The Adoption of an Intelligent Waste Collection System in a Smart City

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***Abstract*—Solid waste management has gotten to be a major concern in environmental issues. This can be a problem especially in the cities where the population is quickly developing, and the sum of waste produced is expanding like never before. Programs for smart city waste can help in expanding proficiency, diminishing costs, and improving the aesthetics of open places as the cities endeavor to oversee waste in public regions cost-effectively. This study contributes to the improvement of the smart waste systems by the development of smart technologies and software as additional tools for collection. This research demonstrates how the SQERT model, a periodic trend analysis report which is specific to projects will be used to perform analysis in assessing the smart waste management system and the proposed software technology. Furthermore, A software prototype visualization was created to demonstrate and show how the software system will look like and its functionalities to improve the waste collection system.**

***Index Terms*—Technology, Smart city, Higher education, waste management**

I. Introduction

Cities around the world confront expanding environmental and social weights, infrastructure needs and development of technologies to provide a much better quality of life. In this respect, Smart technologies can help cities to fight these challenges [1]. There are a variety of factors that may cause or make everyone want to move to a city which in turn causes the population in the cities to increase rapidly.

The world is gravitating towards the 4th industrial revolution which is the speedy change to innovation businesses, and societal plans and shapes inside the 21st century due to extending inter-connectivity and smart computerization. This cause urbanization and an increase in population directly affects the waste generation [2]. The population of the world is expected to be 9.7 billion by the year 2050 with 90 percent of the populace living in cities. The waste produced will increase by 70 percent compared to the waste produced as of now. The amaount of metropolitan solid waste produced by the world each year is 2.01 billion tons, with at slightest 30 percent of the waste not overseen in a legitimate way. The waste produced all over the world per individual is 0.74 kg shifting from 0.11 to 4.5 kg [3].

Smart city is a concept that involves joining an arrange- ment of data and communication technologies (the Internet of Things), to manage public and private administrations in a sustainable way. Like other smart technologies utilized by cities to progress city services, smart city waste management technologies use internet of things (IoT) sensors to supply open specialists with point-by-point data about waste and recycling bins all over the city [4]. The sensors may give data about the temperature inside a bin as well as when a bin ought to be emptied or when odours are beginning to cause an issue [5]. With this information, waste management workers can successfully oversee waste and recycling bins to preserve the cleanliness of public spaces. The Internet of Things (IoT) is being utilized by smart cities to construct a successful and cost-effective framework, that spares human assets, and the environment [6].

To improve the waste collection system, it is imperative to develop additional systems to work in hand with the existing technologies. Therefore, we have chosen to implement the waste management software technology which will make it easier for collection organizations to complete their tasks and also be beneficial to the society to make their environment clean and in a more legitimate way as it will be additional technology to be utilized. The software technology will work in an embedded system with existing smart city waste man-agement technologies which will complete the waste collection system.

II. Related Works

The authors of [7] demonstrates how they created an app that communicates with smart bins. Three technologies are used in this app namely: identification technology, input/output technology, and Geo-spatial technology [8]. An integrated

system that combines the three technologies utilizes a Geo-location tool to track and monitor the position of bins and waste collection vehicles, identification technology to locate bins and determine when to collect them, and sensor technol- ogy for data capture [9].

In [10] a smart waste management system was created, and its identified and classified waste according to what was in the waste bin. This uses TensorFlow Lite and the LoRa- GPS Shield to sort garbage into distinct segments. Utilizing TensorFlow Lite and LoRa-GPS Shield [11], waste items are divided into various containers. A search capability in a discrete and continuous domain for waste management is created by an optimized IoT-based model that incorporates intelligent vehicle routing strategies with spatial constraints.

A Smarter Waste Disposal System is developed. The waste bin will have ultrasonic sensor to detect garbage fullness, Load sensor to measure weight of the garbage, GPS sensor to locate bin location and Gas sensor to measure hazardous gas emission from bin [12]. The Smart Waste Management System uses RFID system to honour the person in exchange of disposal of waste it collects the waste and then gate of candy vending machine which gives the reward to the student.

Paper [13] proposes an integrated organic waste manage-ment system. The author shows how the IoT architecture might improve waste management efficiency. The creation of a methodology for putting these answers into practice is also significant for the research.

In [14] they focus on AI technologies to solve the problem of waste detection in a manner suggestive of smart waste man-agement. High tech companies play a big role in developing smart waste management systems.

In [15] high tech companies play a big role in developing smart waste management systems. Envac is most one of the successful ultramodern company for waste collection. It holds the record for most patents issued for waste management in China and is the founder of pneumatic waste collection for hospitals. Envac supplies smart waste management systems for airports, cities, and health care sectors.

In [16] cross-section online surveys were conducted in order to fully understand the modern digitalization efforts and the master plan of private and public waste management companies in Germany. They differentiated several waste man- agement performances according to companies and recorded the company's anticipated relevance and the results of modern digitalization to the waste management firms.

The MFA is defined in [17] as a systematic assessment of the state and change of materials flow and stock in space and time. The MFA estimates the amount of food waste generated in European Member States.

The author of [18] describes the difficulties associated with household solid waste management during the COVID-19 lockdown in Zimbabwe [19] [20]. According to this, during the lockdown period in Harare COVID-19, only essential service providers were permitted to walk in the streets, and municipality workers were not among the essential service providers, resulting in solid waste accumulation at the house-hold level that was not managed by responsible authorities. The same study on AI-based waste management strategies for the COVID-19 pandemic was published in papers [21] [22].

Many times in [23], The author shows studies on solid waste management in Iran that have been conducted. In Mashhad, a new GIS-based method for optimizing waste collection routes and waste bin locations was developed [24].

There were strategies implemented for municipal solid waste in India in [25]. Because the average waste generation rate (per capita) is 370 grams per day, the implementation of these measures raised significant concerns. The MSWM system is used to address environmental and public health concerns, assets, artistic, appropriate land use, and garbage removal. It consists of several components, including waste collection, segregation, transportation to landfills, waste pro- cessing in plants, and disposal at landfills/dumping sites. This is a smart waste management solution aimed at Indian citizens to help with waste management [26].

III. METHODOLOGY

To bridge the gap discovered in the literature analysis, the SQERT model was adopted. This model is a periodic trend analysis report specific to projects that helps us to look at project constraints. It is a useful model presentation for Project Management field experts. This will include scope, quality, effort, risk and time as the typical project constraints to examine the planning, execution, and implementation of what it will take to finish a project as presented in Fig 1.

Fig. 1. The SQERT Model

A. Scope

As the population of modern cities increases, more and more waste materials are being disposed. Citizens need an environment that is clean and healthy to live in. They require a well-managed environment, and a waste management system is essential in achieving this. More people moving into cities means more waste, hence the development of this system is very much needed and important.

Development of a waste management system requires a use large variety of technologies to grant its service. This will involve a software end of the system where the location of a bin can be identified. It will use GPS for its location as LoRa real-time (a use of wireless sensor network) will give

information about that location and monitor the situation of waste material in a bin. This will perform over a chip installed to a "bin" which will be playing a role of monitoring the situation (is the bin empty or full?).

B. Quality

The chip will be embedded in a container-like object where a bin can be easily pushed inside of and will have an infrared sensor which will perform these activities (locating and monitoring bins) [27]. This container-like object will act as a medium between this software and the bin itself as it will play a big role in locating, monitoring, and performing other required activities. When the bin is full the bin will be able to lock itself [28].

The container will be designed in such a way that citizens do not interfere with a bin directly but will be interacting with this container object where they will simply insert waste inside of it. From this, the container will handle the rest of the process by putting waste inside of the bin as it will be interfering with it. The reason for this is because bins may sometimes have a very unpleasant smells, so separating these environments will make sure that citizens do not come across these kinds of issues when using bins.

The software end of the system will be useful in waste collection. This software will connect with the container object through an RFID (radio frequency identification) technology embedded inside of it. A binman is the one that will be able to utilize this software as it will tell the export location, together with the situation of the bin. They can use this software to detect if the bin is empty or not, to avoid delays. This system will also be useful in collecting more data about bin collections daily. Supervises may also use this information to discover working patterns of binmen on the job. The movement of binman is tracked all the time as they utilize this software.

C. Effort

The development of the software may affect the investment of this whole project. Costs will be high as this system use large variety of technologies. Some technologies may require maintenance which will affect the budget of this service provision a lot moving forward. Binmen must also be trained for this kind of software as they will be utilizing it a lot when collecting waste from bins. The container object carrying the sensor technologies will also be an expensive piece of the system. Installing these types of technologies on objects needs a lot of investment to make sure that the quality of the service is good, and citizens are satisfied all the time.

D. Risk

As technology sometimes malfunctions, satisfaction of citizens may be affected causing the quality of this service to be negatively impacted. This will affect the operation of the system as the technologies involved play a big role on locating and monitoring of a bin. Used technologies will undergo maintenance to keep the service provision going; therefore, by this there are more costs to be dealt with.

E. Time

For efficiency of delivering a good project, time must be considered as a factor to this. As the project deliverable already discussed together with the scope, a project schedule is developed with key dates in a form of a Gantt chart. It shows all relevant tasks from initiation of this project, through designing the software and other components of this system like the container object, to the completion of it. A Gantt chart is presented showing how long these tasks will take and key dates for completion and start of different tasks.

F. Design Science Research Method

Design science research (DSR) methodology is suitable for this study because it is all about creating new innovations that are presented by builds, models, strategies, and instantiates. It uses design knowledge to show how things needs to be created and arranged. It is used in many fields to create new solutions to real world problems. Design science uses academic knowledge to find journal and already built framework to build on the already existing project combines, changes, and expands extant design knowledge as shown in Fig 2.

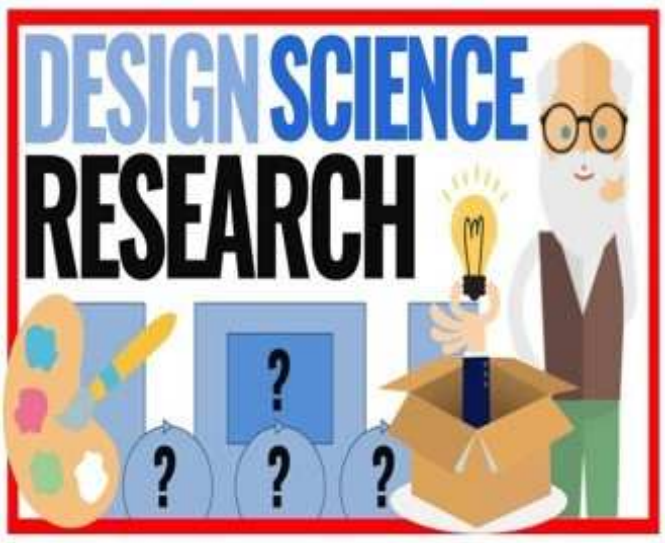

Fig. 2. The Design Science Research

Design science research allows the use of many research methods [29]. The evaluation in DSR allows early feedback which helps creating a more sophisticated framework. This evaluation allows changes to be made early in the prototype. Design knowledge of DSR makes sure that the framework meets the needs of the problem. The DSR method allows for design entities or to design hypothesis. the design knowledge and the DSR project works together to allow researchers to question and update the project scope. It permitted us to utilize diverse online articles to discover what is as of now existing so that ready to construct on the as of now existing extend combines, changes, and grows extant design knowledge. Using DSR helped in finding the background of the smart ways to manage waste in smart cities.

IV. Results Analysis

The prototype model of the software system was designed using one of the very popular designing tools Figma. It is a collaborative interface which makes it possible to connect everyone in the designing process. This prototype is a simulation form of the software which presents the front-end designed.

Fig 3 shows the prototype model for the software end of the waste management system. It can use locating and monitoring technologies installed to the bin which gives more information about the situation of a bin. It has a map that shows bin route location which is useful for a binman for directions to where they can find a bin. It also has a bin counter which displays the number of bins collected for that period. The data collected by this counter is set to be useful when it comes to monitoring the working patterns of binmen. This makes the collection process easier and beneficial for the organizations utilizing this software in their waste management system.

Fig. 3. The Prototype of a Software System

The Gantt chart shown in Fig 4 reflects how long these tasks took and key dates for the start and completion of different tasks. This is a tool used for planning and scheduling projects. They assisted on assessing how long a project should take, determine the resources needed, and plan the order in which tasks will be completed.

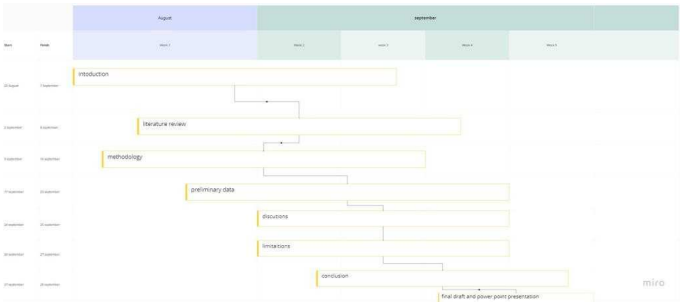

Fig. 4. The Timeline for the Project Tasks

Conclusion

In this paper, different projects where reviewed and the findings are that some cities are already using smart bins, and the installation of the smart bins is expensive which means the government should start now investing in smart waste management. The research question was answered using many different types of models and techniques. Project management tools where used. The development of a smart waste management system is important in cities. Smart waste management allows the city to be managed efficiently. It allows for different innovations to be bought forward by different researcher and helping in creating future technologies. In this study we managed to create a smart bin management system that will be able to send it real time location, checks the level of fullness in the bin manage the smell of the bin so that it does not affect humans. One day these technologies will be appreciated as its significance yet unnoticed fight against waste pollution will start to become our big savers towards the fight against climate change.

These technologies make state of living easy and help to fight against issues of the world as this system could be the first step towards that. It is one of the important tools for the well-being of the future for citizens.

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