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RESEARCH TITLE

IOT Based Smart Waste Container System in Southern Jordan Valley Municipality

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Abstract

Municipalities are responsible for providing essential services to their citizens, including waste management, transportation, and public safety. Internet of Things (IoT) technology can improve the quality of these services and make them more efficient. IoT technology can help municipalities to collect data from various sources, analyze the data, and use it to make informed decisions. IoT can help municipalities to reduce costs, improve service delivery, and enhance the quality of life of their citizens. This paper discussed the use of IoT in municipalities to improve their services, the benefits of implementing IoT in waste management by proposed an IOT waste container model for municipality of Southern Jordan Valley, and the future prospects of this technology in municipal services. The proposed model is based on connecting the containers with capacitive sensors so that they measure the level of fullness of the container (the percentage is 80%) of the total capacity of the container, so that a notification is sent to the health monitor about the fullness and location of the container as the sensors and the server are connected to each other through (Wireless Sensor Networks) to make a decision By running mechanisms to collect waste as needed, the model relies on providing it with a real-time data, which means accuracy, reliability, and reliability of the data, as well as contributing to cost reduction, improving service, and facilitating the transition to smart municipal services and achieve environmental and economic benefit.

Key Words: Smart waste management, Smart Municipality, Southern Jordan Valley, IOT, Wireless Sensor Networks.

1. Introduction:

Since 2014, the government in the Hashemite Kingdom of Jordan has started moving towards the automation of government services under the name of e-government, which means transforming the services provided by government departments into digital services that can be obtained using websites and smart applications with the least possible time and effort in order to facilitate the work of government agencies [1]. in addition to reducing the cost and time used for citizens; the rapid spread of the Internet and high expectations of users have helped accelerate the process of digital transformation of government services, and since the Ministry of Local Administration is an integral part of the government system; This means that it is axiomatic to adopt automation and computerization in all its departments and municipalities, and indeed, digital transformation has been initiated in the ministry in partnership with municipalities and other administrations. And with the start of the spread of new technologies such as: the Artificial Intelligence (AI) which is define as studying and designing smart systems that understand their environment and take measures that increase their chances of success [2]; and Internet of Things (IOT) which means the new generation of the network that allows communicating between devices that interconnected with each other via Internet Protocol. These devices include tools, sensors, various AI tools, and more [3]. all that concepts make the trend will be towards transforming into fully smart cities, this concept goes beyond the traditional communicating of people with computers and smart phones through a single global network and through the well-known traditional Internet Protocol. What distinguishes the IoT is that it allows a person to be free from place, that is, a person can control tools without the need to be in a specific place to deal with a specific device. for example, we have become shopping from anywhere in the world while we are sitting in our homes and without the need to move from one place to another, as well as we are participating in courses, conferences and learn-distance, if we start thinking outside the box and exploit these technologies in the services provided by municipalities, being responsible for providing basic services to their citizens, including waste management, transportation, and public safety such as using artificial intelligence and the Internet of things to track the path of municipal mechanisms and public transportation to monitor their movement, parking spaces, and load capacity, or monitor employee time.

IoT technology can improve the quality of these services and make them more efficient. Also, can help municipalities collect data from different sources, analyze it, and using to make informed decisions. The IOT also can help municipalities in many great benefits that can be provided by using it in municipal services, which contributes to the improvement of the municipal sector, including:

1- Increasing efficiency

2- Improving the quality-of-service delivery

3- Reducing costs

4- Improving the efficiency of service provision

5- Faster response times

6- Reducing waiting times

7- Improving the quality of life of their citizens by providing better services

Knowing that the targeted municipality in this study is the municipality of the Southern Jordan Valley, which covers a wide area of administrative organizations, which is in Al-Karak Governorate in the south of the Hashemite Kingdom of Jordan. It is considered as a part of

the rift crater and it is lower than the sea level by about (400 m) [4], extending from the Mujib in the north to the Ghuwaiba area in the south, with a length of (93 km) and a width of (5 km). The total area of the brigade, according to the latest statistics, amounted to approximately (465 km^2) [4]. There are about (10) administrative divisions served by only one municipality as seen the green area [4] in figure (1) below.

Figure 1. Southern Jordan Valley area[1]

Therefore, the municipality of the Southern Jordan Valley is considered the largest municipality in Al-Karak Governorate by area, and this makes it face several challenges in the quality of services it provides to citizens, which are listed below as the most important challenges [4]:

1- The wide area covered by the municipality and the high population, which cause an increase in the burden of providing services

2- The random spread of the population

3- The difficulty of the topography of the area, where you find residential areas spread among mountains, valleys, plains, and sandy areas that may be difficult to reach.

4- Lack of capabilities and insufficient availability of mechanisms

5- Poor infrastructure such as streets and sewage

And many other challenges and weaknesses, which the municipality works to limit and find possible solutions to them as much as possible, based on the municipality's vision to provide the best services in partnership with members of the local community.

[1] Ministry of Interior _ Administrative divisions of the governorates / Al-Karak Governorate

The Municipality of the Southern Jordan valley, collects waste from within the neighborhoods, residential and tourist areas, then disposes of it in the designated waste dumps through the Public Health and Safety Department, by providing the following[4]:

1- The human resources: health monitors and national workers/Clean Workers (68 workers) and drivers of waste compactor (14 drivers) distributed among the administrative organizations of the municipality's regions and working within a specific program on a rotational system to carry out waste from containers, street sweeping, spraying and various cleaning campaigns.

2- Machines and vehicles: It is represented by waste compactors (8 compactors) distributed in the municipality's areas, working within fixed daily paths by passing through all streets and residential neighborhoods to collect waste regularly and from all containers and drums used by the population for waste and disposal. The shift system works (morning and evening) in 24/7.

3- Tools of the sanitary operation, such as brooms, cleaning equipment, and metal containers distributed by the municipality in the amount of approximately (480) containers with a capacity of (1100) liters, in addition to supporting equipment and mechanisms such as tractors, pick-ups, and water tanks that are used in various cleaning and spraying campaigns.

Where the waste that is collected from areas and population centers is disposed of and treated by landfilling in waste dumps designated for that in cooperation with and management of the Joint-Services Council of the Southern Jordan Valley as follows [4]:

1. Al-Buraika waste dump - Ghor Al-Mazraa area, which is 10 km away from the nearest residential settlement.

2. Al-Sammar waste dump - Ghor Al-Safi area, which is 7 km away from the nearest residential settlement.

The cost of managing waste and maintaining public cleanliness in the areas of the Municipality of the Southern Jordan Valley is estimated at (18-20%) of the general budget of the municipality (according to actual statistics from the budget for the year 2022) distributed among the salaries of Watan workers and compressor drivers, and the cost of fuel is estimated at (100,000) One hundred thousand JD from the total allocations for the health department, in addition to the maintenance of machinery and containers, a subscription to the waste dump, and many other exorbitant costs that burden the municipality.

Based on the facts listed above about the Municipality of the Southern Jordan Valley and the many IOT benefits, the idea of this research came about, which aims to present a proposed model for the process of waste collection and management in the municipality of the Southern Jordan Valley using the IOT techniques, for the purposes of improving the waste management process by removing it in a timely manner which leads to reducing the costs of the Fuel for waste collection mechanisms.

2. Related work:

recently, there are many papers have been published related to the use of IOT and artificial intelligence applications in Municipal administration and the transition to smart cities, the following papers selected to be reviewed to name a few in this field as follows:

In [5] researchers talked about the impact of the Internet revolution and the IOT on the development of many devices and their role in establishing smart cities that depend on the use of devices with important computational capabilities to be converted into smart objects to monitor and collect information about the city environment. waste management is one of the

most important problems that affect Smart cities since it is directly affected by many factors, such as: increasing urban areas and rapid population growth. The proposed solution was an improved design for the waste management process in a way supported by the IOT and cloud computing. This design takes into account population and urban growth by using different truck sizes according to the type of waste, and IoT devices that facilitate communication between system entities, such as smart bins, waste source areas, waste collection trucks, and waste management centers, which leads to improving the activities of collection systems in the source area, which is the most important stage in waste management, especially with regard to recycling waste in urban areas around the world. This proposal helped to improve the tracking of containers in terms of their size and the amount of waste in them. Instead of tracking empty containers while the full containers leak onto the street, the status of each container is read, and the truck is sent with the appropriate size based on the type and quantity of waste with a smart routing system for collection and disposal. Which leads to the optimal use of equipment and the elimination of unnecessary costs.

In the research paper [6], a survey of Greek municipalities on waste management technology was conducted with the aim of discovering the direction of Greek municipalities to adopt electronic solutions provided by IoT, especially with regard to smart boxes, and they propose using them to recycle waste and convert it into energy, which is a project developed by the University of Western Macedonia to reflect the current situation In their area, this case study was conducted on 332 municipalities in the whole country through the distribution of a questionnaire in Greek as well as phone calls to get initial information on knowledge related to solid waste management. The targeted information for the municipalities about that smart waste management using smart bins can greatly maintain the cleanliness of public places through the cleaning process and prompt collection of waste, thus saving large financial resources and helping to avoid overfilling the bins. The proposed design for the smart bins in this paper is to add sensors to the waste bins so that they identify the different types of waste in addition to enabling them to work as indicators in real time to determine if the bins are full or not, which helps in adjusting the waste collection schedule accordingly. Smart boxes are environmentally friendly, as they significantly reduce the need for misleading collection methods, resulting in lower emissions of carbon dioxide and associated greenhouse gases.

Also, other benefits from the smart use of the Internet of Things in designing these boxes from an economic point of view is that they are more durable in the event of vandalism, resistant to combustion, and thus reduce the costs of container maintenance, and are practically lighter than traditional boxes. After analyzing the data collected from the municipalities, the results showed that the municipalities are interested in adopting smart and unique practices for waste management and calls for investments in smart funds to be sustainable and effective.

In [7] proposed a smart waste management system to overcome the biggest challenges that municipal organizations in waste management, based on smart containers that enable context-specific waste management via a general exhaustive context ontology. Real-time monitoring through smart devices or containers is furthering the digital era of waste management by enhancing transparency, dependability, agility, security, resilience, connectivity, and sustainability of waste chains. The proposed system, based on smart containers and general contextontology, is leading the way in developing smart context-based waste management systems, increasing the quality of life today and assuring a greener world for future generations. The adaptation of a system context can take many aspects, such as behavior content, or presentation adaptation. In this approach, focus is given on the adaptation of a smart waste management system to different waste contexts of different stakeholders. It is possible to manage the waste process situations in different contexts, i.e. the waste management domain, waste objectives, and waste activities, such as waste generation, collection, transformation, segregation, cleaning, etc. The proposed solution implements an

intelligent and adaptive system for waste management according to the context and the different objectives according to various stakeholders. The main contributions of this paper are:

 A unique way to combine two technologies, namely IoT and ontological engineering, ensuring an optimal and general based context in the waste management field.

 An architectural development process of the smart garbage box and the process of complete waste management in addition to the objectives, activities, reuse, and intelligent learning of the waste management system, as well as a smart way to monitor waste in real time.

The context ontology is opening a variety of data sources that could give the waste management system a context aware picture. Any documentation of the contextual information contained in a container is helpful to the coordination and predictability assuring quality and optimizing waste management. It is possible to predict when a container will be ready for the next operation and effectively manage risk in accordance with the waste management process by simply being aware of the status of a specific container, its contents, all relevant contextual information, and the waste management objective at a given time. As a perspective of this work, we suggest the use of deep learning methods as an intelligent way to classify waste through image classification. Machine learning algorithms can be very beneficial in the waste management data analytics in order to take the best decisions and optimize smart waste management.

[8] the researchers here talked about the smart city, specifically the smart municipality in smart cities, which is one of the applications of the IOT, which provides services in digital and automated ways and with the least possible human intervention while achieving high accuracy to improve the living standards of citizens, such as waste management, smart transportation, etc., but the possibility of Interoperability between heterogeneous services leads to some issues in data security and privacy, which are critical for both the government and its citizens to maintain. Therefore, the researchers proposed a service security architecture based on authentication and authorization for constrained environments during collaborative tasks of Software-defined networking (SDN), smart contract-enabled municipal smart cities, and Blockchain technology. The proposed method is new of its kind to use smart contracts in multi-chain blockchains for data security as it relies on the dynamics of smart contracts to securely control all interactions and transactions between different heterogeneous IoT networks by implementing a use case supporting collaborative services in an SDN-enabled IoT architecture to evaluate Feasibility of a service security architecture.

The researchers justified the main reason for integrating SDN, IoT, and blockchain is to create an intelligent, manageable, and scalable system that supports billions of networked IoT devices, due to the centralized management and programmability features of SDN, and the ability of Blockchain technology in providing an improved traceability for mass deployment of smart city.

Through evaluations of service security algorithms, the researchers demonstrated that the proposed system is scalable, especially when connecting two different networks for collaborative tasks.

In [9] this paper, the researchers proposed a new structure to improve solid waste management so that it works on the principle of a wireless sensor network (WSN). The proposed architecture adopts sensor nodes and data transmission nodes (DTN) so that the sensors measure the filling of waste bins and in turn the DTN pass a notification to the remote server through long-range communication units where the state of the entire system is controlled and in turn the user monitors remotely and interacts with the system Using a web browser and a decision support system with a friendly user interface. One of the

disadvantages of this model is that the sensor nodes will always need maintenance due to the short life of the used batteries. The accuracy of the system may also be affected due to the large number of electromagnetic interferences in the nodes' fields, and thus it may give inaccurate readings.

And many other research and projects that are published from time to time looking at this field.

3. Proposed Model

Returning to the information included in the introduction, we can see that the use of the IOT in municipal services in general and in waste management in particular (provided the availability of the necessary infrastructure and preparations for smart transformation) has a good environmental and economic impact on municipalities, such as reducing gas emissions resulting from exposure of waste to heat, pressure and oxidation factors with the long period of stay in the containers, the costs of periodic maintenance of the containers are also reduced because they are followed up and emptied periodically, in addition to reducing the cost of fuel since the tracks are made according to the percentage of containers full and only when needed. Accordingly, capacitive sensors, which depend on the ability of the material to store electrical energy in an electric field surrounding the material [10], can be used to control the amount of waste in containers and organize waste collection, by installing the sensors inside the containers and connecting them to the Internet and an intelligent control system. The following is a proposed model for a waste collection system using IoT and capacitance sensors, with steps that show how to implement this idea, as shown in Figure (2) which is as flowchart of proposed model:

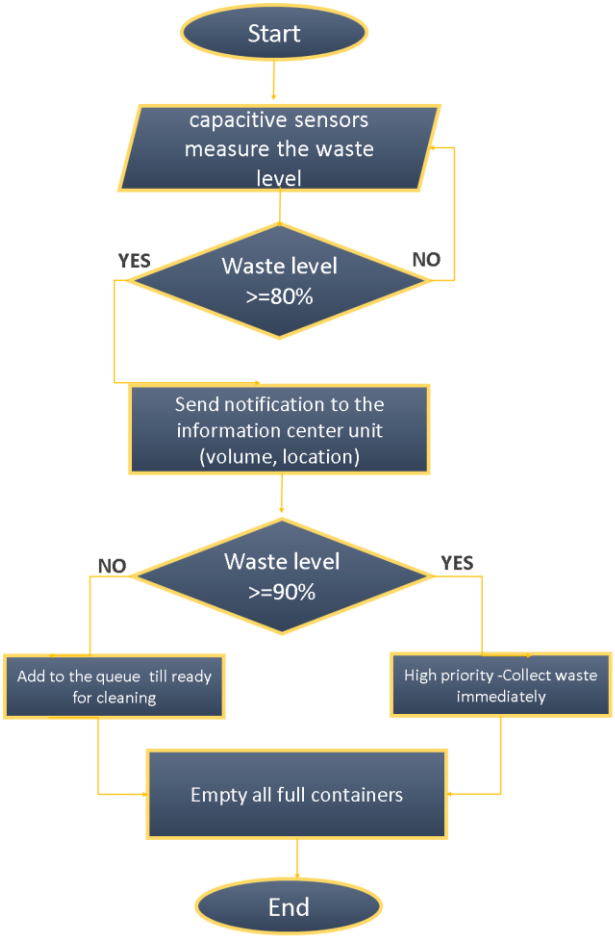

Figure 2: Flaw Chart

1. Sensor's installation inside the container: The sensor is installed inside the container so that it is in a position where it can measure the waste level. The capacity sensors available in the market provide features such as accuracy, reliability and fast response. Also we need GPS sensors to detect the containers location.

2. Connecting the sensors to the web system: The sensors are connected to the web system using wireless communication technologies such as Wi-Fi or Bluetooth.

3- Connecting the sensor to the control system: The sensor is connected to a control system that measures the level of waste and determines when it should be collected.

4. Set the completion limit: The completion limit is set, which determines when the waste should be collected, and in our proposed model, it is set when the waste level reaches 80% of the container capacity.

5. Waste collection control: An intelligent control system is used that allows operators to monitor the level of waste inside the containers and control waste collection effectively and in a timely manner so that the waste collection schedule is organized based on the signals from the sensor, where the waste is collected when the waste level reaches specified limit.

By using these steps, the waste collection process can be improved, and the costs and effort involved in the process can be reduced by determining the appropriate time and place for waste collection and reducing transportation and disposal costs. Also considering that the devices installed in the containers provide a real time data collection. so, the waste management center can analyze the collected data from the IoT devices and provides useful information for decision-making within the intelligent waste management system and identify patterns and trends in usage.

4. Methods and Materials:

This proposed model consists of a web-based user interface to help the health monitor/cleaner in the municipality to get all the information about the waste containers in the area to monitor the real-time data from the capacity sensor and to make the decision about the routes to follow for the waste collection based on the maximum capacity of the container considering priority as needed. The suggested tools and techniques in the design consist of the following:

4.1. ARDUINO UNO

The Microcontroller used here is an Arduino UNO. The UNO is a Microcontroller board based on ATMEGA 328P. The ATMEGA 328P has 32kB of flash memory for storing code. The board has 14 digital input and output pins, 6 analog inputs, 16 MHz quartz crystal, USB, an ICSP circuit and a reset button. The UNO can be programmed with the Arduino software.

4.2. SENSORS

4.2.1 The NEO-6M GPS module is a GPS receiver that can locate all locations on Earth as it is able to track approximately 22 satellites. It consists of a high-performance u-blox 6 positioning engine. Measuring 16 x 12.2 x 2.4 mm, its compact architecture along with its low power consumption makes it a good choice for IoT projects. Overall, it is a good cost-effective GPS receiver.

4.2.2 Sensoneo Smart sensors to measure fill-levels in waste containers via ultrasonic beams. it is can monitor any type of waste (mixed waste, paper, plastics, glass, clothing, bio-waste, liquids, electronics, metal….) in bins and containers of various types and sizes, robust, water and shock resistant, fully functional within wide temperature range, and are set to measure from 3 centimeters up to 12 meters..

4.3. The Aggregation Node: one gateway responsible for maintaining the connected network and communicating with the server and is responsible for receiving messages sent from the sensor nodes and sending them to the server. This is how information is exchanged within WSN, from sensor information to operator actions. LoRa is the communication standard chosen for WSN connection, due to its ability to dispose of redundancy devices, long range and low power consumption, as well as the fact that it operates on unlicensed radio spectrum, which means that there are no associated costs. Then, those information's will going on to the main server to make a decision, Therefore, some kind of internet connection is needed, In order to create a low-power static data connection, the MQTT protocol proposed, due to its high connectivity and low energy consumption, is adopted when compared to other protocols. MQTT is a messaging protocol built on the highest TCP protocol, which uses a publish / subscribe mode, to provide flexibility and simplicity transmission making MQTT the ideal communication protocol for IoT and M2M, suitable for small, cheap, low-power, low-memory devices with low bandwidth networks.

4.4. WI-FI MODULE: The NodeMCU (ESP8266 Wi-Fi module) is a self-contained SOC (System on Chip) with integrated TCP/IP (Transmission Control Protocol/Internet Protocol) protocol stack that can give any microcontroller access to any Wi-Fi network. Each ESP8266 module comes preprogrammed meaning, it can be simply hooked up to Arduino device to get Wi-Fi ability. This module has a powerful enough on-boarding process and high storage capacity that allows it to be integrated with the sensors and other application specific devices.

The above-mentioned tools can be replaced with other tools and techniques depending on the situation of the region and the nature of the model, as they are suggested materials due to their low cost and ease of use, and they are compatible with the proposed model.

5. Conclusion:

The IoT is transforming the way we live, work and communicate. In recent years, the Internet of Things has gained popularity in improving the quality of life in cities through smart city initiatives. Municipalities are starting to use the Internet of Things to improve their services and improve the quality of life of their citizens.

The Municipality of the Southern Jordan Valley faces some challenges in waste management, collection, disposal and recycling. This challenge also includes a lack of understanding of the various factors that influence those different stages of waste management, inefficient route planning, and lack of resources.

This research proposes a waste management system based on smart containers by placing capacitive sensors to measure the level of waste in the containers so that it sends a notification when reaching the fullness limit, which is 80% of the container capacity, and sends the location of the container to the server to take action to collect the full containers as needed, which contributes In determining the optimal path for the mechanisms in waste collection, thus achieving material and environmental benefits. The proposed model is based on real-time data, thus achieving higher reliability and accuracy in decision-making.

The collected data can be used to be analyzed and machine learning algorithms can be used to predict the times of filling the containers, and to identify the crowded places that need more paths. It is also possible to improve the proposed model so that the mechanisms are run according to the size of the container and the type of waste in it, by providing it with special sensors to determine the type of waste. Which facilitates recycling or disposal and these points can be considered as directions in the future work of the proposed model.

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