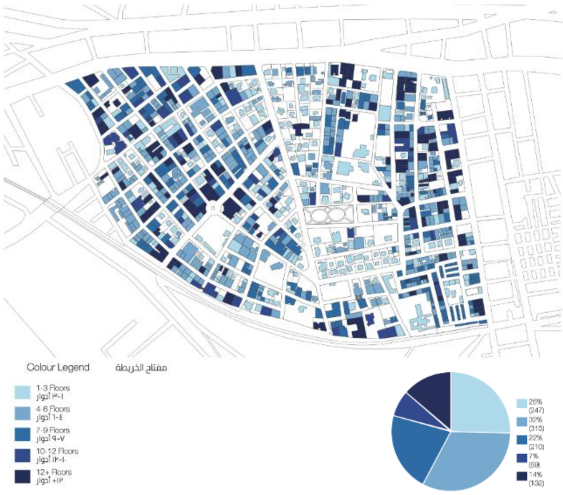

Fig 10: Building Heights Map and Proportion Pie Chart

This map showcases the building heights in terms of its urban layout. The low-rise buildings are the most dominant in Kafr Abdou, taking more than half of the buildings, while the high-rise buildings are the least. Although building densities have increased near the main streets, as newer buildings are risen higher. The high-rise buildings are mostly along Khaleel El-Khayat St., Abou Quer St., and Mohammed Farid St; with predominantly commercial roads and the train line which acts as the south boundary of the neighborhood. The low-rise buildings are more concentrated around Alenby's Garden and the historically preserved spaces.

What can be drawn from the building heights map are the waste stream densities and their relation to efficient waste collection. With a directly proportional relation between waste density, collection efficiency, and building heights; as building heights increase, the waste generated increases, and the waste collection efficiency and cleanliness decreases as illustrated in figure 11.

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Volume 3, Issue 1, pp: 215-227 www.ijemh.com

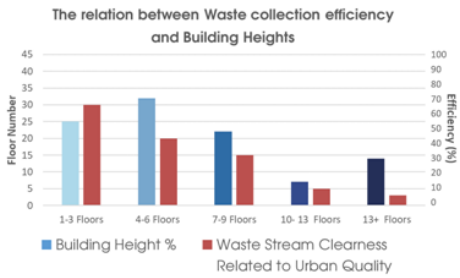

Fig 11: The relation between waste collection efficiency and building heights

General Land-use Map

This map shows the types and intensities of different land uses in Kafr Abdou. It is the basis for qualitative economic evaluation and is essential for proper scientific planning of the neighborhood. This map is general in identifying and reflecting all types of land resources found inside of Kafr Abdou. Going through this section, a breakdown map of specific land uses is illustrated as shown in figure 12.

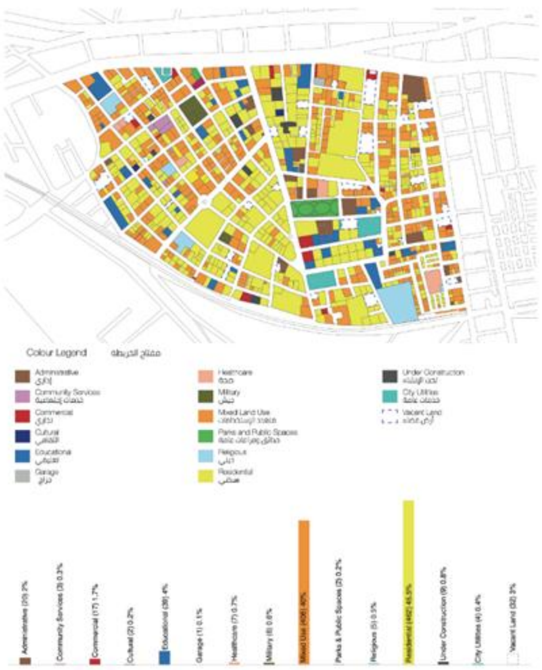

Fig 12: General Land-use Map and Proportion graph

Understanding the urban land use map, would help with insights. These insights can be beneficial in expecting and predicting the kinds of wastes in relation to their urban location, and their generation rates. Where for instance, educational areas would generate waste in the morning, but also would experience higher traffic at the time. The data acquired from the knowledge of land use would help make more accurate predictions.

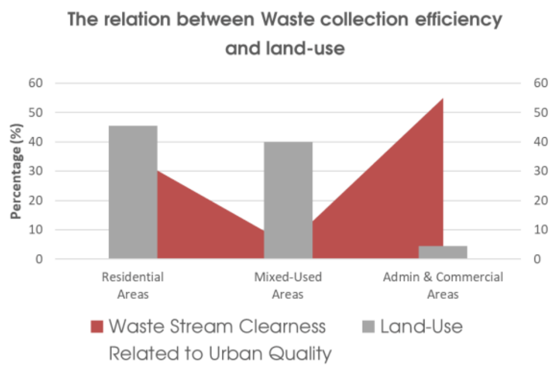

Fig 13: The relation between waste collection efficiency and land-use

With about 40% of the neighborhood land use being attributed to Mixed Use, this renders it as a typical example of an Alexandrian neighborhood. 45% of the neighborhood being residential, is an indicator that residential concern is one of the main priorities. Mixed use areas have less waste stream clearness and efficiency as observation shows in figure 13, perhaps due to the less influence and requests which have been ordained by residential areas and commercial areas, where communities are assembled. With Mixed use areas covering 40% of the neighborhood, this problem becomes exponentially worse. Especially since this is the case even when a lot of mixed-use areas are near collection points and are on the line routes of waste collection trucks.

VI. PROPOSAL FRAMEWORK AND MODEL

The proposal follows a specific framework which utilizes the data offered from the urban analytics of the previous section. The basic idea is that after gathering useful inputs from the urban fabric, and analysis of the waste stream data, and applying these inputs into a real time geo-database, where AI engages with operations in the form of a dashboard available for decision making as a single model for urban metabolism. The outputs expected, and characterized as objectives, are the elements of a desired smart urban waste management system. Figure 14 illustrates this framework and identifies the process flow, with three main elements in focus.

International Journal of Engineering, Management and Humanities (IJEMH)
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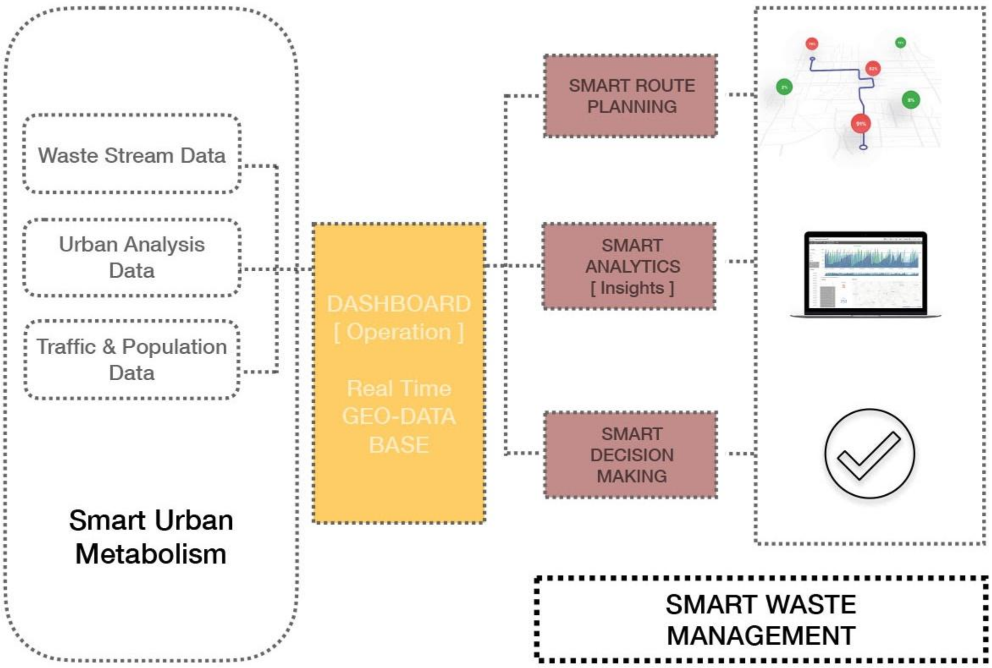

Fig 14: Proposal AI-Based Waste Management Framework

The inputs of big data, the smart processor using AI tech, and smart outputs.

The inputs of big data are waste stream data, operations data, and urban analytics data which are analyzed into the following:

- The IoT sensor-based waste stream data consists of waste compositions, waste generation times, and waste generation density levels.
- The Operations Data consists of operation costs, vehicle properties, bin types and capacities, workers' working hours, pick-up duration of emptying the bins, and bin condition.
- The urban analytics data consists of collection points, traffic data and available routes, land use data, population density, and income levels of urban areas.
- These inputs are applied to the smart processor which utilizes AI following specific key considerations and proposed model for operation interface. These considerations are based on four main modules. They are the dashboard, analytics, and monitoring.
- The Dashboard as the operation and decision-making interface whose considerations are smart bins with sensors, smart route planning, and feedback.
- The Analytics are the classifications and predictions of the algorithms, which recognizes patterns. These considerations are history and pickups.
- The monitoring considerations based on real-time data, and they are measurements, IoT network, sensors, and warnings.

Table 1 showcases the main considerations and their counterpart objectives and criteria. It is the most essential aspect to the model as it encompasses what should be utilized from the field, assets, and urban analysis.

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 3, Issue 1, pp: 215-227 www.ijemh.com

Table1. Key Considerations, Objectives, and Criteria of the Proposed Model

Key Considerations	Objectives	Criteria
Bins	• Offer an efficient bin monitoring interface.	• Equip sensors for fill-level monitoring. • Administer warning alerts. • Cater IoT messages. • Add capacity information. • Add density information. • Arrange collection times.
Fleet	• Provide good navigation for the fleet drivers to utilize. • Offer efficient fleet management. • Reduce the amount of CO2 emissions (Greenhouse Gases).	• Implement GPS tracking in the Drivers' App for navigating the streets. • Prepare live route updates. • Grant crew registrations. • Administer driver alerts. • Add problem reporting in the interface. • Relative adjustment of collection times.
Routes	• Infer and manage the optimization of Route Planning. • Manage efficient Fuel Consumption. • Manage and adjust real-time route plans. • Infer field predictions from the given situation reports. • Administer a decent platform for Operator involvement. • Estimation of Costs and fleet trip durations.	• Maintain bin monitoring data acquisition. • Arrange fleet managing dashboard data. • Produce real-time fleet monitoring. • Include the integration of machine learning into the analytics. • Offer an updated urban geo data base map. • Implement an easy to use dashboard Operator interface.
Field Experts	• Offer useful feedback to successfully manage the situations. • Contribute Real-time Reporting.	• Administer the Citizen App. • Manage and arrange pick up requests. • Add an easy to use Customer/User interface for Cooperation.
Analytics	• Provide historic data from the containers and make timestamped snapshots. • Provide exact reports about the pickups within timeframes, and percentage evaluations concerning the relation between pick up events and bin fill-levels.	• Integration of Machine Learning and IoT into the system for Analytic and Data monitoring and acquisition. • Record Bin/container history. • Record pick up event data within the context of the field and bin fill-levels. • Keep records within timeframes.
Administration	• View reports from the Citizen App to evaluate the current condition. • Edit and Add sections within the dashboard such as specific vehicles, discharges, depots, and other aspects.	• Manage partners, users, etc. • Maintain access to SMS/IoT payloads received to support field troubleshooting and installation.

Among these considerations is also the proposal model which is the operations interface. As illustrated in figure 15, this proposed model offers a comprehensive overview on the decision-making process and utilizes the relations involving the operator, data entry, and crowdsourcing. This model can be used as a hybrid system, where AI, and the operator are communicating with options and decision-making tools. Insights and history are provided by the model, after making use of the inputs, and representing the data in a way which makes the interface practical. This interface also considers crowdsourcing as a source of data, where complimentary Apps like the field expert app or the drivers' app are in communication with the main dashboard for the operator to oversee.

VII. CONCLUSION

Synergies between (WS, BH . GL, T&T, and PD) have a great impact on the waste collection process as part of a waste management system. After a thorough examination on Kafr Abdou by observation, surveying, and engaging with the community, a few points are made clear.

- The narrow streets of Kafr Abdou make it difficult for navigating and collecting wastes in some parts of the neighborhood.
- The mixed-use nature of the neighborhood isn't aligning well with the current waste management system.
- The community has a desire to improve the waste management system but struggles to do so because of inefficient communication with formal and informal sectors of waste collection.
- Both formal and informal methods of waste collection are inefficient.
- The urban fabric is greatly affected by the poor condition of wastes and waste handling.

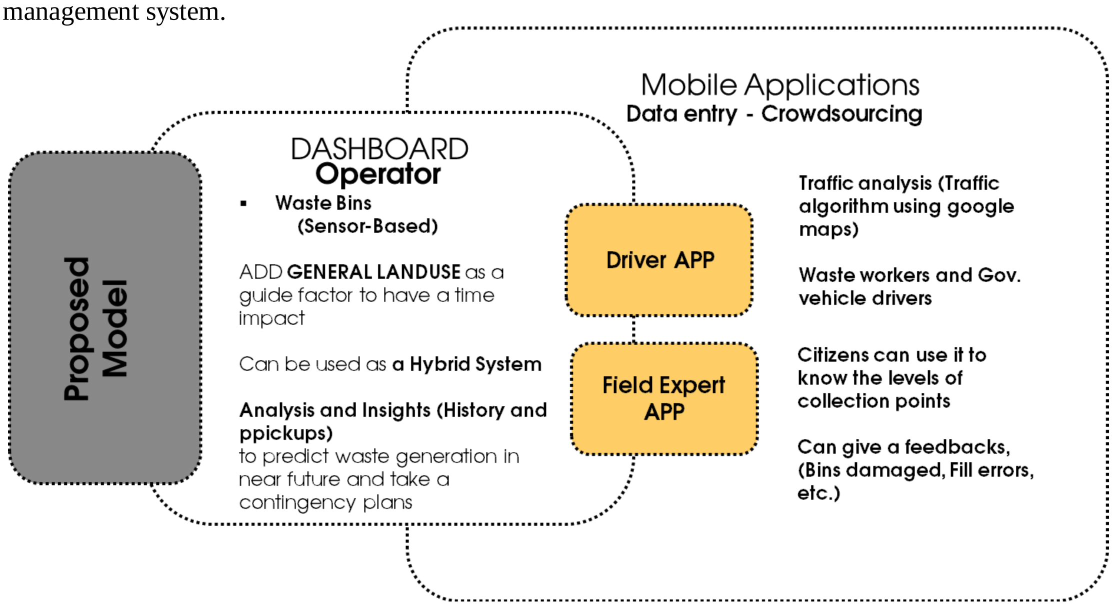

Fig 15: Proposal AI-Based Waste Management Model (Operation Dashboard)

As the observation and investigation goes, it was approximated that of the accessible areas of the Kafr Abdou neighborhood, where collection trucks navigate there is a 20% waste management efficiency, with 40% managed by formal and informal systems. Whereas the area associated with narrow streets, it is approximated that 55% waste management efficiency with 60% managed by informal systems. This leaves much to be desired and a lot of room for improvement. With the utilization of AI and IoT the efficiency rate is bound to increase exponentially. A similar solution was evident in Nitra, Slovakia. Where the enterprise of Sensoneo developed a smart waste management system with similar considerations and criteria, which ended in a higher efficiency rate and saved a lot in collection costs. Considering that Kafr Abdou is a typical Egyptian neighborhood, sharing much of the similarities with most of the Egyptian neighborhoods, this framework and model would not just be an efficiency solution to an exceptional neighborhood, but rather an efficient solution that is a prototype, eligible to work with most neighborhoods in Egypt.

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