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Waste Collection Monitoring: Towards a Digital Platform

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ملخص

يعتبر توليد النفايات ، وعدم كفاية جمعها ، ونقلها ، ومعالجتها ، والتخلص منها قضايا بيئية خطيرة في البلدان النامية. أنظمة إدارة النفايات الحالية في هذه البلدان غير قادرة على التعامل مع الكميات المتزايدة من النفايات الناتجة عن التوسع السكاني الحضري، والتي لها عواقب سلبية على البيئة والصحة العامة. العقبات والتحديات كبيرة، ولكن الفرص والإمكانات كذلك أيضا. هدفنا الرئيسي هو انجاز نظام أفضل لإدارة النفايات يمكنه التعامل مع الصعوبات والتحديات الجديدة، بدءًا من مراقبة جمع النفايات ، مع الخطط المستقبلية لتوسيع جهودنا لتشمل طرق التخلص من النفايات المناسبة ، وتخطيط لإعادة التدوير ، وغير ذلك ...

Abstract

Waste generation, inadequate waste collection, transportation, treatment, and disposal are serious environmental issues in developing countries. Current waste management systems in these countries are unable to cope with the increased amounts of waste generated by an expanding urban population, which has negative consequences for the environment and public health. The obstacles and challenges are substantial, but so are the potential. Our top objective is to implement a better waste management system that can deal with today's difficulties, starting with waste collection monitoring, with future plans to expand our efforts to include proper waste disposal methods, recycling planning, and much more.

Resumé

La production de déchets, la collecte, le transport, le traitement et l'élimination inadéquats des déchets sont de graves problèmes environnementaux dans les pays en développement. Les systèmes actuels de gestion des déchets dans ces pays sont incapables de faire face à l'augmentation des quantités de déchets générées par une population urbaine en expansion, ce qui a des conséquences négatives pour l'environnement et la santé publique. Les obstacles et les défis sont considérables, mais le potentiel l'est tout autant. Notre objectif principal est de mettre en place un meilleur système de gestion des déchets qui peut faire face aux difficultés d'aujourd'hui, en commençant par le suivi de la collecte des déchets, avec des plans futurs pour étendre nos efforts pour inclure des méthodes d'élimination des déchets appropriées, la planification du recyclage, et bien plus encore.

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General context

Waste management is one of the current challenges in urban areas and it has become a critical denouement due to the rapid increase in population. Appropriate waste direction systems are considerable for improving the environment and the well-being of residents, such systems can be found in developed countries such as the USA or France, which implement smart systems relying on technologies such as A.I. or IoT costing the government a considerable amount of money to achieve, but in this project we are trying to come up with an affordable and simple system, that relies on bringing the citizen closer to the government and enable the control center to be connected to the drivers and have a constant live feed on the progress of the collection process, all in the hopes of reaching the level of urban cleanliness that residents in developed countries enjoy.

Problematic and Objectives

One of the biggest factors that separates developed countries and developing ones is Urban Cleanliness, and that leads us straight to address the issues and challenges that the waste management system of our city faces, which includes Waste Disposal problems and much more, not to mention that Most of the waste is toxic. So the goal we hope to achieve from this work is to provide the government with a new system composed of three application that rely on technologies like IA and GPS to help the people responsible for waste collection and ease their job by enabling them to follow the progress of the collection process and to control the different aspects of it.

Outlines

Our work is organised as follows:

In the 1st chapter, we talk about the literature review of Waste Management and its definition as well as waste classification and hierarchy, also we've talked about smart cities and Digitization.

In the 2nd chapter, we discuss the technologies used to improve waste management systems mainly being AI and IoT, and of course some related works that relied on these technologies to achieve their goal.

In the 3rd chapter, We present the design of our proposed architecture of the system as well as the data base schema, then we focus on the tools and software used in the development of the applications that makes the system, and finally we go through the design of each application and some of the functionalities of each one.

These chapters are concluded in the general conclusion where we will provide a summary of this work and discuss some perspectives

Chapter I

Literature Review

I.1 Introduction

One of the most prominent government functions is street and public facility cleaning. Residents allow their views about their town and local leaders to be influenced by their opinions of the cleanliness of public streets, whether consciously or unintentionally. The cleanliness of the streets and other public facilities is likely to give visitors their first, and often lasting, impression of a community. The prevalent practice of depositing solid trash on public streets and in public areas, along with dust-laden desert winds, generates an urgent demand for street and public facility cleaning in all populous regions of any city.

I.2 Waste Management

Due to rising human population and urbanization, the amount of garbage produced has been continually increasing. Manufacturing operations, industries, and municipal solid wastes all generate waste materials (MSW).MSW is defined as waste durable-goods, non-durable goods, containers and packaging, food scraps,yard trimmings, and miscellaneous inorganic wastes from residential, commercial, and industrial sources. Liquid waste management consists of wastewater treatment, sewage treatment, and chemical and biochemical processing. Waste management practices differ for developed and developing nations, for urban and rural areas,and for residential and industrial, producers [5].

I.2.1 Definition

Waste is defined as any material that is no longer usable to its owner, the waste creator, and has no economic value. Waste is classified as solid, liquid, or gaseous depending on its physical state. Planning, financing, construction, and operation of facilities for garbage collection, transportation, recycling, and final disposal are all part of waste management. Every five years, the amount of waste produced increases by one million tons. If it is not disposed of in a timely manner, it poses major health risks and has a negative impact on infrastructure. The current garbage collection system, which collects trash from streets, households, and other businesses once a day, is unable to efficiently manage the waste generated, resulting in spillover into roadways, society [6].

I.2.2 Waste classification

The waste products of a home include paper, containers, tin cans, aluminum cans and food scraps, as well as sewage. The waste products of industry and commerce include paper, wood, and metal scraps, as well as agricultural waste products. Generation refers to the amount of material that enters the waste stream before recovery, composting, or combustion. Recovery refers to materials removed from the waste stream for the purpose of recycling and/or composting. MSW typically contains between 10.5 and 11.5 MJ/kg of energy. MSW generation and recovery differ greatly from country to country, and thus demands specific attention. According to contemporary estimates, the UK generates roughly 30 million tons of MSW each year, with 90% of it being land-filled. Sweden, on the other hand, only filled 34% of its MSW generation with land.

The following table shows how the different kinds of waste are classified into 10 different classes (types):

Table I.1: Waste Classification [13]

Classification	Waste description
Type 1	A mixture of highly combustible waste, primarily paper,cardboard, wood, boxes and combustible floor sweepings;mixtures may containup to 10% by volume of plastic bags, coated paper, laminated paper,treated corrugated cardboard, oily rags and plastic rubber scraps.Commercial and industrial sources.
Type 2	A mixture of combustible waste such as paper, cardboard, wood scrap, foliage, floor sweepings and up to 20% cafeteria waste. Commercial and industrial sources.
Type 3	Rubbish and garbage. Residential sources.
Type 4	Animal and vegetation waste from restaurants, cafeterias, hotels, etc. Institutional, club and commercial sources.
Type 5	Human and animal remains consisting of carcasses, organs and solid tissue wastes from farms, laboratories and animal pounds.
Type 6	Medical waste including sharps pathological, surgical and associated infectious waste materials.
Type 7	Department store waste.
Type 8	School waste with lunch programs.
Type 9	Supermarket waste.
Type 10	Other wastes (radioactive wastes, metallic wastes, gaseous wastes etc.)

I.2.3 Waste Hierarchy

An integrated waste management system is based on the hierarchy of waste management ,which combines the concept of 'reduce, reuse, recycle' (3Rs). The most popular pillar is waste prevention, which encourages individuals to limit waste production and sort recyclables from non-recyclables at the source. Waste pricing is recommended as a means of reducing and preventing waste. When people utilize the system less, they pay less for it. People in industrialized countries are conscious of their consumption patterns. As a result, trash generation puts them ahead of underdeveloped countries, which are still struggling to change their systems. The reuse of garbage and recycling of recyclable resources are the following priorities. A separate system must be constructed in order to achieve high sorting and collecting recovery efficiency. Separation of trash at the source is required for waste minimization, reuse, and recycling. The government should establish a new recycling market. After reuse or recycling, the recyclables produced by each waste industry are returned to the consumption cycle, fostering a CE across the country. Waste prevention, reduction, and reuse are more cost-effective than disposal since they demand less expenditure and produce a higher return on investment. This allows the country's cities to take advantage of a variety of climate co-benefits, including increased income and energy security. This necessitates the alignment of mitigation and adaptation policies in cities, as well as financial and technological assistance for climate-sensitive development projects [7].

The following figure I.1 describes the 7 ways that waste is generally dealt with, ranging from least to most preferred (top to bottom):

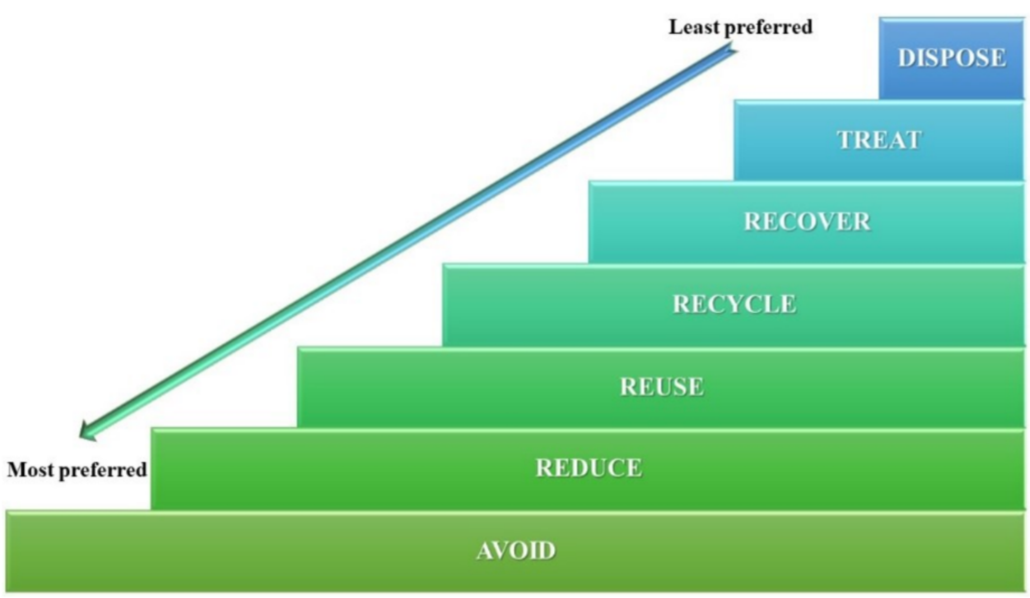


Figure I.1: Waste management hierarchy

I.2.4 Disposal methods

Solid garbage has traditionally been disposed of in landfills. which is The most cost-effective waste management solution. on the other hand, we have hospital waste that include expired drugs, plastic syringes, surgical dressings, etc. They can be very infectious biomedical wastes. Proper medical waste management requires special treatment of such waste, such as incineration or hazardous waste landfill facilities. Many people consider the disposal of radioactive waste to be a complicated, difficult, and dangerous technological task. One of the safest methods of disposing of radioactive waste is geological disposal, Geological disposal is based on the concept of multiple barriers that work together to provide containment. The natural barrier is provided by the rocks and soils between the repository and Earth's surface [5].

- Landfill:A landfill is not a normal environmental condition, though, nor is it intended to be. Instead, a landfill is more like a tightly sealed storage container. A landfill is designed to inhibit degradation to protect the environment from harmful contamination. Deprived of air and water, even organic wastes like paper and grass clippings degrade very slowly in a landfill

- Incineration: Incineration is a waste disposal procedure that involves the burning of garbage. "Thermal treatment" is a term used to describe incinerators and other high-temperature waste treatment facilities. A solid waste incinerator, according to Yang et al., is a facility that is designed, built, and operated under specific design circumstances. A typical incinerator treats waste that has been collected as input material, meets its purpose of waste treatment, and recovers heat energy from the combustion process as a secondary benefit.

- Bio-gas: Anaerobic digestion (AD) is the process of converting organic matter directly into bio-gas, which is a mixture of mostly methane and carbon dioxide with tiny amounts of other gases like hydrogen sulfide. Methane is the primary component of bio-gas, which is utilized for cooking and heating in many households. The bio-digester, also known as a bio-gas plant, is a physical structure that is used to create an anaerobic environment that promotes different chemical and microbiological reactions, culminating in the decomposition of input slurries and the creation of bio-gas—mostly methane.

I.2.5 Household participation in waste management

Communities continue to be regarded as passive beneficiaries of government services in many parts of the world, and they are frequently ignored even in local decision-making processes. Participation could be a missing link for better solid waste management in the presence of many solid waste management approaches. There is also growing agreement on the immediate stakeholders in the solid waste issue. The waste generators, in this case the residents, must work together with the authorities to address this problem, which has far-reaching environmental and human health consequences. Garbage volumes have increased in urban areas, owing to the expanding urban population, concentration of industries, resident consumption, and a lack of financial and facility resources to handle waste collection and disposal. As a result of this situation, the volume of solid waste generated has exceeded the capacity of the current facilities. As a result of increased lobbying for the end of top-down development policies in favor of greater engagement of development program subjects, participation as a concept has gained traction. Although participation is usually understood to be a choice process, in certain cases it necessitates people being pulled into operations that they do not want to be a part of, but are coerced in the name of participation. Between developed and developing countries, the level of public participation in solid waste management is noticeably different. Household participation in solid waste management in industrialized nations may extend to sorting the waste created. Private companies then charge a fee to collect the rubbish that has already been sorted. The fees paid compensate for the processes in which the general public should have been involved in garbage management. To put it another way, In other words, the burden is passed on to the private waste collectors at a fee. The situation is different in developing countries. First and foremost, the majority of the population is unable to afford waste collection fees on a regular basis. Second, many people unknowingly dispose of waste irresponsibly, with little regard for the long-term consequences of their actions. Third, some people simply do not comprehend the complexity of the waste problem or who will eventually take the burden of the consequences. Households appear to believe that it is entirely the responsibility of the local government to ensure proper waste disposal at no additional cost. Households must be well-informed about important concerns and how they can engage effectively in national solid waste management [15].

I.2.6 Challenges

Several factors, depending on the method used for this aim as well as the features of the home in a given place, challenge the process of household participation in solid waste management. It is stated, for example, that proper opportunity, facilities, understanding, and convenience influence attitudes toward recycling. People differ in terms of their knowledge base and what they consider to be convenient for them. As a result, their perspectives are automatically different. The other problem is that there are gaps in information, knowledge, and awareness among the general people, which makes involvement difficult. Read et al (1998) discovered that there was little awareness of best practices in waste minimization across different administrative areas/local governments in a study on waste minimisation in local governments in the United Kingdom. To maximize the benefits of family engagement, knowledge and awareness gaps must be addressed. Involving the public with their knowledge gaps may only result in a challenging participation process in solid waste management. A major limitation is a lack of or limited awareness and appreciation of best practices for environmentally sound garbage management, necessitating a paradigm shift among communities and society as a whole. The management of solid waste is influenced by policy. In an ideal world, policy serves as a driving force behind the solid waste management system, providing direction and energy. However, the data demonstrates that, in most parts of the developing globe, such activities have not prospered due to a lack of clear public policies as well as the economic certainty of investments in municipal trash segregation and recycling, it becomes extremely difficult to properly involve families in solid waste management within a structure that lacks defined governmental rules [15].

I.3 Smart Cities

During the latest years, smart city projects have been more and more popular and widespread all over the world.The ever-increasing population of cities, as well as the complexity of city management, push local governments to make more use of technology in order to support a higher quality of urban environments and a better delivery of public services. The allure of smart cities, which may integrate high technology, the environment, and citizen well-being, piques the curiosity of all municipalities, regardless of their size, geography, or culture. The concept of a smart city, on the other hand, is far from clear. Several examples from throughout the world indicate that cities characterize themselves as clever, yet the meaning ascribed to this term varies depending on the context. Smart city concept has been growing from empirical experience, therefore a systemic theoretical study about this phenomenon still lacks [4].

I.3.1 Definition

The term "smart city" is defined in a variety of ways. Because the notion is well-known but is utilized in a variety of ways around the world under different names and in different contexts, there are a variety of conceptual variants that can be formed by substituting smart with other adjectives. Smart city, according to some countries, is a "urban labeling" phenomenon, particularly in terms of what the title philosophically reveals as well as hides. Smart city is a nebulous term that is applied in a variety of ways. There is no one-size-fits-all definition of smart city or a single blueprint for framing smart city [11].

I.3.2 Components

We can better understand what makes a smart city by identifying and clarifying some of its key conceptual components, then re-categorizing and simplifying them into three categories of core factors:

- technology (hardware and software infrastructures).
- people (creativity, diversity, and education).
- institutions (governance and policy).

Given the interconnections of the components, a city is smart when investments in human/-social capital and information technology infrastructure fuel long-term growth and improve quality of life through participatory government [11].

We can take a closer look at the most fundamental components of any smart city in the following figure I.2

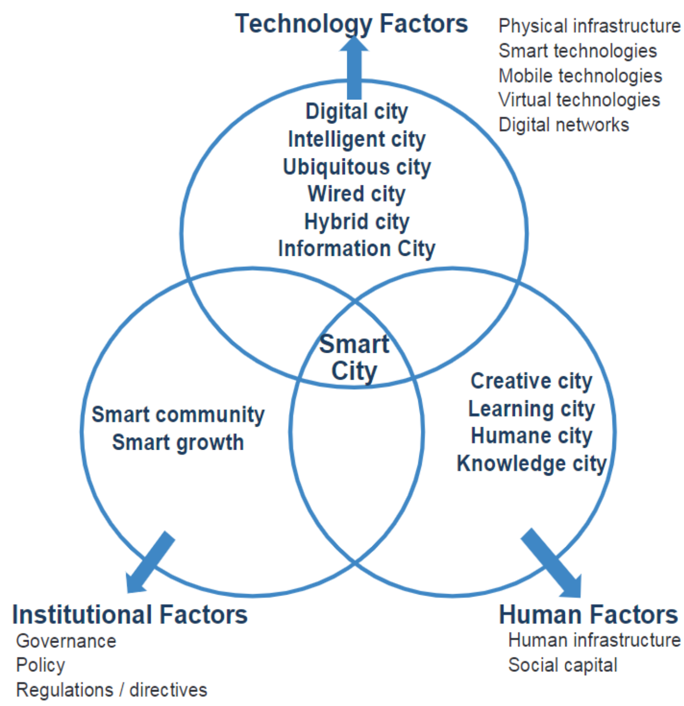


Figure I.2: Fundamental Components of a Smart City [3]

I.3.3 Applications

As a smart city connects the physical world and the information world, many intelligent applications are emerging, from local to global, from sensing to control. as these applications benefit people and the city in a variety of aspects: energy, environment, industry, living, and services, we introduce several key applications as follows:

- Smart Energy: Exploiting the widely deployed sensors to monitor energy generation, transmission, distribution, and consumption, smart energy leverages utility usage, electric vehicle charging, smart grid, and so on.
- Smart Environment: The smart environment is pushed to help the smart city maintain a comfortable climate and a sustainable environment. In smart environment applications, ubiquitous sensing and intelligent climate control are combined.
- Smart Living: In home areas, smart living offers intelligent management of a variety of appliances and utilities in order to create comfortable homes while also increasing energy efficiency.

The figure I.3 summarizes the applications that a smart city can provide to it's residents:

Figure I.3: smart city applications [8]

I.3.4 Requirements and Challenges

- **Flexibility and Programmability**: To access multiple cloud apps, millions of diverse devices generate a lot of network traffic. To access these applications, this network traffic takes a variety of routes. Routing policies, which include route computation and notification of modifications, must also be followed by a municipal network. In order to safeguard assets from cyber threats, the network must also follow certain security regulations. In this setting, an effective method is essential to ensure that city services run smoothly. Individually modifying network devices to boost networking functionality is one such method. However, this method may result in an increase in both cost and time. As a result, a programmable and centralized network manager is required to apply network flow rules to multiple devices.

- **Communication Latency**: In a smart city, traditional resource management relies on cloud services. Because of its infinite computing capability, cost effectiveness, and adaptability, these solutions are advantageous. Moving all data and services to the cloud, on the other hand, comes with a number of drawbacks, including significant communication latency, the chance of failure, and security risks.

- **High-Speed Network Traffic**: To access cloud apps, smart sensing devices continuously generate significant amounts of network traffic (packets). Before reaching the cloud, these network packets go through a series of network processes. Packet processing entails parsing each packet and extracting valuable data from it, such as the header and payload. This information is used for additional processing by several network functions (NFs), such as content-based routing, virus detection, and firewall rules. Due to their hardware design, CPU-based packet processing systems typically have performance restrictions. As a result, they require a viable solution for high-speed packet processing.

- **Network Security**: Smart city networks require the highest level of protection and security. Because many smart applications use the city network, they are exposed to security risks like eavesdropping, manipulation, and alteration. They're also vulnerable to assaults like Sybil, Man in the Middle, and Denial of Service. These circumstances may cause city services to be disrupted or degraded. The severity of these vulnerabilities varies depending on the application. Service outages in the smart grid, for example, may have an unacceptably high impact on end consumers. A waste management system, on the other hand, can endure service interruptions. The influence of network security on city services has been summarized. This necessitates the implementation of a sophisticated network security system.

- **Privacy**: Data has become a valuable tool that has the potential to dramatically improve local services. Online social networks, such as IoP and mobile crowd sensing, generate heterogeneous data that is vulnerable to attacks such as the Sybil attack and the man in the middle attack, among others. These potential attacks are geared toward user privacy concerns, such as identity theft (name, address, phone number, etc.), sensitive data leakage (occupation, health status, etc.), inferring sensitive information (smart meter reading to violate residence privacy), and location privacy violations. As a result, an effective solution is required to address privacy concerns.

  [14]

I.3.5 Proposed Solutions

- **Network Programmability and Adaptability**: The first criteria specifies that smart applications require programmable and adaptive network services. The incorporation of the above critical components is ensured through a software-defined network (SDN). SDN's fundamental characteristic allows for the deployment of a centralized network manager, known as an SDN controller. Depending on the current network status, network administrators can adjust the configuration on an SDN controller. To get a global picture of network pathways, we recommend implementing a controller at the cloud layer. All network devices get network policies from the controller, such as route computation, updates, and priority route selection.

- **Fog Layer**: When talking with the cloud layer, the second criterion focuses on lowering communication latency and security issues. To get around this problem, we propose using fog computing, which acts as a bridge between the sensing layer and a distant cloud. Communication latency and reaction time are reduced by using application-processing techniques at the fog layer. At this layer, we recommend implementing the GS witch, which is useful for reducing security concerns and choosing the best network path.

- **Accelerating Network Traffic**: In order to achieve a fast reaction time, the third condition necessitates high-speed packet processing. The rise of network functions virtualization (NFV) allows network applications to run on commodity hardware, allowing for greater flexibility and scalability. At fog nodes, we propose implementing NFs such packet processing, dangerous content detection, and application-aware forwarding. This implementation is useful for a variety of reasons. First, it saves network bandwidth by filtering packets before they enter the core network. It also encourages cost-effectiveness and programmability, which are two prerequisites for supporting a large number of applications in a smart city. We've been motivated to use GPUNFVs to achieve high speed. To improve scalability, fog nodes can be supplied with numerous GPUs.

- **Network Security**: The necessity of network security considerations for smart applications is emphasized by the fourth criteria. We advocate gathering and evaluating data about system calls, system events, and file systems before deploying GPU-based HIDS. We also recommend using GPU-based NIDS to protect against many types of attacks, such as DoS assaults, port scans, and so on. In general, NIDS makes use of the data retrieved from the DPI module to help detect malicious behavior in a variety of ways. It recognizes unusual activity and detects malicious material in network packets by constructing a profile of routine network behaviors that do not match normal behavior. Furthermore, NIDS protects the network by enforcing firewall rules that prevent network traffic with questionable behavior from entering the network. [14]

I.4 Digitization

Digitization has been identified as the most significant technological trend that is changing both, society and business. Firms are under constant pressure these days to adopt digital technology and adjust their business models to this new reality. However, while turning digital has numerous advantages, it also necessitates investments and costs [12].

I.4.1 Definition

Digitization is the process of spreading of a general purpose technology. The last similar phenomenon was electrification. Digitization of products and services shortens distances between people and things. It increases mobility. It makes network effects decisive. It allows the use of specific data to such an extent that it permits the satisfaction of individual customer needs be it consumers or businesses. It opens up ample opportunities for innovation, investment, and the creation of new businesses and jobs. Going forward it will be one of the main drivers of sustainable growth [12].

I.4.2 Examples

the following are three of the main fields where Digitization are applied:

I.4.2.1 Banking

Digitalization is becoming increasingly important in today's fast-paced environment. Almost all sectors of the economy rely on digitization for growth, and the banking industry is no different. In comparison to those countries who are lagging behind in implementing digitization, those that are easily adjusting to it are functioning remarkably well. Financial inclusion benefits greatly from banking digitization, and the economy as a whole grows more quickly as other industries advance.

I.4.2.2 Education

Digital education is generating new learning opportunities as students engage in online, digital environments and as faculty change educational practices through the use of hybrid courses, personalized instruction, new collaboration models and a wide array of innovative, engaging learning strategies.

I.4.2.3 Healthcare

Traditional healthcare organizations have understood that they need to modify the way they function; for example, most significant pharmaceutical corporations have hired a chief digital officer in the last two years. There are still a lot of unknowns regarding how to digitize processes and what the different options are for maximizing their potential, as these healthcare organizations and start-ups have different cultures and approaches to development and manufacturing.

I.5 Challenges and Solutions

The network infrastructure of smart cities is complicated, with multiple networking devices at the core, edge, and sensing levels. To access the distant cloud, network traffic (packets) from a diverse group of apps share network resources. Communication links, switches, and network middle boxes are examples of these resources. As a result, using cloud apps causes increased communication delay, packet loss, and a reduction in available capacity. Attacks such as side channel, man in the middle, botnets, and cold boot assault compromise the security and privacy of smart city networks. Users may be hesitant to accept the smart city concept if security and safety systems are insufficient. For quick response, smart city applications require high-speed network packet (header payload) processing. Payload-based functions, such as harmful pattern identification and content-based routing, rely on packet processing information.

I.6 Conclusion

For long years, authorities have recognized that digitization has the potential to significantly improve economic, social, and political outcomes. However, unlocking the potential of broadband will require that policymakers undergo a shift in their thinking. They must look beyond ICT and instead concentrate on digitization, with a focus on ICT usage rather than access. They must consider their present degree of digitization to ensure that they are concentrating on the necessary investments in order to get to the next step. They also need to look at rules made a decade ago with fresh eyes to see how they may be revised for a new era. Policymakers are optimistic about this opportunity, and several have already taken steps to take advantage of it. Whether they can turn chance into reality will be determined by the initiatives they take in the following years. In the next chapter we'll talk about AI and some of the applications it can bring into the waste management field, we'll be discussing some of the related works done in this field.

Chapter II

Research Methods: Artificial intelligence

II.1 Introduction

As the world moves towards sustainable development, in developing countries, growing population numbers, a thriving economy, fast urbanization, and rising community living standards have dramatically accelerated the accumulation of municipal solid trash. Municipalities, who are normally in charge of trash management in cities, face a difficult task in providing residents with an effective and efficient system, due to the absence of structure, financial resources, system complexity, and multidimensional. smart cities on the other end are integrating cyber-infrastructure to support all-around economic growth, including greater quality of life and more efficient resource management, by increasing their focus on developing solutions to these issues using smart enabling technologies like the Internet of Things (IoT), big data, and artificial intelligence (AI).

II.2 Definition

artificial intelligence (AI), the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience. Since the development of the digital computer in the 1940s, it has been demonstrated that computers can be programmed to carry out very complex tasks—as, for example, discovering proofs for mathematical theorems or playing chess—with great proficiency. Still, despite continuing advances in computer processing speed and memory capacity, there are as yet no programs that can match human flexibility over wider domains or in tasks requiring much everyday knowledge. On the other hand, some programs have attained the performance levels of human experts and professionals in performing certain specific tasks, so that artificial intelligence in this limited sense is found in applications as diverse as medical diagnosis, computer search engines, and voice or handwriting recognition.

II.3 AI in Waste Management

In this part we will talk about the role of AI in waste management:

II.3.1 Artificial intelligence applications in waste management

Numerous technological, climatic, environmental, demo-graphic, socioeconomic, and regulatory elements are often involved in waste management operations. Modeling, predicting, and optimizing such complicated nonlinear processes using traditional methods is difficult. Artificial intelligence (AI) techniques have recently gained traction as an alternative computational approach to solving solid waste management (SWM) issues. AI has proven to be effective in solving ill-defined issues, learning from previous experiences, and dealing with uncertainty and incomplete data. Despite the fact that significant research has been done in this area, several review studies have evaluated the potential of AI in handling a variety of SWM challenges, such as waste character forecasting, waste bin level detection, process parameter prediction, vehicle routing, and much more.

II.3.1.1 Prediction of solid waste characteristics

MSW collection, treatment, and disposal are all dependent on accurate waste characteristics predictions, which are influenced by a variety of technological, social, legal, environmental, political, and cultural factors. Unconventional modeling tools were expected to account for these aspects because to their interconnection, as well as a lack of data and accompanying uncertainties. The majority of studies looking into the use of AI in waste management focused on the prediction of solid waste characteristics. Waste generation predictions was the most commonly studied use in these studies. In those applications, ANNs were the most extensively used, followed by SVMs. Several other studies looked at how to classify waste materials for use in automated sorting systems that eliminate the need for manual garbage separation. ANNs were employed in the majority of these research for the identification of different waste fractions [1].

II.3.1.2 Bin level detection

Models for predicting the fill level of garbage bins have been created, and they can be used to successfully combat inappropriate waste disposal and waste bin overloading. Temporal fluctuations in discarded quantities have an impact on the performance of smart trash collection systems. Real-time data from level or image sensors installed in smart garbage bins is often supplied into the algorithms. Few studies have employed artificial intelligence (AI) to improve the solid waste collection process by using gray level aura matrix (GLAM) to build the picture texture of a 120L waste bin and comparing the performance of an MLP BP neural network with the KNN algorithm for waste level classification. The GLAM system showed more than 95% efficiency in generating image textures of the bin. Similarly, both algorithms achieved accuracy level greater than 95% [1].

II.3.1.3 Vehicle routing

A successful integrated SWM plan requires proper waste collection routing; collection costs typically account for 70 to 85 percent of total SWM costs. Unorganized collection schedules and insufficient truck allocation lead to excessive vehicular emissions and traffic congestion, as well as higher operational expenses. Several research have created optimization models for garbage collection frequency and route planning, with the bulk of them relying on GA and hybrid variants. During the collection of electrical and electronic household garbage, some companies used GA to optimize their routes. Because of the streamlined route distance, number of collection trucks, and staff, GA reduced collection expenses. Users were encouraged to participate in the scheduling of garbage collection requests in order to develop efficient routes, according to the methodology. The findings of the analysis revealed that, while the AI-optimized route length was reduced, the average service time was 85 percent longer than the non-optimized approach [1].

II.3.1.4 Waste management planning

SWM planning entails making management decisions and optimizing management processes in order to achieve strategic objectives and goals. It covers a wide range of topics, including designing waste collecting plans, locating SWM facilities, avoiding unlawful disposal, and reducing costs and environmental implications during trash collection, transportation, treatment, and disposal. AI approaches for waste management planning have been used in several studies. One study used DTs to detect unlawful garbage disposal and was successful in identifying over 500 trucks that may have been involved in illegal dumping. SVMs and satellite data were utilized by some to find agricultural plastic trash and aid in the location of disposal facilities and route planning. With a 94.5 percent accuracy, SVM was used to categorize photos and distinguish between crops and plastic garbage. Another experiment used rough sets to determine the optimal cost-based waste allocation strategy to be implemented for the available waste processing and disposal facilities [1].

II.4 Related Works

In this subsection, we will mention some of the previous work on different models, in order to make a comparison between our work and their work:

II.4.1 Waste Monitoring System Using ICT

The proposed solid waste monitoring system is built by combining communication technologies such as radio frequency identification (RFID), global positioning system (GPS), general packet radio system (GPRS), and geographic information system (GIS) with a camera. The goal is to improve the way we respond to customer inquiries and emergency situations, as well as estimate the amount of solid trash without involving the truck driver. The suggested system includes an RFID tag mounted on the bin, an RFID reader as the truck module, a web server, a map server, a database server, and a control station server [2].

II.4.1.1 Integrated Technologies

- RFID: stands for "radio frequency identification", and it is a technology that allows readers to read data from tags and transmit it to a computer system without the need for a physical connection. Unlike traditional inventory systems, auto-ID technologies have been employed to reduce the amount of time and effort required to manually input data while also improving data accuracy. Automotive, contact-less payments, laundry, library, livestock, pharmaceutical, retail supply chain management, and ticketing are just a few of the applications that RFID technology is employed in around the world.
- GPS: stands for "Global Positioning System", is a satellite-based navigation system that uses satellites in orbit to record locations from all over the world. The satellites send out brief radio pulses to GPS receivers on a regular basis to determine distance and compute two-dimensional or three-dimensional position. Today, GPS is widely utilized in automobiles for delivering emergency roadside assistance, calculating the vehicle's position on an electronic map display, and assisting drivers in maintaining track of their whereabouts. Modern technologies generate a route and provide turn-by-turn directions to certain sites automatically. The truck's position is determined via GPS in this clever solid work system.
- GPRS: stands for "General Packet Radio Service", it's based on the existing GSM system (Global System for Mobile Communications) and can be connected to the internet. It connects mobile users to the data network and provides high-speed wireless IP. Packet switching technology is used in GPRS, and each user can use many wireless channels at the same time. Data transfer speeds of up to 160 Kbps are possible. Users can stay connected at all times and pay their bills in real time by using GPRS technology to send and receive data packets. It drastically reduces the cost of servicing. The GPRS network has a large coverage area and can provide fully ubiquitous, real-time requests.
- GIS: stands for "Geographic Information System", GIS is a computer-based system that combines hardware, software, and data to gather, manage, analyze, and display all types of geographically linked data. It aids in the visual analysis of data and the identification of patterns, trends, and linkages that may not be obvious in tabular or written form. A GIS differs from conventional information systems in that it combines standard database operations like query and statistical analysis with the benefits of visual and spatial analysis via maps [2].

II.4.1.2 System Operation

In order to obtain the serial number of the bin, RFID tags are put on 120 and 240L bins. The serial number is captured by an RFID reader positioned in the truck and relayed to the control station via GSM/GPRS network. When the truck approaches the bin, the RFID reader communicates with the RFID tag to capture the ID and other information about the bin and send it to the control server. Once the control server receives the serial number, the system is ready to receive the first image and compare it to the reference image stored in the database. The camera then takes the first picture, After the collection process is done, the camera captures the second image. The actual content of the bin and its surrounding area can be accurately calculated in this manner. The shape and area of the goods can be determined using a camera connected to an RFID reader mounted on the truck's roof. In terms of the camera, it's a low-resolution RGB camera that's installed on top of the truck and can cover a 3m radius around the bin. A passive LF RFID tag is attached to the container. The reader obtains the serial number and location of the bin via the tag when the truck is in close proximity to the bin. The reading distance between the tag and the reader is approximately 3m, ensuring proper trash collection and management due to precise data in less time. When the RFID reader reads the bin's serial number, LF RFID provides resilience to environmental factors. Because moisture does not absorb the large radio frequency wavelength of LF, it is more water-resistant. Because of these factors, LF RFID is appropriate for systems with high humidity and rainy weather.

The following figure II.1 summarizes the proposed architecture of this work:

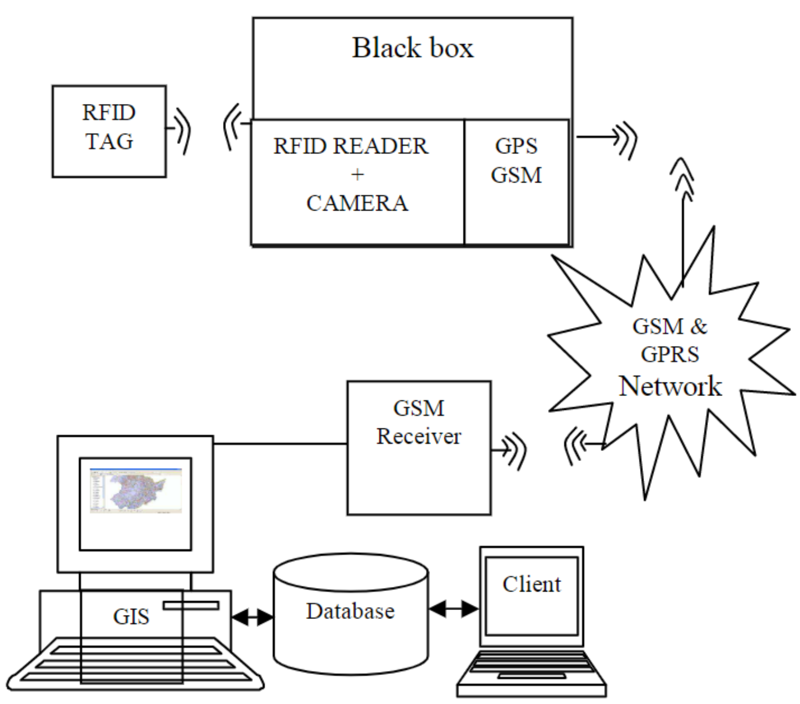


Figure II.1: Architecture of waste monitoring system

II.4.2 Multi-Agent based IoT smart waste monitoring and collection architecture

Researchers have proposed an Internet of Things (IoT) architecture to monitor and collect waste in real time; Able to improve and optimize solid waste collection in the city. Netlogo's multi-agent platform was used to simulate real-time monitoring and smart waste management decisions. The level of waste filling in containers and truck collection process is extracted into a multi-agent model and citizen participates by paying for waste collection services. Moreover, waste level data is continuously updated and recorded and provided to decision algorithms to determine the optimal path for the vehicle to collect waste to the distributed bins in the city. Several simulations were carried out and the results were validated. The presented solution gives substance Benefit all waste stakeholders by enabling the waste collection process to be more efficient [10].

II.4.2.1 Functional Requirements

The following are the functional requirements of the simulated multi-agent based model:

1. The waste level in a bin should be generated in minutes per simulation tick.
2. Waste levels in individual bins must be updated and recorded on a regular basis.
3. The citizen is responsible for the cost of each garbage unit to be collected.
4. For waste collection, the truck must follow the generated optimal path.
5. The bin and vehicle must have the highest capacity for carrying waste while maintaining the nonfunctional performance of the simulated model in order to have adequate response time and throughput during waste collection.

II.4.2.2 Conceptual Design

- General architecture: The conceptual design depicts the suggested overall architectural execution as well as the central system architecture. The general design, identifies three actors: the citizen, the system administrator, and the truck driver. The corporation sells the citizen a smart bin, which he or she registers in the central system. The bin is in the designated area for citizens (home, church, mosque, hospital, school etc.). Through the internet, citizens can obtain information and make payments for waste collection. For continuous and real-time waste monitoring, the integrated circuit board will be embedded in the bin's lid. The gateway for delivering waste status data into the central system database is an Arduino WiFi Shield with GSM/GPRS connectivity.The administrator oversees citizen registration and payment information, as well as browsing and retrieving processed trash collection and transportation information, and assigning the best route to truck drivers.

  The figure II.2 describes the general architecture of this proposed work:

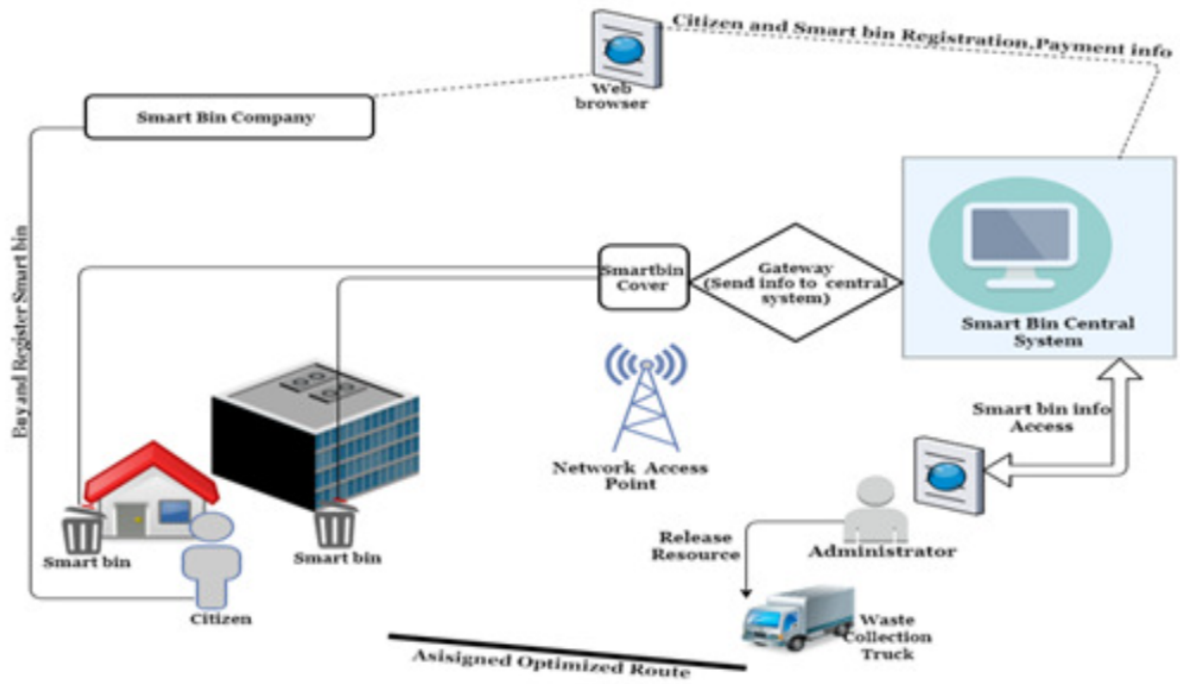


Figure II.2: General architectural implementation[9].

- Central system architecture: There are three tier architectures in this system: upper, medium, and bottom tiers. The upper tier is made up of a central database linked to the optimization model, the middle tier is made up of the gateway, and the lower tier is made up of sensor nodes. After establishing a connection with the server, the central system gets updates and saves waste status via gateways from various citizen locations. The linked optimization model is used to assess the data and determine the best trash collection path. The central system provides role-based constraints for both administrators and citizens through the user graphical interface.

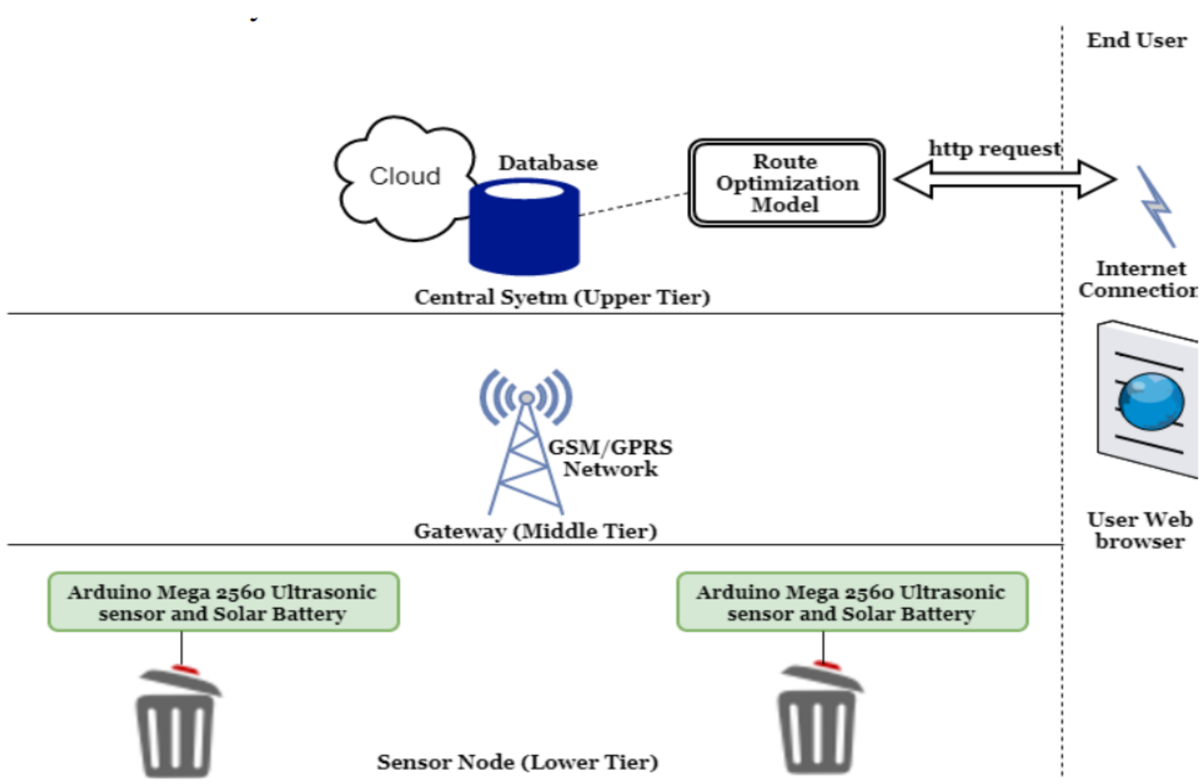


Figure II.3: Smart bin and Central systems architecture [9].

II.5 Conclusion

AI has proven to be one of the most promising and useful fields of research in computer science, not to mention that its application can be extended to touch almost every aspect of our daily lives, in this chapter we have have started with some of the benefits and advantages that it can bring to the waste management field, and then we've talked about some of the related works done in this area which used technologies like IA, IoT and ICT to reach their goal.

In the next chapter, we'll focus on the designed architecture of our system as well as the tools and languages we've chosen to use during the development, and finally we'll see how each application looks and some of its functionalities.

Chapter III

Design and Implementation

III.1 Introduction

After presenting some of the applications of AI in waste management as well as some related works in this field, our goal now is to design a new system for monitoring and managing the collection process with the help of three Web/Android applications that interacts with each other, in this chapter we'll discuss the design of the system and the functionalities that each application provide to it's user.

III.2 Proposed Architecture

The objective of the project is to design a system that consists of three main actors: Administrator, Driver and the Citizen, where each actor will be using a different application. In this project the system architecture will contain 3 different layers responsible for different tasks.It begins with the user interface layer where the users can interact with a map of our city of biskra and receive more information depending on the user. The Treatments layer provides the users with the appropriate map as well as providing basic functionalities that helps the user to interact with the map.Finally we have the Data source layer which is responsible for storing and retrieving all information related to our system, from basic login and user profile data to Geo-spatial and other map-related data. The Figure III.1 below show's our system architecture.

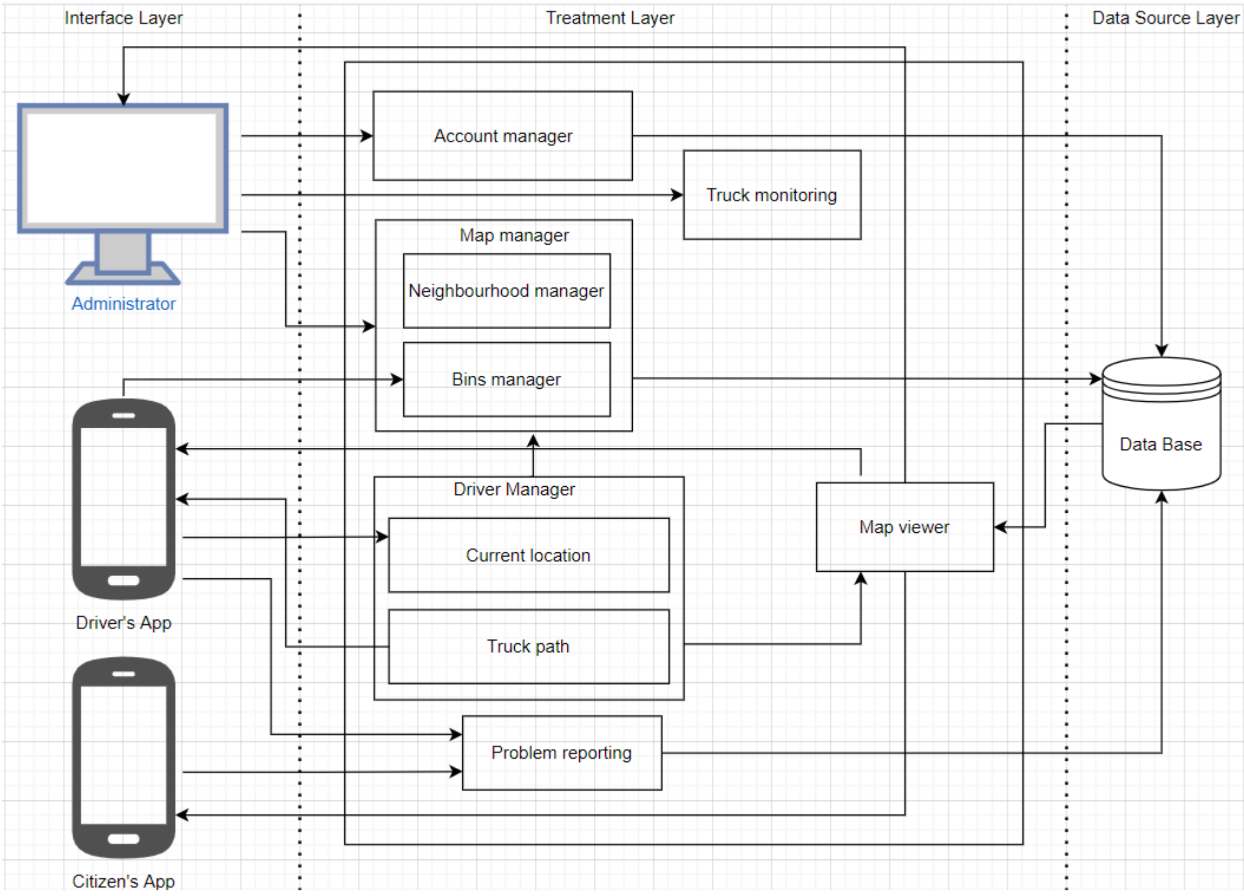


Figure III.1: The proposed architecture

III.2.1 Architecture Description

To understand the role of each component presented in the figure III.1, this subsection presents the process of each layer:

1. **Interface layer :** This layer represents the main way of interaction between the users and the system,

   - **Admin's web application interface:** which provides the admin with a map of biskra containing markers that represent both the locations of the Bins and the movement of the trucks in the city, as well as the ability to manage and control the bins locations/capacity, this interface also allows the admin to manage all of the workers profiles along with the Drivers accounts(username and password).
   - **Driver's mobile app interface:** it provides the driver with a map of the city that contains the bins but most importantly it enables him to report the progress of the collection process to the control center as well as reporting any problems that may occur during his shift.
   - **Citizen's mobile app interface:** it's main purpose is to show the citizen his location on the map along with the closest bins around him, also enables him to report any problems regarding the condition of the bins or the collection hours.

2. **Treatment layer:** This layer represents the whole system as this contain the most functions and the main methods. This layer composed by six different modules.

(a) **Map manager:** this module allows for interactions between the User and the system, it allows the user to manage all information regarding the bins and the neighbourhoods, it consists of two main managers:

- Bins manager: responsible for creating, deleting, editing, the bins locations and capacities.
- Neighbourhoods manager: responsible for creating, deleting, editing the neighbourhoods boundaries (represented by polygons), as well as their names and colors.

(b) **Account manager:** this module is responsible for the management of all of the workers profiles as well as the Drivers Accounts which the drivers will use to access the mobile application

(c) **Driver manager:** this module is reserved for the driver's app and has 2 main tasks:

- Update current location: this task requires the app to constantly update the system's server with the live position of the driver's phone therefor the trucks position.
- Truck path: in this task the module calculates the most optimum path for the truck to take in order to collect the bins located in its path.

(d) **Map viewer:** this module is responsible for providing the users with a map containing all the necessary information about the bins and neighbourhoods for the user of the app.

(e) **Problem reporting:** this module gives both the citizen and the driver the ability to report problems about the condition of the bins (broken, overflowing, missing...), as well as being able to report wild trash or any anomalies regarding the collection hours.

(f) **Truck monitoring:** this module keeps the admin updated on the movement of all the trucks by visualising the path each truck takes on the map.

3. **Data source layer:** this layer is represented as a relational database in the back-end which stores all information concerning the 3 applications, which we'll discuss in more depth in the next section.

III.2.2 Use Case Diagram

The following is the Use Case Diagram for describing how the 3 actors interact with the system:

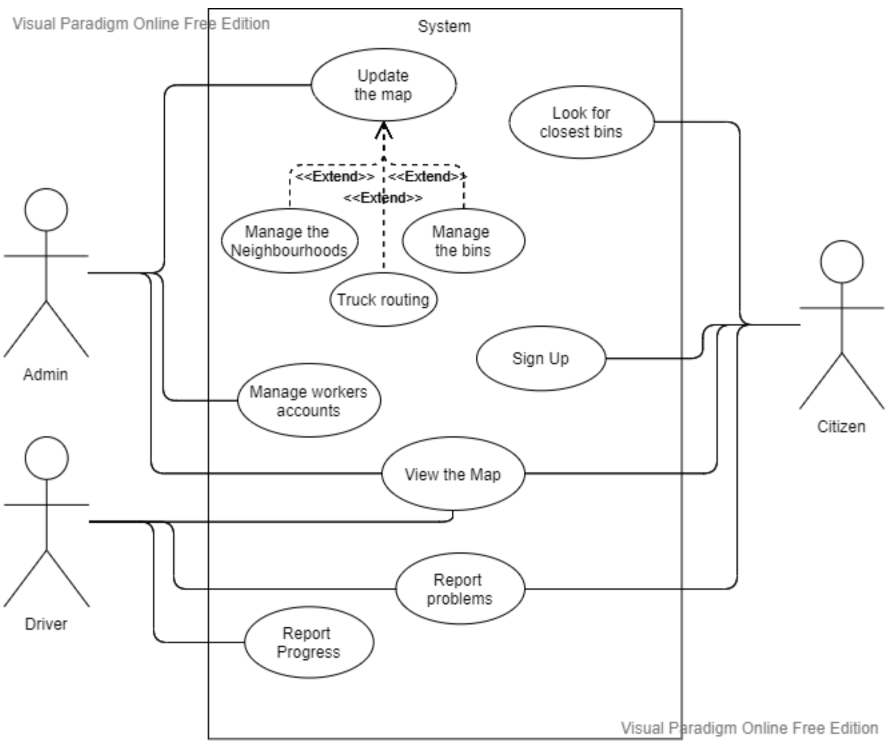


Figure III.2: Use Case Diagram

III.2.3 DB Description

the following figure is the proposed data base schema for our system:

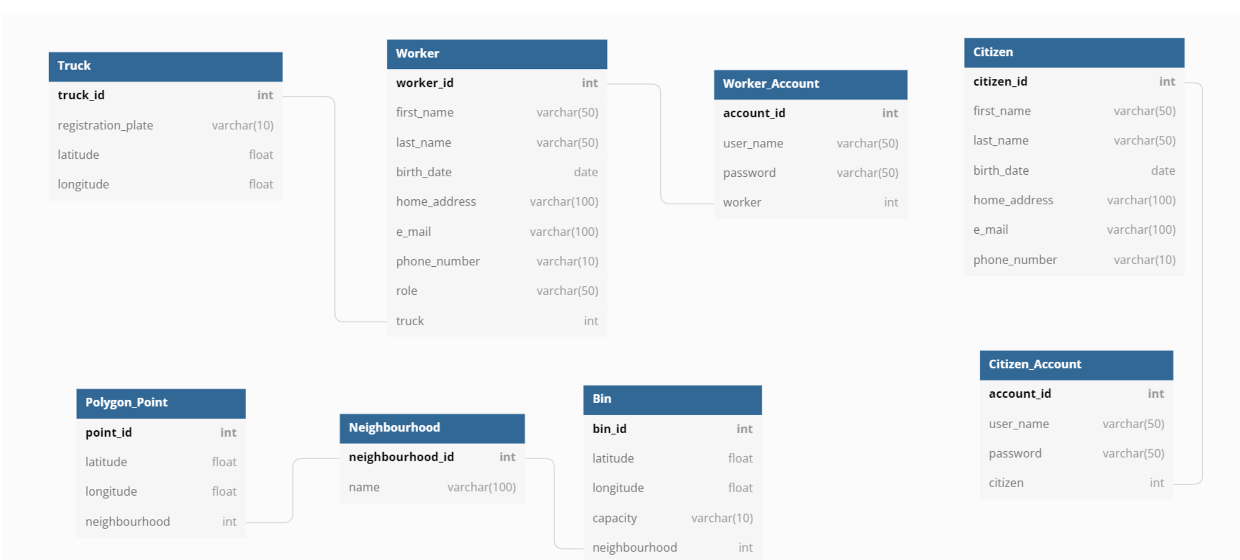


Figure III.3: Data Base diagram

for our system we opted for a relational SQL data base for storing all information about the workers, citizens as well as their accounts, in addition to the Geo-spatial data like the locations of the bins (latitude, longitude) and the boundaries of the neighbourhoods, here we'll take a closer look at the relations between the tables:

1. Worker - Truck: a **Many-to-One** denoting that every truck can have one or more workers but a worker can only be assigned to work in one truck.

2. Worker - Worker Account: this is a **One-to-One** relationship, where every worker can have one account, but only if his role is "Driver", and every account is used by only one worker.

3. Citizen - Citizen Account: this is a **One-to-One** relationship, similar to the previous, here every Citizen can have one account, and an account is used by only one citizen.

4. Bin - Neighbourhood: a **Many-to-One** meaning that a neighbourhood can contain many bins inside of its perimeter, but a bin only belongs to one neighbourhood, this relation is important in determining how much bins are inside a neighbourhood or where the bins are mainly concentrated in the city.

5. Polygon Point - Neighbourhood: a **Many-to-One**, this relation is needed because the neighbourhood is represented by a polygon on the map, this means we have to store the points that makes the polygon in a separate table where each point has a reference to the neighbourhood it belongs to.

III.3 Development tools and used platforms

After presenting and discussing the architecture of the system and its components in the previous section, in this one we'll show the developed apps through some results, as well as the used tools, platforms and libraries in the development of the three applications, in the end, we present the applications interfaces and discussion about given results provided by our system.

Our system, as mentioned before is composed of three applications, a Web application for the Admin who'll be located in a control center, a mobile application for the driver who'll be using it during his shift to report the progress of the collection process to the control center, and finally another mobile app for the citizen. The Soft-wares and libraries used in this project are listed below with a brief definition and explanation.

III.3.1 Admin Web application

III.3.1.1 Visual Studio Code (Code Editor):

VS Code is a code editor made by Microsoft, it's a light-weight tool that allows the editing of source code files. It comes with a huge library of extensions that ease the work for developers. Our choice landed on VS Code, since our project contains different programming languages (python, html, js, css).

Figure III.4: VS Code

III.3.1.2 Python:

Python is a high-level, interpreted, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation. Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly procedural), object-oriented and functional programming. It is often described as a "batteries included" language due to its comprehensive standard library.

Figure III.5: Python

III.3.1.3 Django:

Django is a Python-based web framework, free and open-source, that follows the model–template–views (MTV) architectural pattern.It is maintained by the Django Software Foundation (DSF), an independent organization established in the US as a non-profit. Django's primary goal is to ease the creation of complex, database-driven websites. The framework emphasizes reusability and "pluggability" of components, less code, low coupling, rapid development, and the principle of don't repeat yourself. Python is used throughout, even for settings, files, and data models. Django also provides an optional administrative create, read, update and delete interface that is generated dynamically through introspection and configured via admin models. Some well-known sites that use Django include "Instagram", "Mozilla", "Nextdoor" and "Clubhouse".

Figure III.6: Django

III.3.1.4 HTML:

The HyperText Markup Language or **HTML** is the standard markup language for documents designed to be displayed in a web browser. It can be assisted by technologies such as Cascading Style Sheets (CSS) and scripting languages such as JavaScript. HTML elements are the building blocks of HTML pages. With HTML constructs, images and other objects such as interactive forms may be embedded into the rendered page. HTML provides a means to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes and other items. HTML elements are delineated by tags, written using angle brackets. Tags such as ¡img /¿ and ¡input /¿ directly introduce content into the page. Other tags such as ¡p¿ surround and provide information about document text and may include other tags as sub-elements. Browsers do not display the HTML tags but use them to interpret the content of the page.

Figure III.7: HTML

III.3.1.5 CSS:

Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a markup language such as HTML. CSS is a cornerstone technology of the World Wide Web, alongside HTML and JavaScript. CSS is designed to enable the separation of presentation and content, including layout, colors, and fonts. This separation can improve content accessibility; provide more flexibility and control in the specification of presentation characteristics; enable multiple web pages to share formatting by specifying the relevant CSS in a separate ".css" file, which reduces complexity and repetition in the structural content; and enable the ".css" file to be cached to improve the page load speed between the pages that share the file and its formatting. The name cascading comes from the specified priority scheme to determine which style rule applies if more than one rule matches a particular element. This cascading priority scheme is predictable.

Figure III.8: CSS

III.3.1.6 NuxtJS:

Nuxt.js is a free and open source JavaScript library based on Vue.js, Node.js, Webpack and Babel.js. Nuxt is inspired by Next.js, which is a framework of similar purpose, based on React.js.

The framework is advertised as a "Meta-framework for universal applications". The term universal is used here with the meaning that the goal of the framework is to enable users to create web views in JavaScript utilizing the Vue.js single file component system and that can function both as in-browser single page application (SPA) views as well as server-rendered web views which are then (after server rendering) "rehydrated" to full SPA functionality. Additionally, the framework enables users to have the content, or parts of it, fully pre-rendered on the server and served in the manner of static site generators.

Figure III.9: NuxtJS

III.3.1.7 Leaflet

Leaflet is an open source JavaScript library used to build web mapping applications. First released in 2011, it supports most mobile and desktop platforms, supporting HTML5 and CSS3. Among its users are FourSquare, Pinterest and Flickr.

Figure III.10: Leaflet

III.3.2 Driver's Android application

The Android application developed using Android studio software with combination of JAVA programming language and the Extensible Markup Language (XML) and other libraries.

III.3.2.1 Android Studio

Android Studio is the Google official Integrated Development Environment (IDE) for Android app development, based on IntelliJ IDEA a powerful and intelligent code editor and developing tool. Android Studio offers unique features that enhance the productivity when building Android apps, such as:

- A flexible Gradle based build system
- Cover a large testing tools and frameworks.
- Provide a fast emulator that has many options and functional capabilities.
- A grouped and united environment where you can develop for all Android devices.
- Support code templates and GitHub integration to help you build common app features and import sample code.
- You can Apply Changes to your running app without the need to restart it by pushing code and resource changes.
- Lint tools to catch performance, usability, version compatibility, and other problems

Each project in Android Studio contains one or more modules that contain source code files and resource files, such as Library modules, Android app modules, and Google App Engine modules. Each app module contains Manifests,Java where Java source code files and res file where Contains all non-code resources, such as XML layouts.

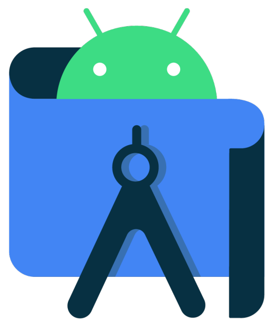


Figure III.11: Android Studio

III.3.2.2 Extensible Markup Language (XML)

XML is used to define documents with a standard format that can be read by any XML compatible application, XML is easy to read and understand both by human and machines. Also, it is scalable and simple to develop.XML is used In Android development for designing layouts, due to his lightweight language so it doesn't make layouts heavy.

Figure III.12: XML

III.3.2.3 JAVA

Java is a popular programming language that is class-based object-oriented, general purpose, concurrent and strongly typed, that is designed to have as few implementation dependencies as possible. It is normally compiled to the bytecode instruction set and binary format defined in the Java Virtual Machine Specification

Figure III.13: Java

III.3.3 Citizen's mobile application

this application was developed with the "Flutter" Framework, which is written with the "Dart" language, with the main reason being that applications developed using this framework are "cross platform" to enable the users (citizens) to access this app using any mobile phone.

III.3.3.1 Dart

Dart is a programming language designed for client development, such as for the web and mobile apps. It is developed by Google and can also be used to build server and desktop applications.

It is an object-oriented, class-based, garbage-collected language with C-style syntax. It can compile to either native code or JavaScript, and supports interfaces, mixins, abstract classes, reified generics and type inference.

Figure III.14: Dart

III.3.3.2 Flutter

Flutter is an open-source UI software development kit created by Google. The critical thing to know about Flutter is that it's a developer-friendly alternative for cross-platform app development. You can develop a flutter app once and cross-compile them for multiple platforms such as Android, iOS, Linux, macOS, Windows, Google Fuchsia, and the web from a single codebase.

benefits of Flutter framework include:

- Being able to preview changes.
- Highly delivering performance applications.
- Working with less-resource-intensive designs.

Figure III.15: Flutter

III.4 System Interfaces

in this section we'll go through the design and some of the functionalities of each application:

III.4.1 Admin Web application

III.4.1.1 Dashboard

The main page for the admin, which represents the dashboard that he'll be using to monitor the collection process including the movement of the trucks, and the management of the bins and neighbourhoods (create, edit, delete):

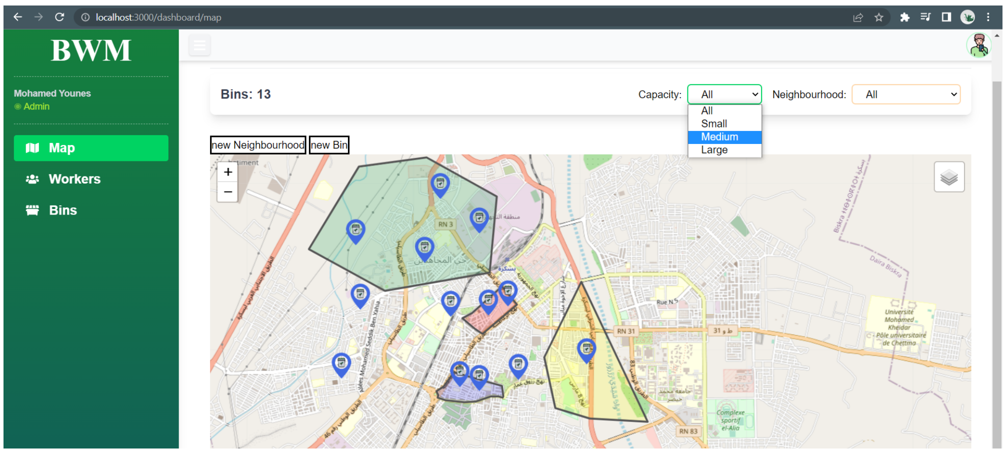


Figure III.16: Map

III.4.1.2 Workers

In this page the admin has the ability to create, delete or manage all the workers registered in the Data Base, he can also sort the workers by name, or search for a particular worker using the search field:

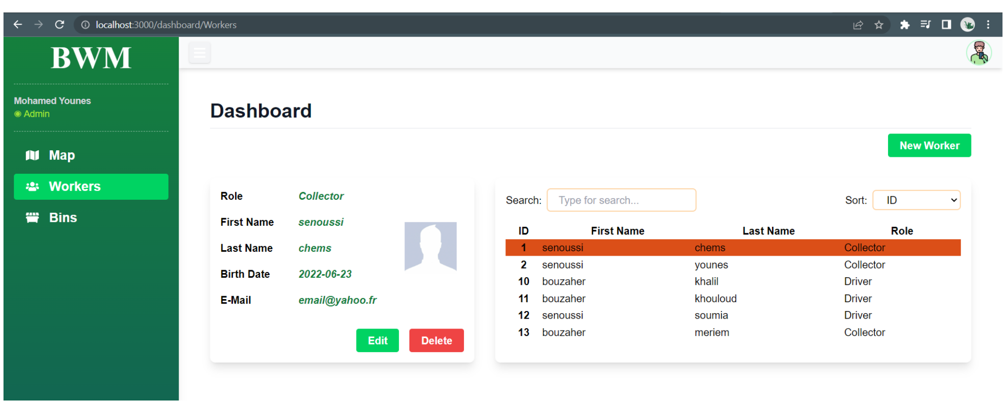


Figure III.17: Workers Table

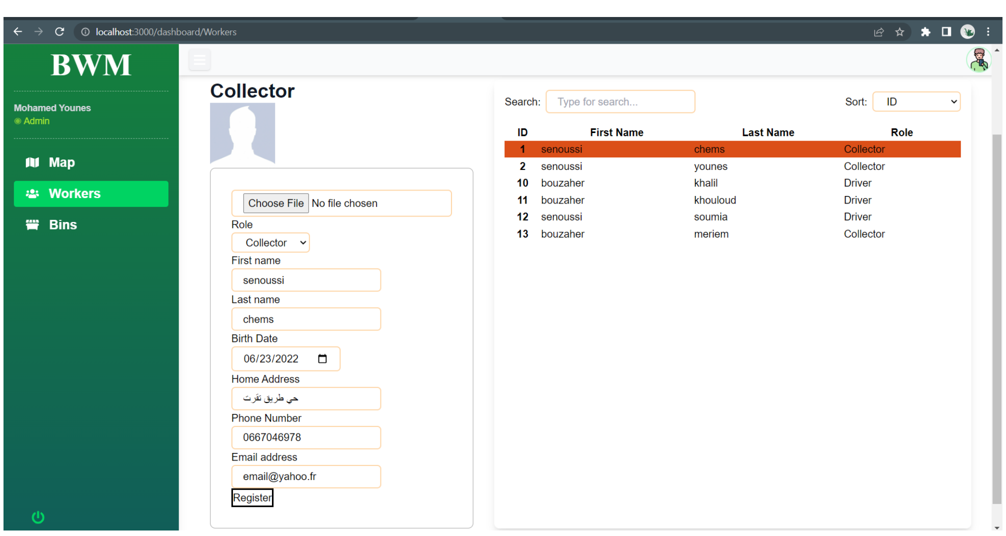


Figure III.18: Workers Form

III.4.1.3 Bins

In this page the admin create, edit or delete any bin, which are defined by their coordinates (latitude, longitude) as well as their capacity,he can also search for certain bins based on the neighbourhoods name or the capacity, as well as sort them by the same two properties

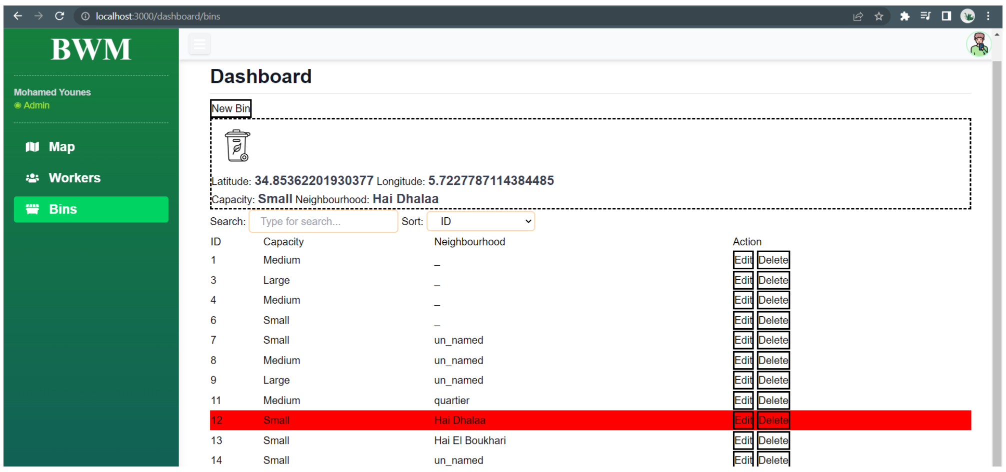


Figure III.19: Bins page

III.4.1.4 Neighbourhoods

This functionality is provided in the dashboard interface, where he can draw a polygon representing the area of which the neighbourhood spans, as well as a name and a color:

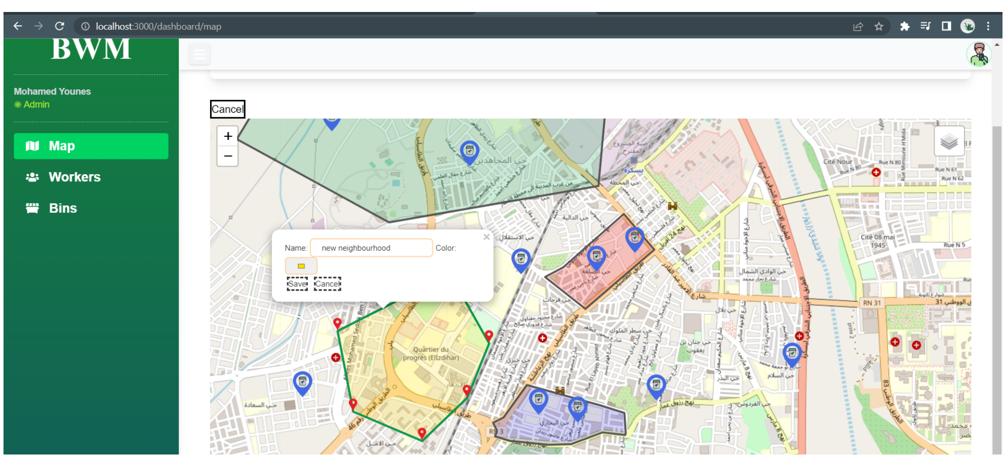


Figure III.20: Neighbourhoods

III.4.2 Driver's Android application

This part is written to describe Android application of trucks drivers

III.4.2.1 Log In

In this interface the driver must enters his user name and password in order to log in, which he receives from the admin after the later creates a profile and an account for the correspondent driver:

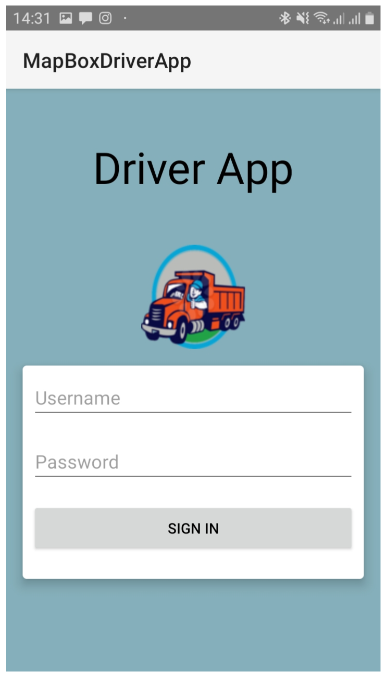


Figure III.21: Log In interface

III.4.2.2 Map and Path

After logging in the driver gets to see his location on the map of biskra with the path he's suppose to follow:

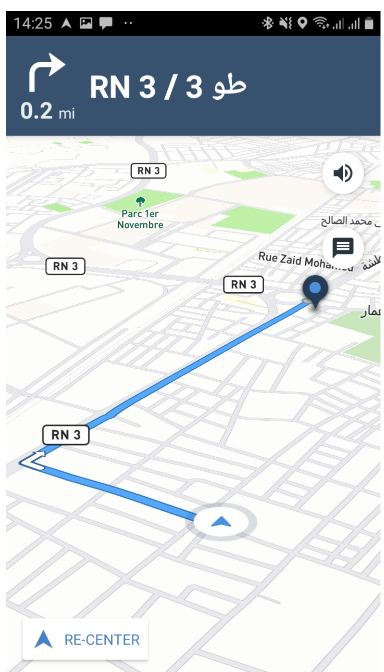


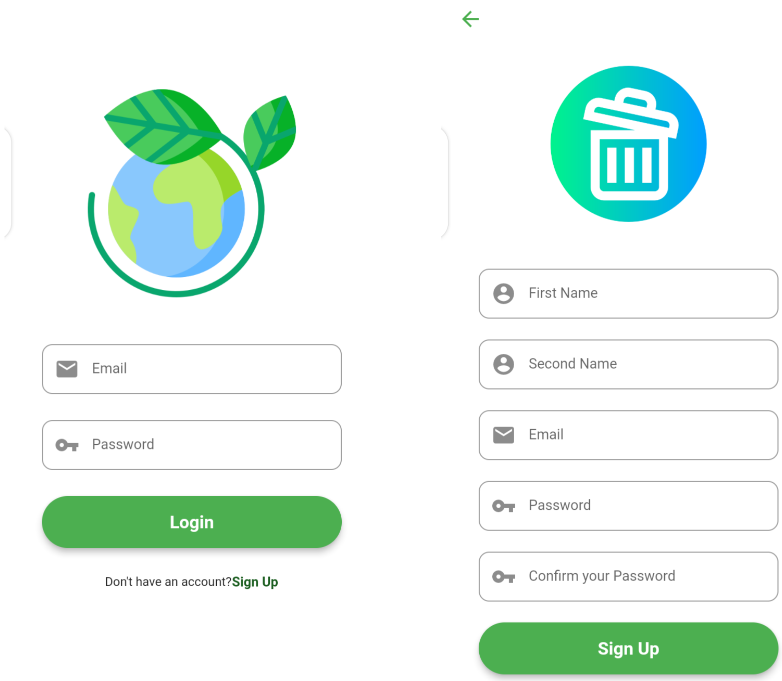
Figure III.22: Map

III.4.3 Citizen's mobile application

This part is written to describe citizen's application

III.4.3.1 Sign Up & Log In

At first, the citizen must create an account or log in if he already has one:



(a) Log in (b) sing up

Figure III.23: Log in and Sign up

III.4.3.2 Home Page

This is the first page after successfully logging in:

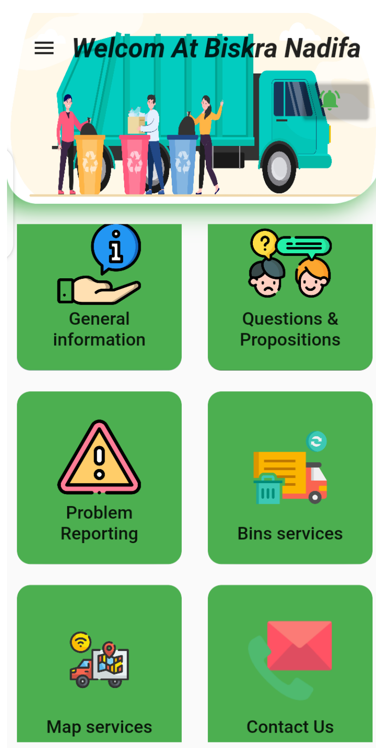


Figure III.24: Home Page

III.4.3.3 Map

In this page the citizen can see his location on a map of biskra:

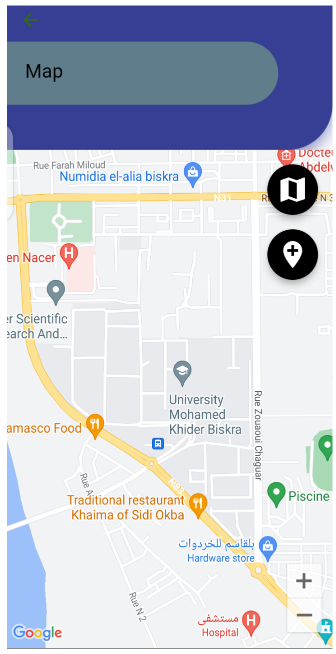
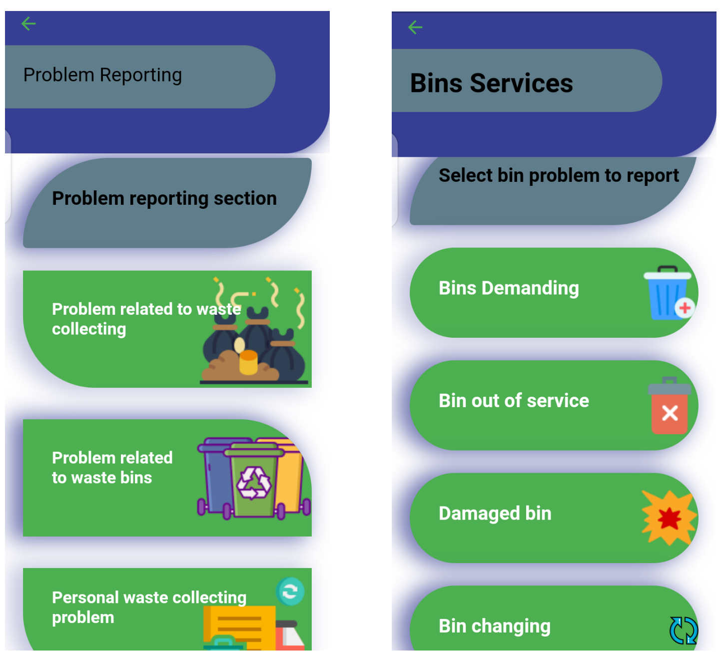


Figure III.25: Map

III.4.3.4 Problem reporting

In this part of the application the citizen has the ability to report any problems related to the collection process of the waste, including the bins:



(a) (b)

Figure III.26: problem reporting

III.5 Conclusion

In this chapter we presented the implementation as well as the design of our system. We chose our software programs and libraries based on the programming needs and the best methods to create the 3 application. We also would like to state that the design of the architecture of the system as well as the development of the applications is yet to be completed, as we hope to extend our work to include many more functionalities in the near future.

Chapter IV

Conclusion and Perspectives

IV.1 Conclusion

Urban cleanliness is one of the most important goals that the government seeks and spend money to achieve, not to mention that it's a main factor to consider for the development of any smart city. The goal of our project is to provide the government with the convenient system following the proposed architecture in the hopes of facilitating the monitoring of the waste collection process by connecting the drivers to the control center and bringing the citizen closer to the government by allowing him access to the map and enabling him to interact with the control center and ask any questions he has in mind.

IV.2 Perspectives

Our work can be extended to include much more functionalities such as using 3rd party APIs like "google Maps Directions API" service to provide both the drivers and the citizens with the shortest paths from their location to the closest bins in their area, also we can use IoT technologies like fill-level sensors to be attached on top of the bins in order to gain more information on the rates that each neighbourhood produces its waste, and finally we can provide more efficient and environment-friendly ways yo dispose all of the waste gathered from the city, like collaborating with the energy sector to use the waste as a source of power for electricity.

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