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THESIS

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An IoT-based platform for waste management system

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This work is dedicated to:

My Uncle who did everything he could to help me in my project, thank you for your calls and support.

My grandparents, Mani and Djedo who spent nights supporting and praying for me

My father who from the very moment he knew about my project did not think twice to send me every article that has a slight relationship with my topic. He kept reading and updating me with every brand new information.
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Abstract

The Waste management is one of the serious challenges of the cities around the world, choosing to stay using the same system can put the world in huge problem, according to the growth of the pollution. That makes the current human think of combining the advanced technologies with the waste management system, like the Internet of Things.

Province of Biskra considered the waste management system as an issue, and it has to be reviewed. The classic system is not able to cover all the administration needs, such as the admin can't manage the system or even monitor either the trucks or the drivers, as an example if the trucks went for a tour, the admin can't know that, also the trucks follow a predefined route without known the state of the dustbins, this could cost time and energy.

So we proposed a new Waste Management System based on IoT, we were able to provide a web dashboard which displays live analytics of the bins' state in real time, and shows the current position of the trucks on the dashboard's map, and the admin will be able to monitor the paths and the tours of the trucks.

As result, we developed an administration web platform to monitor the collection path, the trucks movement and the bins' fill level in real time, we developed also a mobile app for the trucks to notify the administration and to allow them to track the trucks, and we provided a smart bin prototype based on IoT allows to check the fill level without verifying it physically.

Keywords- *GPS, Geolocation, Internet of Things (IoT), Waste Management, Smart Dustbin, Embedded Systems.*

الملخص

يعتبر إدارة النفايات من أكبر التحديات التي تواجه العالم، فاستعمال نفس النظام وعدم السعي الى تطويره قد يضع البيئة التي نعيش فيها في مشكلة كبيرة، خاصة مع تزايد نمو السكان، مما يعني نفايات أكثر. لذلك من اجل محيط أنظف، علينا العثور على أحسن نظام إدارة. لكن في مدينتا يمكننا ملاحظة وجود النفايات ملقاة على الأرض لان الحاويات المملوءة وغير قابلة على تحمل نفايات اكتر واكيد مواطنين المدينة غير راضيين البتة بالمنظر مما يدفعهم الى تقديم لكثير من الشكاوى. هذا ان دل على شيء دل على وجود معضلة في النظام الحالي والإقرار بعدم فعاليته.

لذلك اقترحنا نظامًا جديدًا لإدارة النفايات يعتمد على إنترنت الأشياء، يسمح بتتبع النفايات من مصدرها الى مصبها وإدارة جولات الشاحنات الخاصة بجمع النفاية وتحسين بيئة العمل.

تمكنا من توفير موقع الكتروني على شبكة الإنترنت يعرض تحليلات حية لحالة الحاويات في الوقت الفعلي، ويعرض الموقع الحالي للشاحنات على خريطة في لوحة القيادة الرئيسية، مما يمكن مسؤول الإدارة على مراقبة مسارات وجولات الشاحنات. قمنا كذلك بتطوير تطبيق هاتف يمكن تحميله على هاتف السائق او حتى ادراجه في لوحة محمولة يتم وضعها في الشاحنة، يسمح هذا التطبيق باسترداد معلومات عن الموقع الحالي للشاحنة مثل الاحداثيات والسرعة. كان باستطاعتنا اقتراح نموذج حاوية ذكية باستخدام تقنيات انترنت الأشياء، الذي يسمح بمعرفة حالة الحاوية الحالي ونسبة امتلائها.

الكلمات المفتاحية – نظام تحديد المواقع، نظام إدارة نفايات، انترنت الأشياء، حاوية ذكية، الأنظمة المضمنة،

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General Introduction

1-Context

Day by day, the population is rapidly growing and the economic broadening of the country, there is a very vast growth of the waste of management also. There is no actual right way of its solution or proper chain system to track and monitor the waste and disposal system. And cities are getting smart nowadays, but waste is not [44].

In order to render the waste management system smart in Algeria, the Mohammed Khider Biskra promote a collaboration with province of Biskra.

2-Problematic

The traditional waste management system actually is a functional system, but not in a very reliable and efficient way, because it got a lot of flaws, we can name:

- Administration can't find out the current location of the trucks while they are moving
- The administration can't know the current fill level of the dustbins and their weight, that cause a waste of truck tours, and cost money and energy.

3- Objectives

Mohammed Khider University provided to develop a smart waste management system, that solves the mentioned problematics. The solution composed of two sub systems:

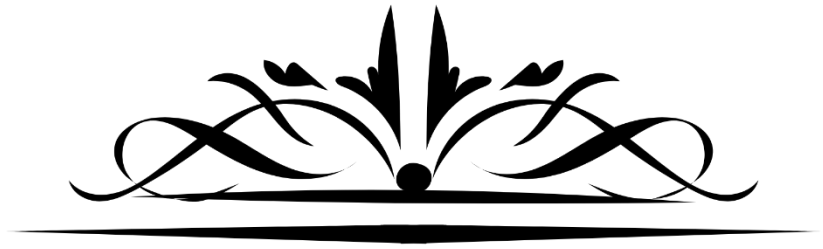
- **Geolocation System:** solves the truck monitoring problem, it enables to track the vehicles in real time, in form of tracking web dashboard.
- **Prototype of Smart dustbin:** Prototype of bins based on IoT, allows to monitor the bins in real time and to check the current fill level and weight.

4- Thesis Structure

The current report is structured into four chapters:

- **The 1st Chapter:** we presented generalities and some used terms in the thesis, such as Geolocation, GPS and Internet of Things.

- **The 2nd Chapter:** we introduced the Smart waste management system and the classic system too, also we presented some startups working on the smart waste management system, after we made a long discussion between them and our proposed solution.
- **The 3rd Chapter:** outlines a detailed overview of our system and presents the functionality of the system in different ways.
- **The 4th Chapter:** presents the implementation of the system, started by the description of all the used tools software tools and IoT material.



Chapter One

Generalities

I.1. Introduction

Smart waste management system is an ecosystem that allows the collection and management of waste using the internet of things (IoT), from its inception to its final disposal, in a very effective way within a short time**.**

This system includes multiple technologies such as geolocation technology which helps for tracking the trucks and Internet of Things in order to connect the dustbin to the system.

In this chapter, we're going to talk about Geolocation and its technologies such as satellite geolocation, geolocation by GSM. Then we are going to explain the GPS technology and its main concept. After that we will mention the car tracking system and then we will cover the Internet of things technologies.

I.2. Geolocation

Geolocation is a process that allows retrieval of the location of objects or users and displays it on a map by their geographic coordinate, for a different purpose of use, such as finding objects or tracking systems.

I.2.1. The definition of geolocation

Geolocation refers to the identification of the geographic location of a user or computing device person based on the digital information given off by their internet connected device [1], in beneficial to set on the surface of the planet (latitude, longitude, altitude) or on the map the exact location, by the geographic coordinates. This operation is carried out using a terminal capable of being located and of publishing its geographical coordinates. This information could be stored and be extracted later, or it could be transmitted in real time to a geolocation software platform [9].

FigureI.1 Location on a map

I.2.2. Geolocation technologies

Geolocation has a several technologies which are using for a different type of functionalities

I.2.2.1. Satellite geolocation

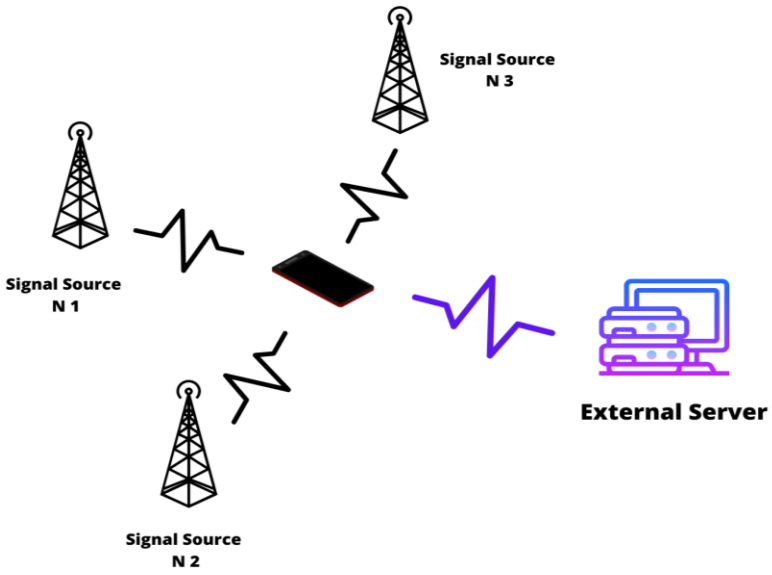
Satellite geolocation based on the calculation of the estimated time of transmission signals between the terminal and several satellites, this little calculation allows to determine the coordinate position of the receptor latitude, longitude and sometimes altitude, which could be then represented physically on a map. The most common technology in satellite geolocation is GPS (detailed more in the next section III).

FigureI.2 Satellite geolocation [10]

I.2.2.2. Geolocation by Global System for Mobile communication (GSM)

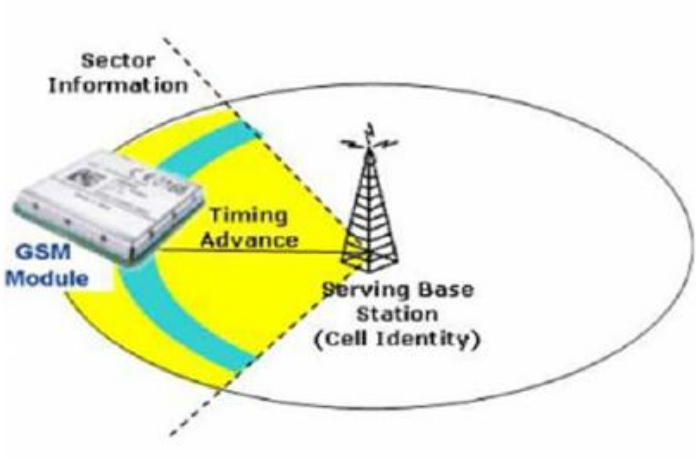
Geolocation by GSM or phones is based on IMEI (International Mobile Equipment Identity), which allows the extraction of the geographic location by some information related to the GSM antenna that the device is connected to. There is multiple technology such as

- Enhanced-Observed Time Difference (E-OTD), it has a simple concept: the phone sends signals to the surrounding antennas, the nearest one sends back the signal, therefore an external server could calculate the location of the phone between the time of transmission and the reception. (FigureI.3)



FigureI.3 E-OTD Concept

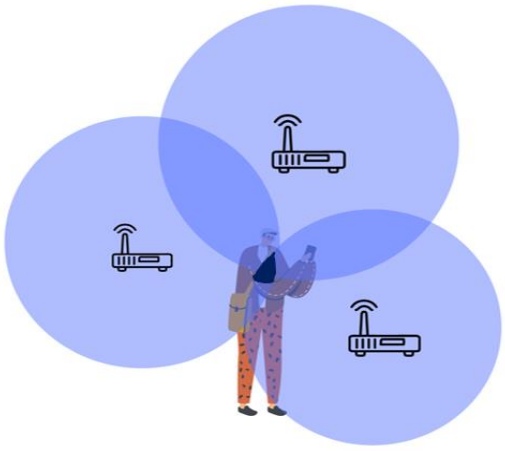
- Cell-ID is the most used GSM technology these days. This method consists of retrieving the identifiers (unique number) of the GSM antennas to which the terminal is connected. furthermore, each SIM card has an identifier that allows to know which cell this card is affected to. This data is transmitted to a database. However, the database knows the exact location of every antenna, so it could extract approximately the location of the sim card [9].



FigureI.4 Cell-ID Concept [9]

I.2.2.3 Geolocation by WIFI

The geolocation by Wi-Fi works by accepting the addresses and signal strengths of cell towers and Wi-Fi access near from the user [7], because of that it becomes simple to figure out the exact position (longitude and latitude) by using a process called trilateration. For more explanation, the user's device scans for near access points, in order to calculate the distance between the device and multiple points, therefore the overlap allows to determine an estimated longitude and latitude (figureI.4).



FigureI.5 Geolocation by WIFI

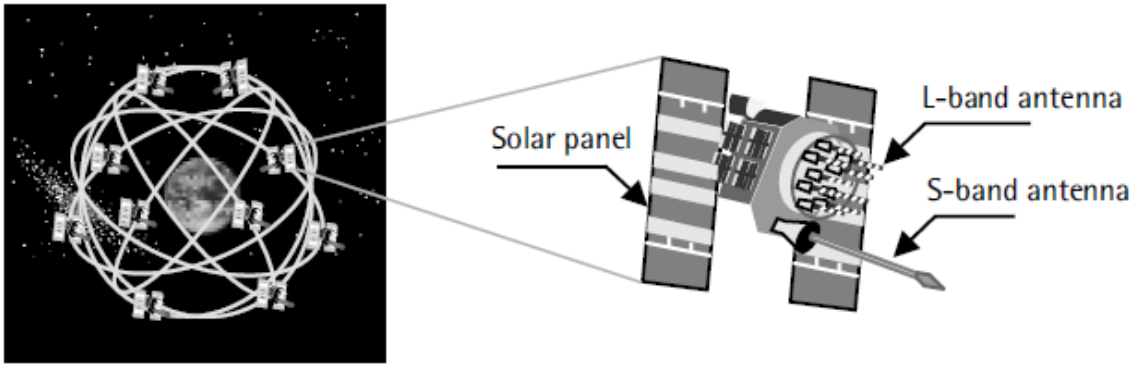
I.3. Global Positioning System (GPS)

GPS has now become a technological advancement that many of us use. It is an acronym for Global Positioning System Satellite Geolocation System.

I.3.1. Definition of GPS

The Global Positioning System (GPS) is a satellite-based navigation system that was developed by the U.S. Department of Defense (DoD) in the early 1970s. Initially, GPS was developed as a military system to fulfill U.S. military needs. However, it was later made available to civilians, and is now a dual-use system that can be accessed by both military and civilian users [2] [3].

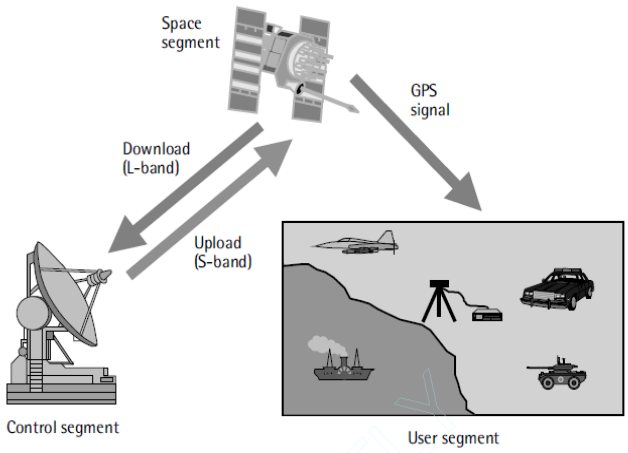
The GPS provides the information, the coordinates (location) anywhere in the world and under any weather conditions, which is the main reason for using GPS.



FigureI.6 GPS constellation [3]

I.3.2. Composition of GPS system

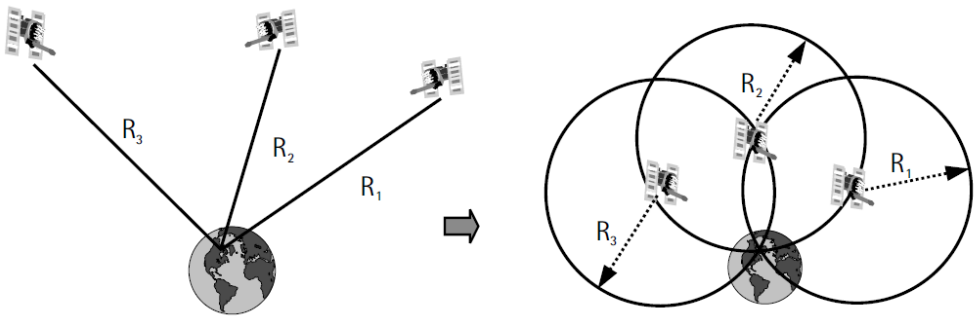
The GPS system consists of three principal elements, called segments, which are: space segment which is formed of 24 satellites (21 on the use and 3 backup) circling the earth at 20,200 kilometers in altitude, control segment consists of a principal station called MCS (Master Control Station) and a bunch of stations around the world, and user segment includes all the users of the GPS system, either civilian or military users, described more in [3].



FigureI.7 GPS Segments [3]

I.3.3. Basic idea of GPS positioning

The GPS system concept is based on the calculated distance between the GPS receiver and the satellite, such as each satellite sends his exact position compared to the earth and the specific time of the transmission. By calculating the difference between the time of transmission and the time of reception, we can figure out the distance between the GPS receiver and the satellite [4]. The distance helps to draw an imaginary circle on the surface of the earth on which the receiver should be located. The intersection of a number of circles, allows one to find the exact position of the receiver.



FigureI.8 Basic idea of GPS positioning [3]

I.4. Car Tracking System

Cars tracking systems is a part of the vehicle tracking, such as the system allows to track any device in this case cars, via computer or smartphone connected to the internet, twenty-four hours a day and seven days a week, by using some methods like global positioning system and other navigation system operating via satellite and ground based stations [5][6]. Furthermore, the system collects a history of information about the car as the exact location (longitude and latitude), the estimated speed and the stopping points and all the following roads, in order to send it in real time to the car's user. The purpose of that is to represent the collected information on a map.

FigureI.9 Car tracking system

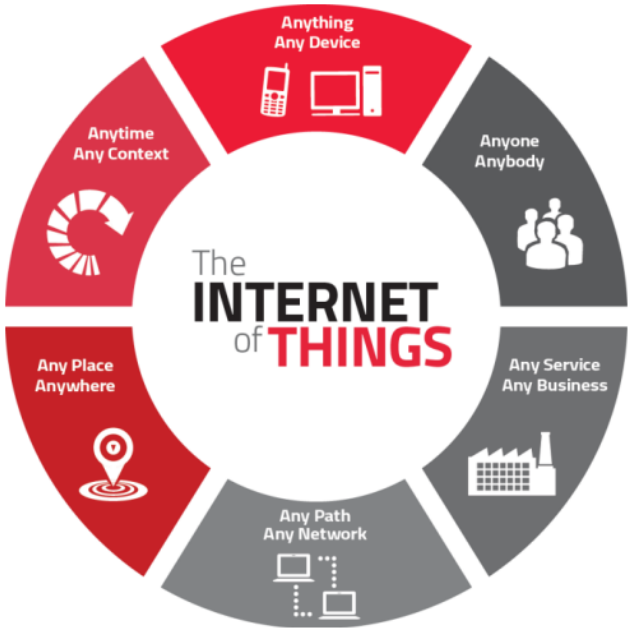
I.5. Internet of Things

The Internet of things refers to a type of network to connect anything with the Internet

I.5.1. Definition of IoT

The Internet of Things (IoT) provides information exchange and communication for device-to-device, device to-people, and device-to-environment. The IoT is a network system that connects equipped with minuscule identifying devices such as RFID, sensors and smart objects with the Internet according to the information shared by the sensing devices and the agreed protocols to

realize quick, reliable and real-time information exchange and communication, achieving intelligent identification, location, tracking, monitoring, and management. The interconnected objects are inexhaustible sources of information, it creates a vast amount of data which need communication infrastructure, computational and processing units to convert this data into useful information to enable real-time decision making. This infrastructure is placed generally in cloud [8].



FigureI.10 Internet of Things [11]

I.5.2. Characteristic of IoT

The Internet of Things has a fundamental characteristic, according to **[**11]

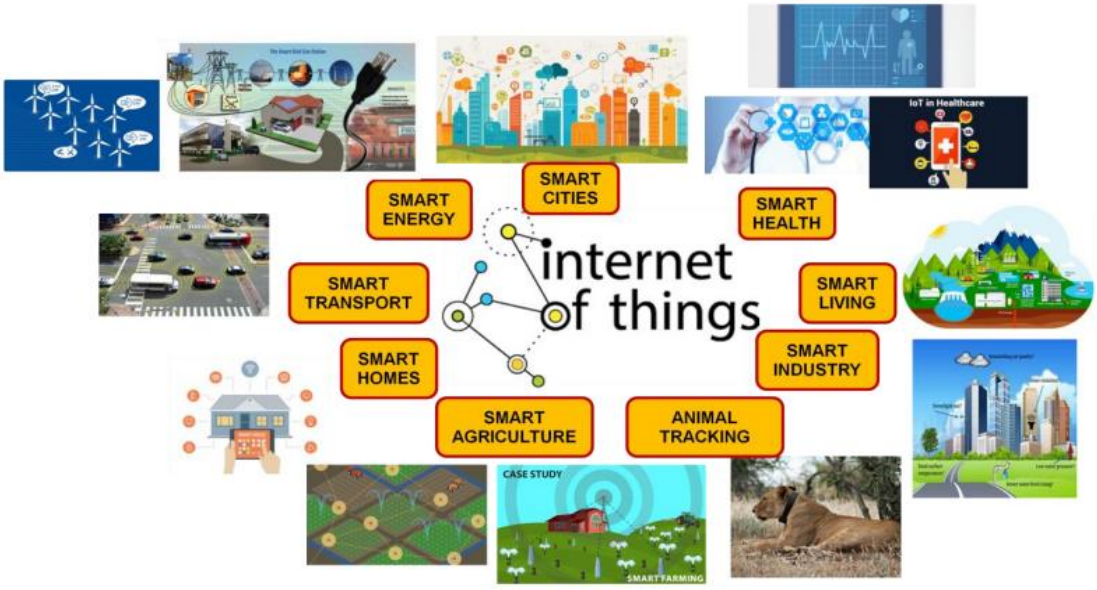
- **Interconnectivity:** with the IoT, anything can be interconnected with the global information and communication infrastructure
- **Things-related services:** The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within

the constraints of things, both the technologies in the physical world and information world will change**.**

- **Heterogeneity:** Devices in IoT are based on different hardware platforms and networks and can interact with other devices or service platforms through different networks.
- **Dynamic changes:** The state of devices changes dynamically.
- **Enormous scale:** The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet.
- **Safety:** As we gain benefits from the IoT, we must not forget about safety. As both the creators and recipients of the IoT, we must design for safety. This includes the safety of our data and the safety of our physical well-being. Securing the endpoints, the networks, and the data moving across all of it means creating a security paradigm that will scale.
- **Connectivity:** Connectivity enables network accessibility and compatibility. Accessibility is getting on a network while compatibility provides the common ability to consume and produce data.

I.5.3. IoT Applications

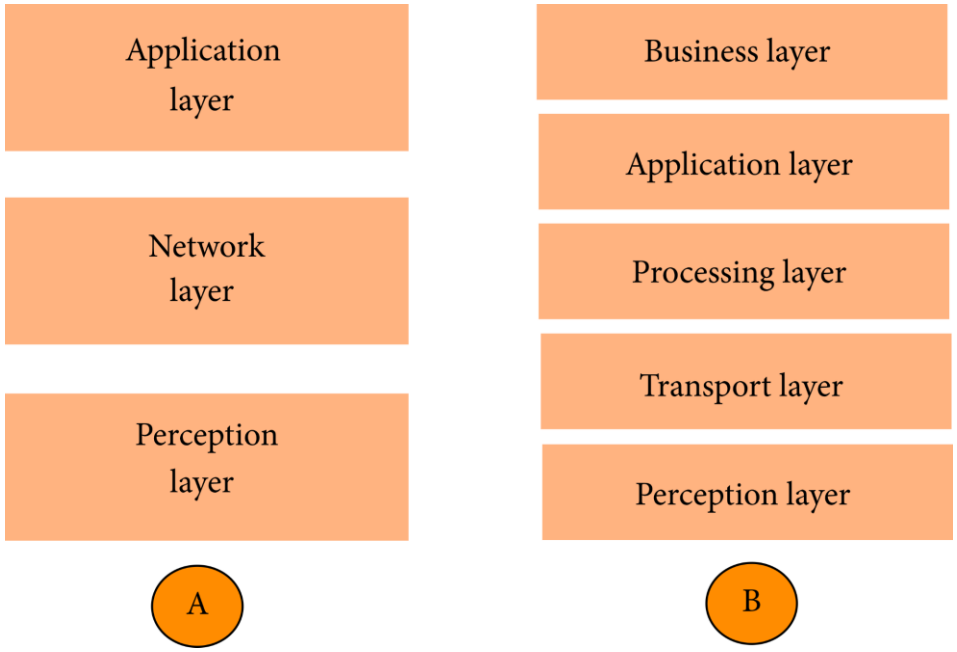
There are a diverse set of areas in which intelligent applications have been developed. All of these applications are not yet readily available; however, preliminary research indicates the potential of IoT in improving the quality of life in our society. Some uses of IoT applications are in home automation, animal tracking, health monitoring, environment protection, smart cities, and industrial settings, which are explained more in [12].



FigureI.11 Internet of Things Applications [11]

I.5.4. Architecture of IoT

Currently, there is no single reference architecture, and creating one is proving very complicated despite many standardization efforts. But the most common architectures are the three layers and five layers (FigureI.8).



FigureI.12 Architecture of IoT (A: Three layers) (B: Five Layers) [12]

I.5.4.1. Three Layers Architecture

The three-layer architecture is the most basic architecture (FigureI.8 -A-). It was introduced in the early stages of research in this area. It has three layers, namely, the perception, network, and application layers [12].

- **The perception layer:** is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment.
- **The network layer:** is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensors.
- **The application layer:** is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

The three-layer architecture defines the main idea of the Internet of Things, but it is not sufficient for research on IoT.

I.5.4.2. Five Layers Architecture

The five layers are perception, transport, processing, application, and business layers (FigureI.8 -B-). The role of the perception and application layers is the same as the architecture with three layers [12]. We outline the function of the remaining three layers.

- **The transport layer**: transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.
- **The processing layer:** is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.
- **The business layer:** manages the whole IoT system, including applications, business and profit models, and users' privacy. The business layer is out of the scope of this paper. Hence, we do not discuss it further.

I.6 IoT protocols

Protocols are competing to become the main choice for connected objects, but for each application, the most appropriate protocol will be different. This point will often make the difference between the functional prototype and the optimal solution. For example, the wireless communication technology that you will use must exactly match its use. When looking at existing wireless technologies, the choice is not obvious, because each technology has its own advantages and disadvantages [33]. Thus, they have emerged new protocols with characteristics adapted to the needs of connected objects: low power consumption, large range, low throughput, ease of implementation, etc. [33] explains all the existing protocols for each layer in IoT, (TableI.1) presents the most common protocols in IoT. Because there are multiple protocols based on the same concepts, the choice of protocol for IoT is difficult and important in the same time, [33] made a long comparison between protocols of every layer.

Protocol	Layer
IEEE 802.15.4	Perception Layer
RFID	Perception Layer
LoWPANs	Network Layer
ZigBee	Network Layer
Z-wave	Network Layer
LoraWLAN	Network Layer
Sigfox	Network Layer
NB-IoT	Network Layer
Message Queue Telemetry Transport (MQTT)	Application Layer
Constrained application protocol (CoAP)	Application Layer
Extensible messaging and presence protocol (XMPP)	Application Layer
Data distribution service (DDS)	Application Layer
Advanced message queuing protocol (AMQP)	Application Layer

TableI.1 Most common protocols in IoT [32].

I.7. Information and Communication Technologies (ICT)

Information and Communication technology evolved in the 1970s. This was to distinguish Internet-based technologies from traditional means of telecommunications. Now it has become a part of our lives.

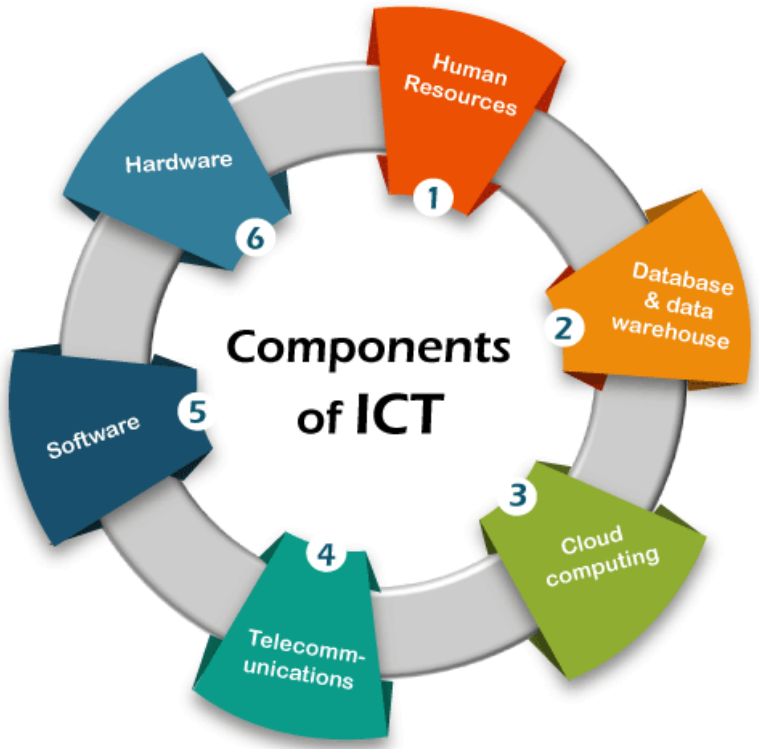
I.7.1. Definition of ICT

There is no universal definition to The term ICT, but it could refer to anything digital in the world, which includes any communication device or application, encompassing, radio, TV, cellular phones, computers and network, hardware and software, satellite systems and so on, as well as the various services and applications associated with them [13].

I.7.2. The components of ICT

The ICT system consists of 6 main components which are examined in [14] [34]:

- ✓ Hardware: presented by the physical technologies that works with information.
- ✓ Software: the software is important for the hardware, to let know what to do.
- ✓ Telecommunication: this is specified on providing the internet to the hardware
- ✓ Cloud Computing: it refers to the available data centers to many users over the internet.
- ✓ Data base and data warehouse: it is where the data is collected and from which it can be retrieved.

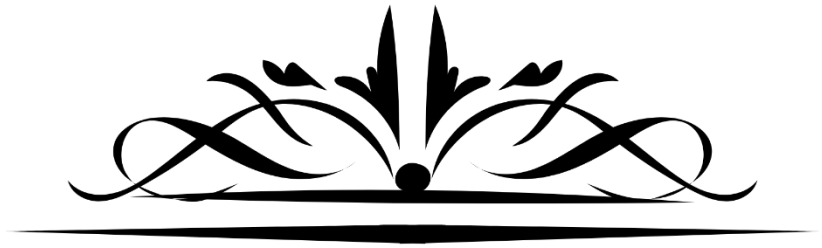


FigureI.13 Information and Communication Technologies Components [34]

I.7. Conclusion

In this chapter we defined some key words and technologies that we are going to use in our solution, (Smart Waste Management System). We talked about the geolocation technologies and more about the most common technologies GPS. Then, we had been through the car tracking system and the Internet of Things, and last but not least the information and communication technology.

In the next chapter we are going to focus more on the waste management system and the difference between existing solutions.



Chapter Two

Smart Waste Management System

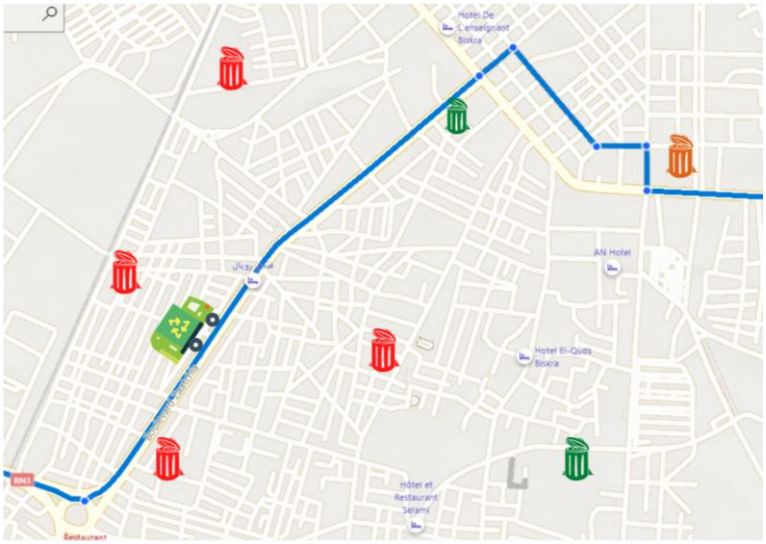
II.1. Introduction

In Biskra, most of the villages are not well-designed and do not facilitate proper waste disposal and collection mechanisms. So waste management was a critical issue to consider. We could notice that the litter is on the ground and not in the dustbins and sometimes it gets blown by the wind.

In this chapter we are going to describe the classic waste management system and the waste management system based on IoT, then we are going to introduce some companies and start-ups working on the same project and their services.

II.2. Classic Waste Management System

In the old waste management system, there were two important components: the administrator and the trucks. The tours of the trucks in the city are already scheduled by the administrator without knowing the state of the spreaded dustbins in the village, if it's full or empty. So the trucks make tours to all the neighborhoods in order to collect the waste for a clean environment, but unfortunately not, because sometimes the truck makes unnecessary tours that the dustbins could be partially filled or completely empty, as we can see on (figureII.1).

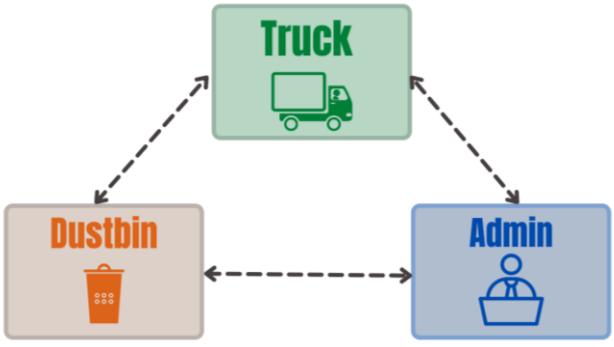


FigureII.1 Classic Waste Management System

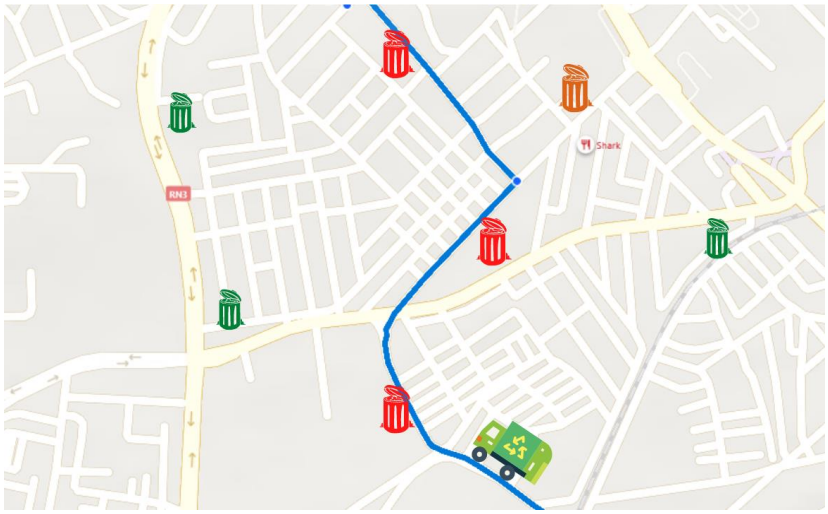
II.3. Waste Management System based on IoT

In the smart waste management system, there are three important components: the administrator, the truck and the dustbin all are connected to each other (FigureII.2).

At various points of the classic system the trucks pass around only for the filled dustbins (figureII.3).



FigureII.2 Smart Waste Management System Components



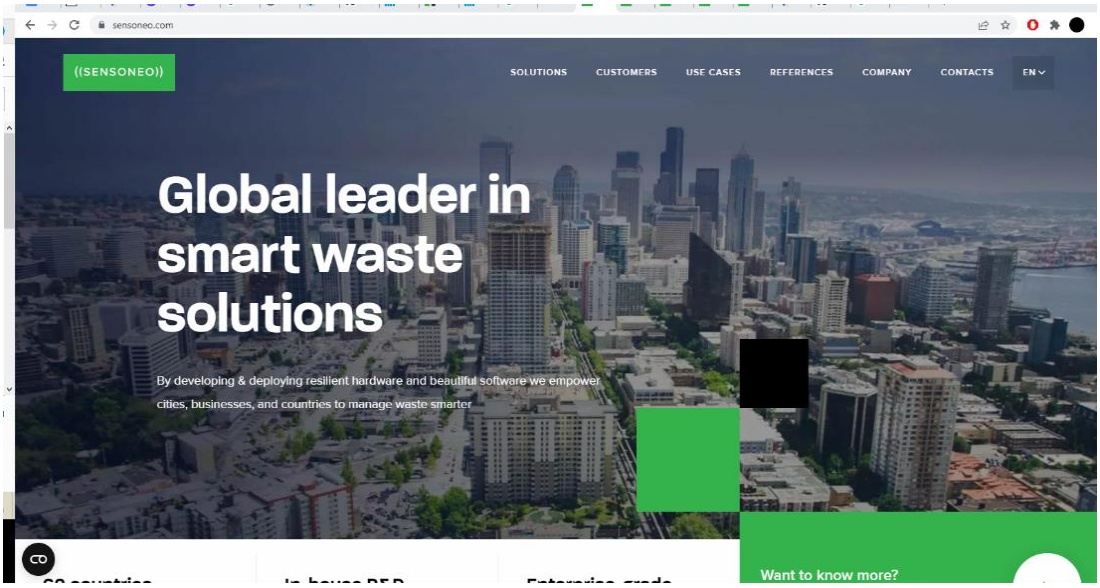
FigureII.3 Waste Management System based on IoT

II.4. Startups working on the waste management system

Smart waste management system has various examples and startups working on it around the world, as our project is an implementation in real life, we chose to make a comparison between some existence solutions, in this section we are going to present some startups and their services.

II.4.1. Sensoneo

Sensoneo is a company provider of waste management solutions, it was founded in 2017. Since then, this Slovakia -headquartered (mid-European country & member of the EU). The solution combines in house produced smart Sensors that monitor waste in real-time with tracking equipment and software providing cities and businesses with digital transformation [15].



FigureII.4 The official website of Sensoneo [15]

- **Sensoneo services**

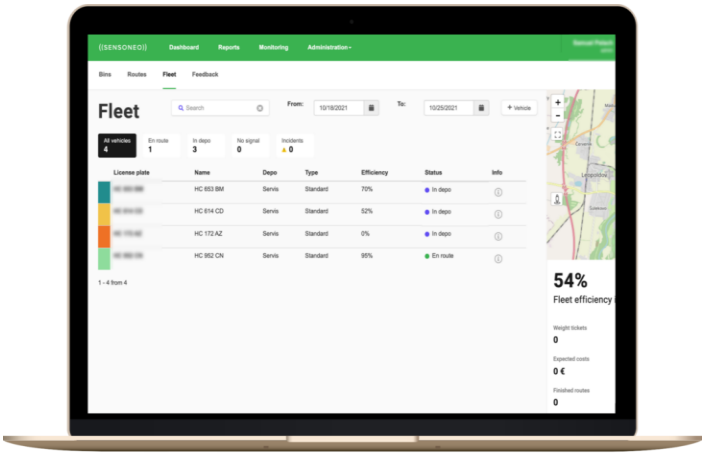
This company provide smart waste management solutions that support the digital transformation of waste management

1. **Web dashboard**

Web dashboard allows the administrator to access in real time data related to monitored trucks, bins and drivers. This dashboard provides multiple pages; we could mention:

➔ **Fleet management page**

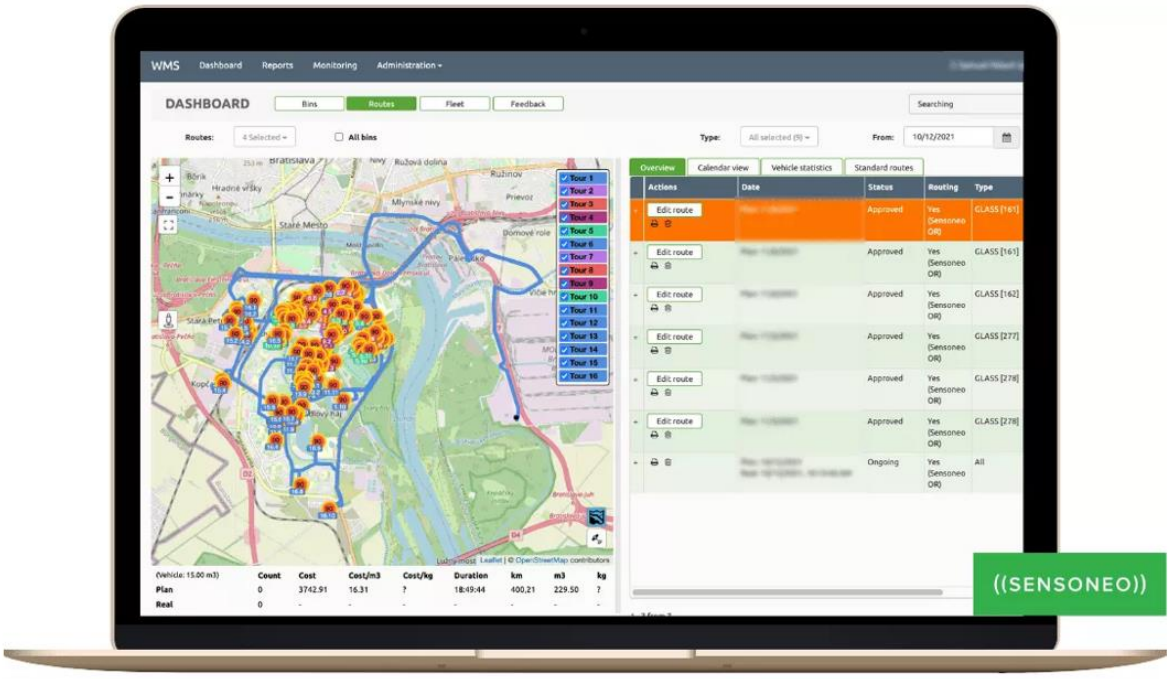
Fleet management page provides control and an overview of all vehicles under the administrator management. It allows to track which of the registered waste vehicles is currently in the depot, which is in the field, and at what speed. It is possible to check exactly the route where the truck was driving and at what time it was located at the specific address [16].



FigureII.5 Sensoneo Fleet management page [16]

➔ **Route Planning Page**

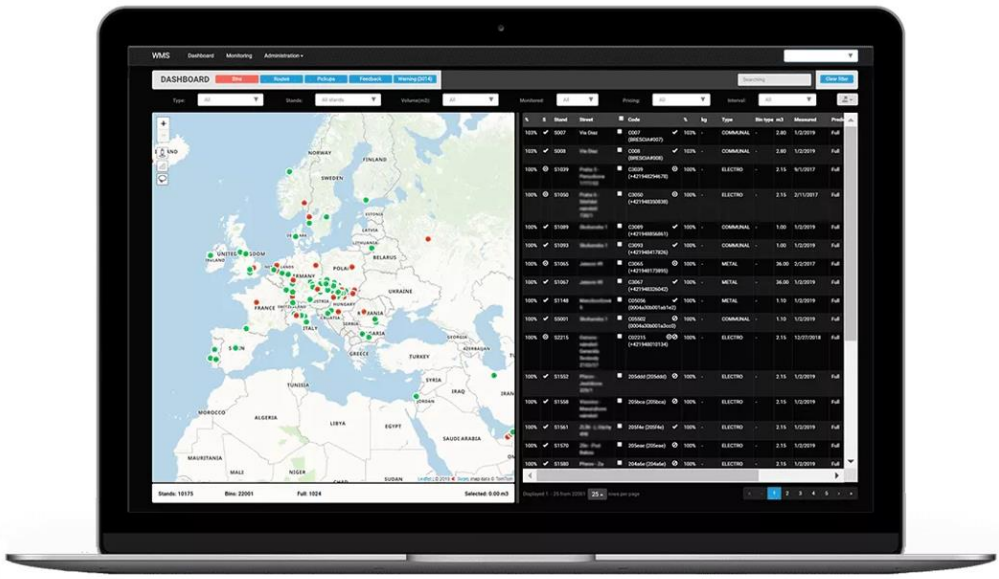
Route Planning Page enables the administrator to automate the management of the waste collection routes, based on precise pre-defined data regarding waste collection vehicles, depots, and landfills/ incineration sides. The aim is that every single waste collection route is planned to maximize the utilization of the resources (fleet, FTEs, time) and to minimize the costs needed to perform the job [17].



FigureII.6 Sensoneo Route Planning Page [17]

➔ **Waste Monitoring Page**

Waste monitoring page concentrates on the bins such as the bins or the stands that are visible on the map as green, orange or red circles. The number in the circle represents the last measurement (%). The administrator can see bin details in the Dashboard like capacity, waste type, last measurement, GPS location and collection schedule or pick recognition [18].



FigureII.7 Sensoneo Smart Waste Monitoring Page [18]

2. Smart bin

These bins include smart sensors which use ultrasound technology that provide remote monitoring of any type of waste in bins of different types and sizes to real-time update on current fill-level, temperature, tilt alarm, and fire alarm (figureII.8). The sensor uses some IoT networks such as Sigfox, NB-IoT, LoRaWAN, GPRS [19].

The company provides different types of bins that only the authorized people can access by access keys (fob or card), such as Semi-underground, Underground and Large-capacity bins (figureII.9). Also it provides another bin type that is identified by RFID tags or QR stickers, this bin could be restricted to only logged users, or to the public [20].

FigureII.8 Sensoneo Ultrasonic Sensor [19]

A-Semi-Underground Bins A- Underground Bins C- Large-capacity Bins

FigureII.9 Sensoneo authorized bin type [20]

FigureII.10 Sensoneo Rfid bin tags [21]

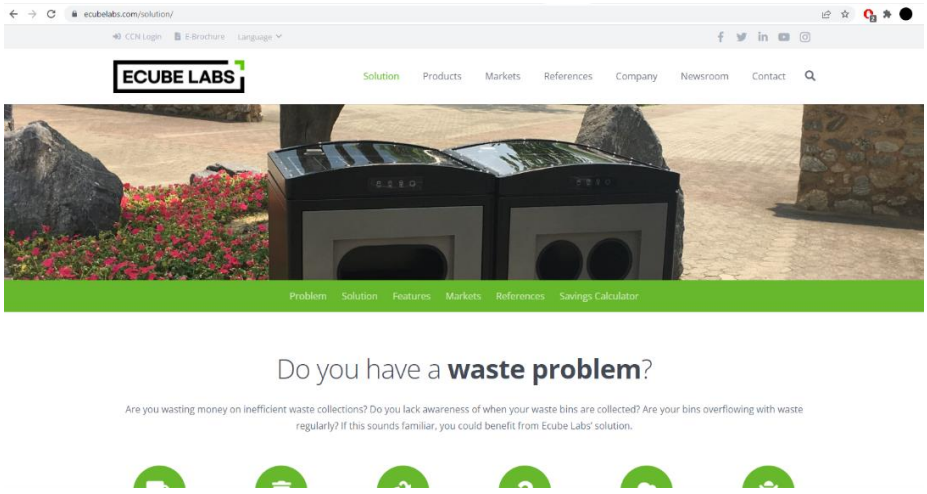
3. Driver App

The Driver App provides turn-by-turn voice-guided navigation via the shortest, and most accessible route. The app uses GPS localization in Android mobile devices to track collection trucks on the route (FigureII.11) [22].

FigureII.11 Sensoneo Driver App [22]

II.III.2. Ecube Labs

Ecube Labs is a company based in Guro-gu, Seoul, Korea, it was founded in 2011. It is a provider of smart waste management and logistics solutions that utilize IoT technologies [23].



FigureII.12 The official website of Ecube Labs [23]

- **Ecube Labs Services**

This company provides a waste management services, which are:

1. Smart Bin

The provided smart bin is called CleanCube, it is a solar-powered, trash compacting smart bin (FigureII.13) [24]. It is equipped with ultrasonic fill level sensors that send and receive real-time data to the company online monitoring platform. This sensor connects to 2g/3g, LoRaWAN and NB-IoT networks, it also contains Internal antenna for overground containers and External Antenna for containers with weak cellular signal strength (FigureII.14) [25].

FigureII.13 EcubeLabs Smart Bin [24]

FigureII.14 EcubeLabs fill level sensor [25]

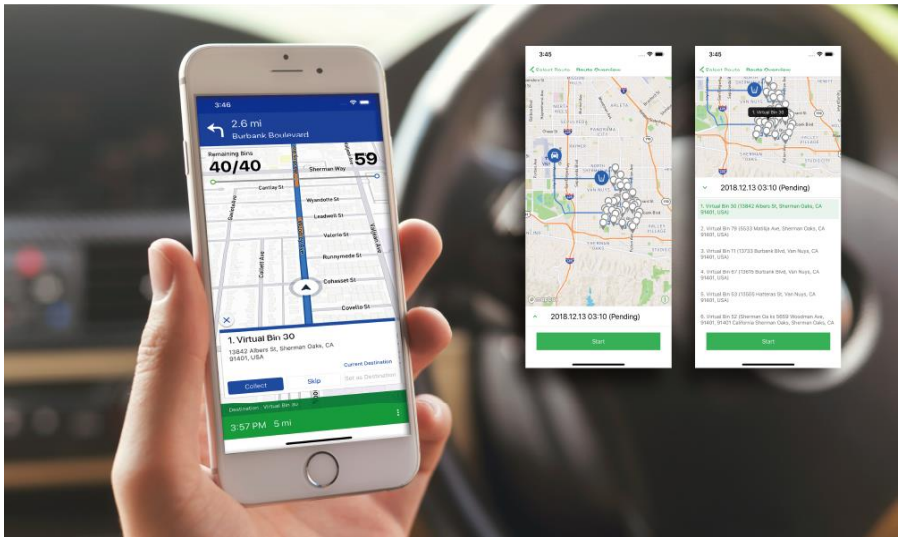
2. Web Dashboard

Web platform enables the manager to keep a track of all the installed bins, monitor fill levels and fill level history, optimize collection routes, check battery levels, geographical locations, collection history, overflow status, response times, fire and events [26].

FigureII.15 EcubeLabs waste analytics platform [26]

3. Driver App

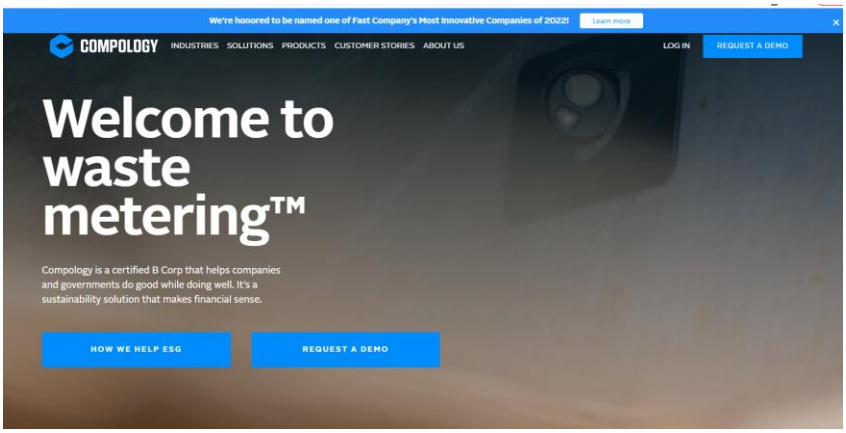
The driver app is a mobile application installed on the driver's phone, it is able to leverage the data and analytics of the driver's current waste management operation, also it could turn his manually scheduled routes into fully optimized routes using machine learning algorithms [27].



FigureII.16 EcubeLabs Driver App [27]

II.4.2. Compology

Compology is a company that provides camera-based IoT and artificial intelligence solutions in waste management systems, located in San Francisco, California.



FigureII.17 The official website of Compology [28]

- **Compology Services**

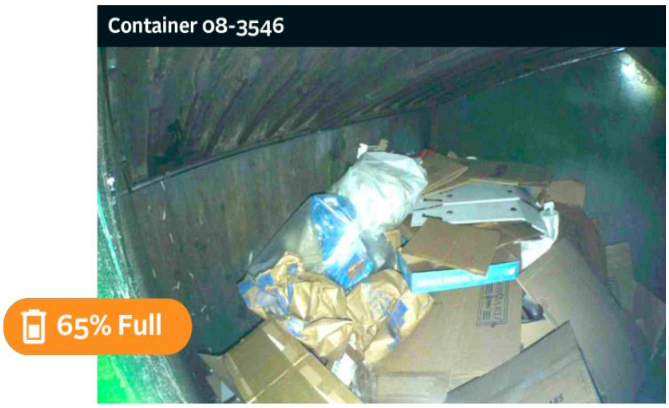
This company provides software and hardware solutions such as intelligent cameras and web dashboard

1. AI Camera

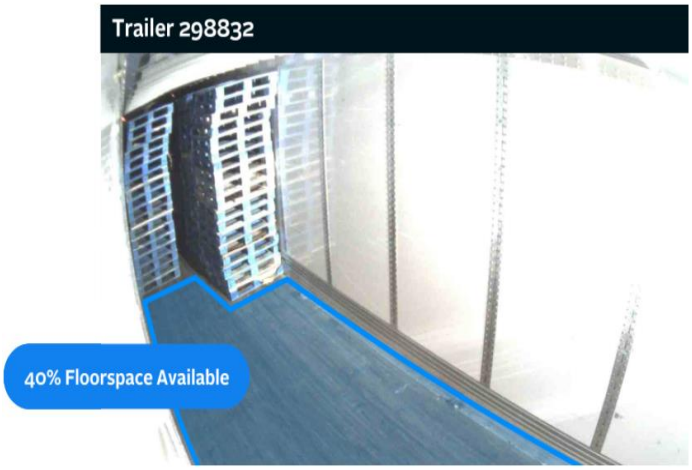
Compology's smart cameras and artificial intelligence-powered software combination delivers the needed data to know what's happening at a single dumpster or across the fleet and the insights to take action [29].

The cameras could be installed on the dustbins in order to know the fill level, the location and even the content, and it could be installed also on the trucks to know the fill level of the trailers, the floor space available, the activity and the location of the truck.

FigureII.18 Compology's AI cameras [29]



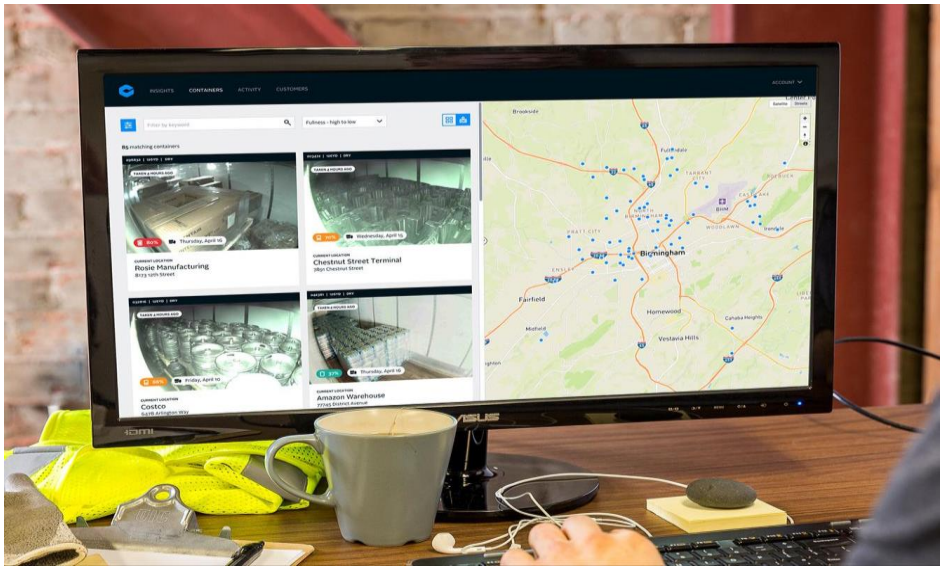
FigureII.19 Bin fill level [29]



FigureII.20 Trailer floor space available [30]

2. Web dashboard

Web dashboard enables monitoring of the trucks fullness and their precise GPS location and all the information related to the truck like driver name and whether or not the trailers are deployed. Also, it allows the managers to know the exact location of the dustbin using GPS, the fill level and the content [31].



FigureII.21 Compology Web dashboard [31]

II.5. Comparison Table between Startups Technologies

In the last section we described some Startups working on the smart waste management system. In this section we are going to make a comparison between all of them, it could be illustrated in a table as shown (TableII.1).

		Sensoneo	EcubeLabs	Compology	Proposed Solution
Web Dashboard	Real time tracking	✓	✗	✓	✓
	Client Reports	✓	✗	✗	✗
	Bin Monitoring	✓	✓	✓	✓
Smart Bin	Sensor	Ultrasonic sensor	Ultrasonic sensor	Ultrasonic sensor	Ultrasonic sensor
	Connectivity	Sigfox, NB-IoT, LoRaWAN, GPRS.	2g/3g , LoRaWAN NB-IoT	AI Camera	IoT
	Power	Battery	AC power / Solar Power	Solar Power	Battery
	Compacting bin	✗	✓	✓	✗
Data stocked in		Microsoft Azure cloud	Cloud hosted	.	Private Database
Driver APP		✓	✓	✗	✓
Citizen App		✓	✗	✗	✗
Recycling		✓	✓	✓	✓

Table II.1 Comparison table between presented Startups

♣ **Discussion**

(TableII.1) illustrates a comparison between three startups presented in the previous sections, after the table we conclude:

- ✓ Web dashboard: The three startups developed a web dashboard, enable to display analytics such as Bin monitoring, in addition Sensoneo and Compology choose to track the tracks in real time, and Sensoneo includes the ability to receive reports from the clients. In our proposed solution, we choose to monitor the bins and track the tracks in real time.
- ✓ Smart Bin: the three startups are using ultrasonic sensor, for the connectivity both of Sensoneo and EcubeLabs choose LoRaWAN and NB-IoT, moreover Sensoneo use Sigfox, GPRS and IoT technologies with battery as a source of power, and EcubeLabs use 2g/3g with either AC power or solar power, different from Compology they choose to use AI camera solar power as a source of energy. Both of EcubeLabs and Compology include a compacting module. About our proposed solution we are going to use ultrasonic sensors and IoT technology like MQTT protocol because it requires minimal resources and support bi-directional messaging between the device and the cloud, and also we are going to use a battery as a source of power.
- ✓ Sensoneo stocked the data in Microsoft Azure cloud and EcubeLabs choose Cloud-Hosted but Compology did not announce that.
- ✓ Sensoneo provides application for both of the driver and the citizen and EcubeLabs provide only an application for driver. About our proposed solution we are going to provide an application for the drivers.
- ✓ All the three startups provide a recycling system as well as our solution.

II.5. Conclusion

In this chapter we introduced the classic waste management system and some startups which are working on the project, and their technologies. At the end of the chapter we made a comparison between these startups on form of a table. In the next chapter we will present our proposed solution.

Chapter Three

Design of the proposed solution

III.1. Introduction

In the previous chapter we described some existing solutions (startups), and we ended with a short comparison between the presented startups and our solution.

In Biskra we proposed contribution a smart waste management system, which is a collaboration with the province of Biskra, for a cleaner environment.

In this chapter, we are going to further details, we are going to introduce our solution, and talk about more details, at the first section we are going to describe the waste management system's architecture, and then we are going to introduce each component and include the needed diagrams.

III.2. General Architecture

In this section we present the general architecture of the project, it's composed of two main components: server and user (FigureIII.1)

- User: it consists of three main components: Admin management, truck management and Smart dustbin.
    - ➢ Admin management: it enables the admin to control and monitor the collection of wastes and trucks.
    - ➢ Truck management: it allows to retrieve the truck location and send it to the server side.
    - ➢ Smart dustbin: it is a dustbin equipped with sensor,

- Server: consists of three component Geolocation System, Dustbin System and a database which allows to store all the transferred data, deployed all on a cloud could be public or private.

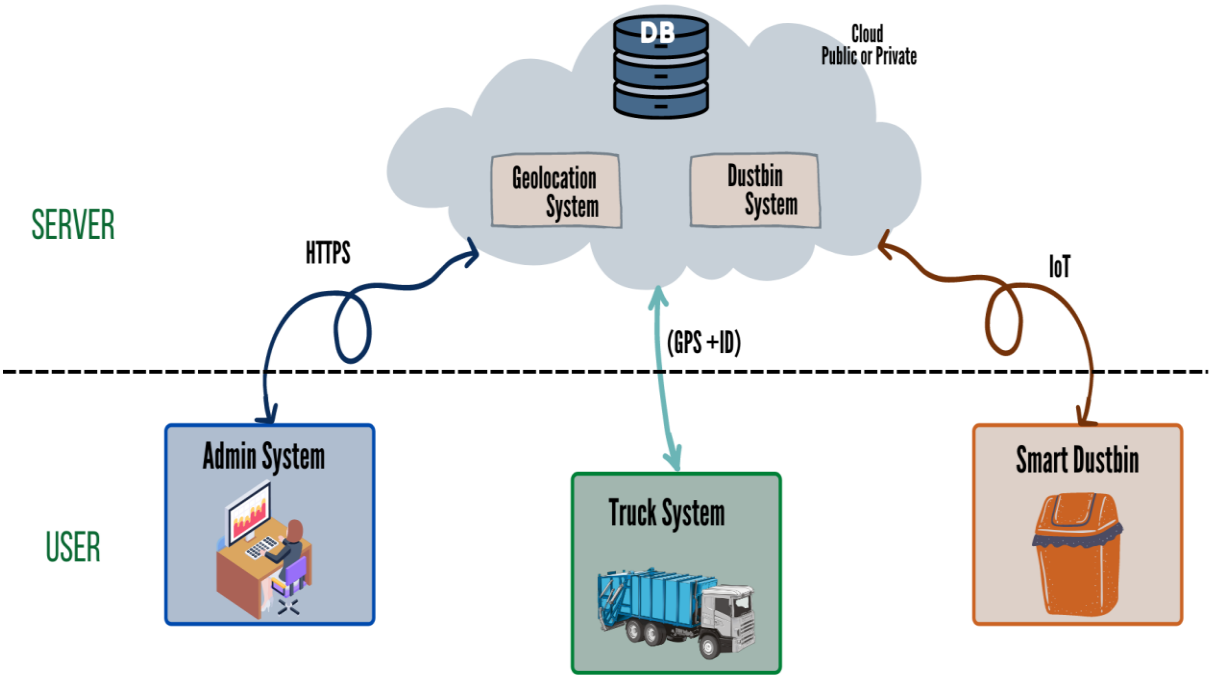


Figure III.1 Waste management system global architecture

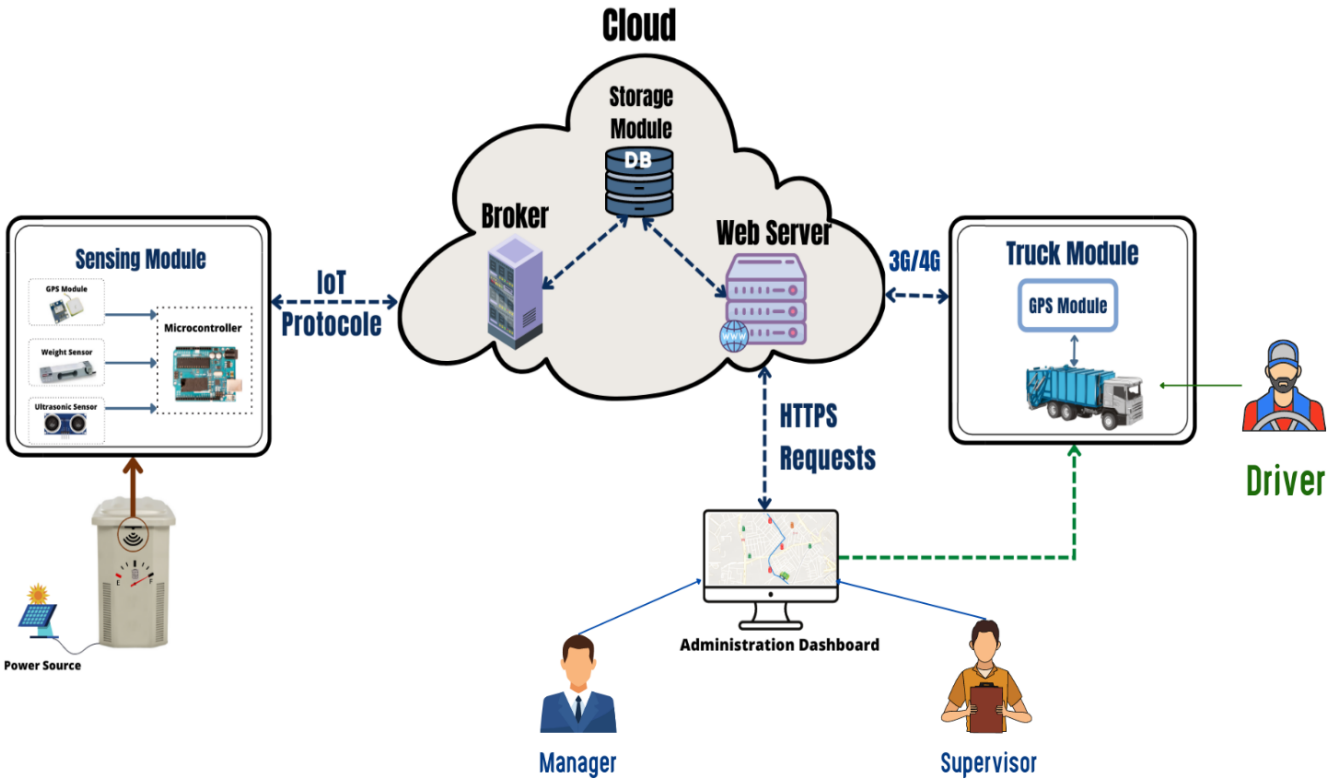
III.3. Detailed Architecture of the system

As we mentioned in the last section the main components of the waste management system, in this section we are going through farther detailed, FigureIII.2 illustrate the detailed system.

- ♣ Truck module: This module is for the truck represented by a mobile application, it contains a gps module that enable to retrieve information such as the longitude, latitude, altitude, accuracy and the speed of the truck while moving, then all of these data will be hosted on the web server and stored on the storage module, and the truck will be displayed on the administration dashboard map (figureIII.3). Before retriving data the driver should login to the truck application first.
- ♣ Administration dashboard: this module is represented by a web platform the admin, it displays all the information of the dustbins (fill level, weight and their

position on the map ... etc.), the drivers of the truck (their full name, birthday date …etc.), and the truck. the dashboard contains a map, display real time location of the trucks which allows the admin to track the trucks. There are two types of admin: one called Manager, he is the responsible of the whole system, he has the right to delete or add any user (like driver, truck bin and path ..etc) he wants, the other admin called Supervisor, he is allowed only to read the data from the dashboard (like checking the moving trucks and the full bin), he has no right to monitor the system.

- ♣ Smart dustbin module: explained more in (section III.4).



FigureIII.2 Waste management system detailed architecture

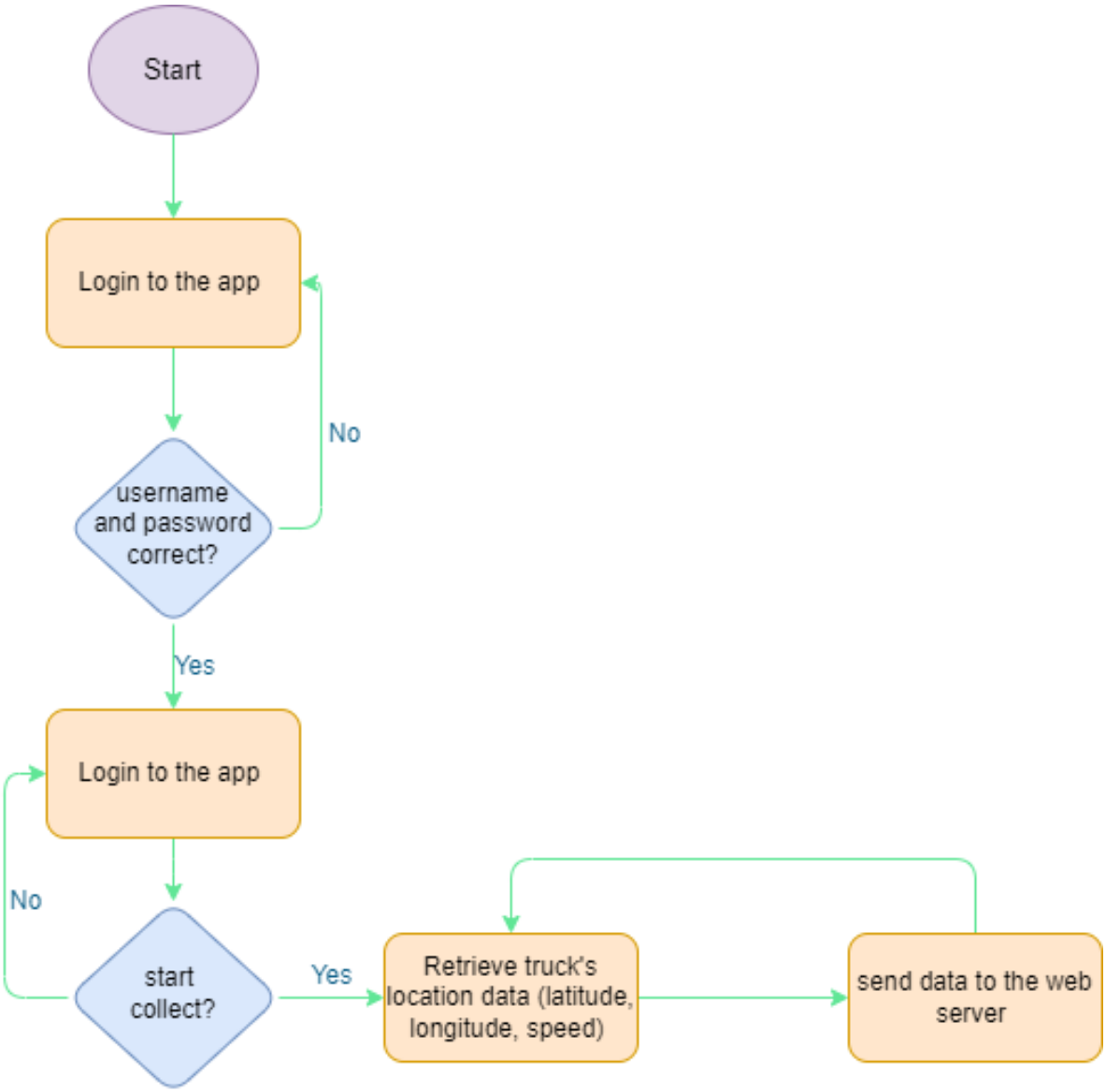
III.3.1. Truck Function

This function is responsible of retrieving the online trucks and display their position and their movement on the map.

Function: TruckFunction ( )

```
Begin
    onlineTrucks = BringOnlineTrucks( );
    ForEach (Truck in  onlineTrucks)
        DisplayTruckOnTheMap ( Truck );
    EndFor;
End
```

Algo III.1. Truck Function



FigureIII.3 Truck module flowchart

III.3.2. Notify Admin Function

This function notifies the admin whenever a new track logged in and started the collect.

Function: NotifyAdmin ( )

```
Begin
    If ( track is online )
        DisplayAlert ( 'Truck '+track.id +' started collecting ' );
    EndIf
End
```

Algo III.2. Notify Admin Function

III.3.3. Display Tour Path

This function displays path of the truck on a map (the road that the track is going to take), from the start coordinate to the last.

Function: DisplayTourPath ( )

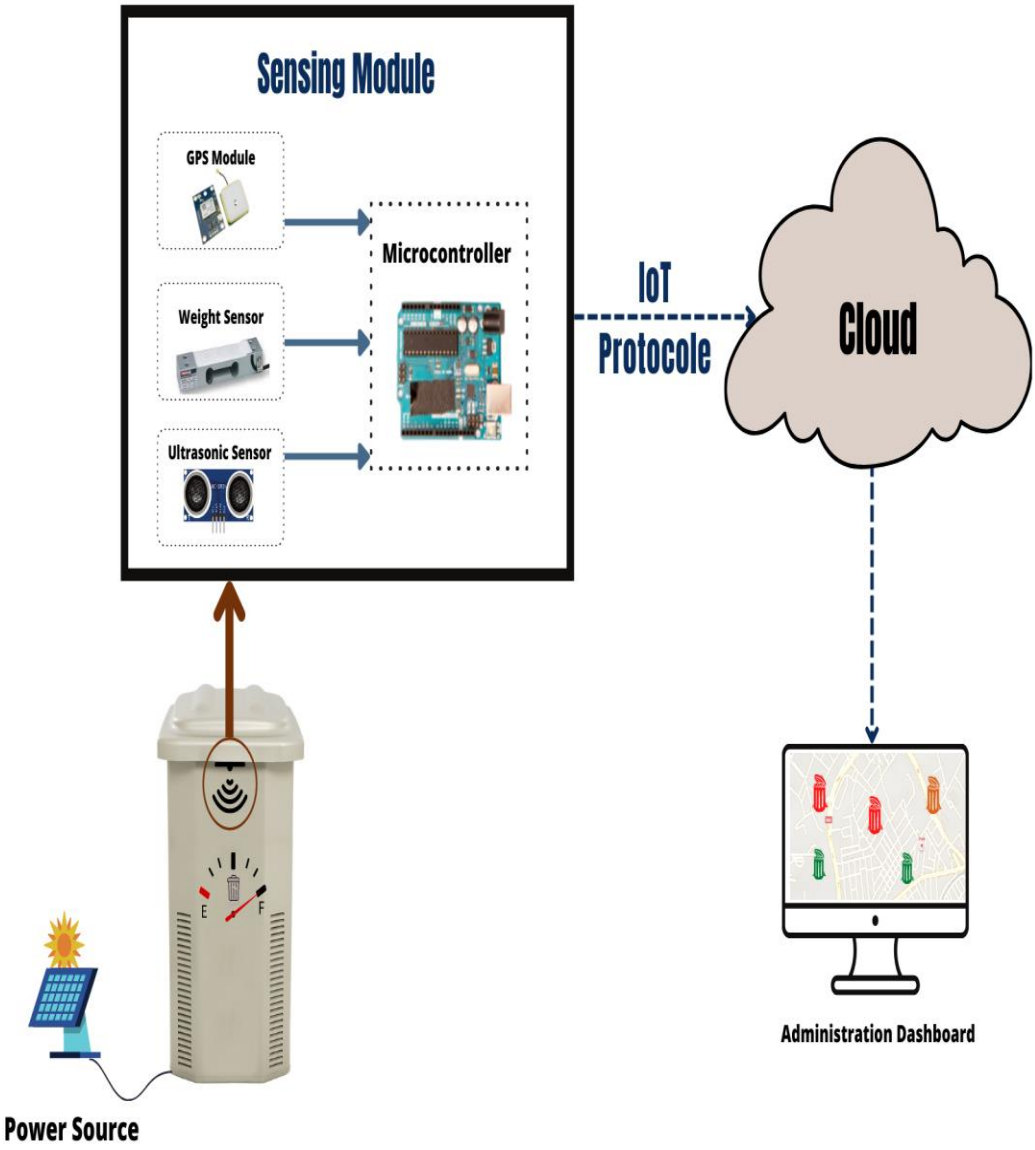
```
Begin
    onlineTrucks = BringOnlineTrucks( );
    ForEach (Truck in onlineTrucks)
        DisplayTourOnTheMap ( Truck );
    EndFor;
End
```

Algo III.3. Display Tour Path Function

III.4. Smart Dustbin Architecture

The smart dustbin consists of two main modules one for sensing and the other for getting the power (energy).

- Sensing module: this module is responsible of retrieving all the real time data of the dustbin, such as the location of it, the fill level, and the weight by using GPS and other sensors. Then all the data is going to be sent to the cloud by IoT protocols in order to display it on administration dashboard.
- Power source: the smart dustbin needs energy to work, it is possible to use either battery.



FigureIII.4 Smart Dustbin Architecture

III.4.1. Sensing module

In this section, we are going to introduce the functionality of the sensing module in form of pseudo code.

Def: -***MaxLevel***: represent the maximum fil level of the bin.

-***MdmLevel***: represent the medium fill level of the bin.

-***MinLevel***: represent the minimum fill level of the bin.

Function: SensingFunction ( )

```
Begin
    BinLevel = getBinLevel ( );
    If (BinLevel >= MaxLevel)
        ChangeBinColor( Red );
        NotifyTheControlSystem ( BinLevel, BinLocation, BinWeight );
    Else
        If (BinLevel >= MdmLevel)
            ChangeBinColor( Orange );
            SensingFunction ( );
        Else
            ChangeBinColor( Green );
            SensingFunction ( );
        EndIf
    EndIf
End
```

Algo III.4. Sensing Function

III.5. Functionality of the system

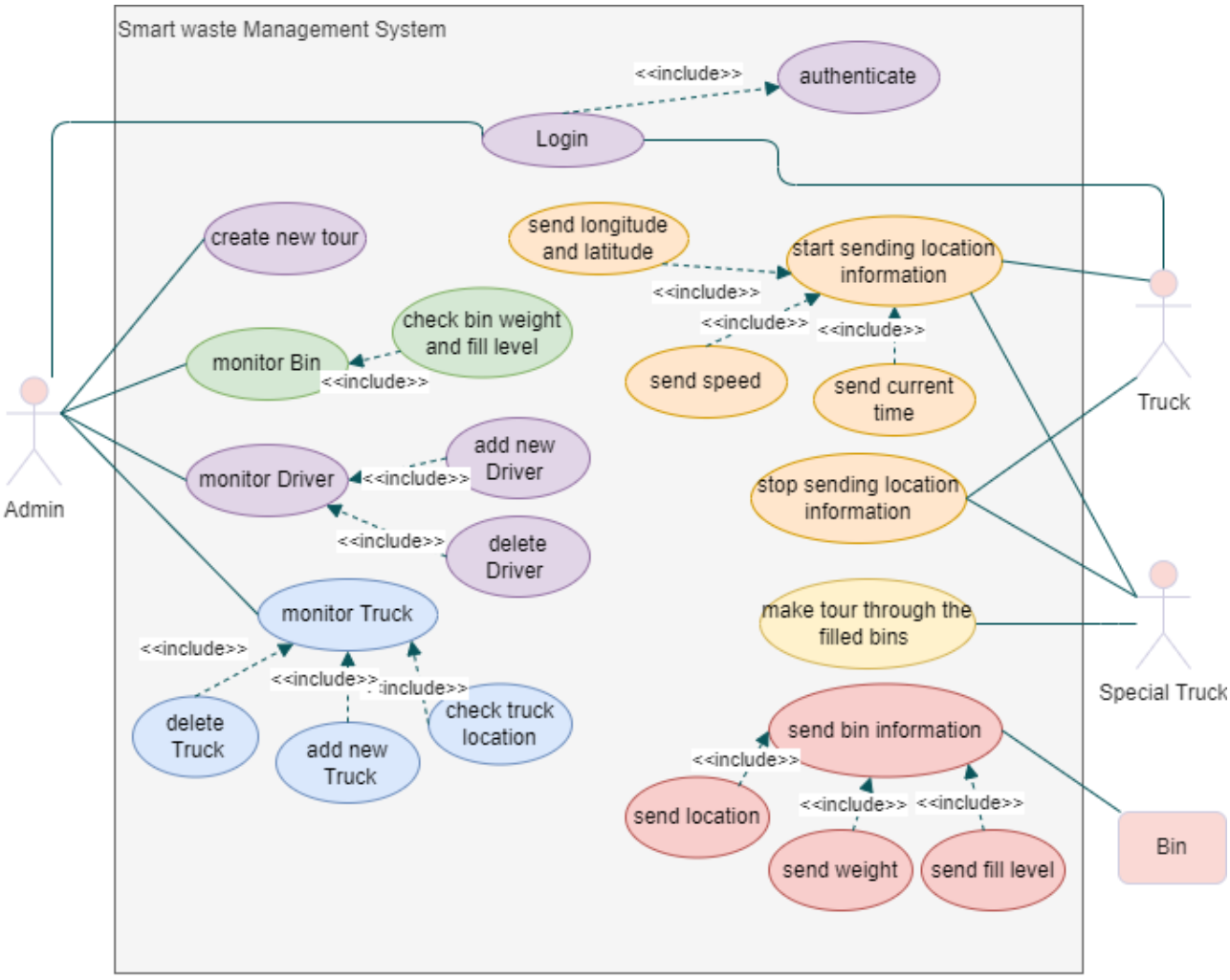
To understand more the functionality of the system, it would be better to represent it in form of diagram, in this section we are going to provide a representation of our system in form of use case, sequence diagram and class diagram (figure III.6, figure III.7). It shows all the action that can the admin, the truck and the bin do:

- **1st Step:**
  - ✓ The admin login to the system.
  - ✓ The admin adds drivers and trucks to the system.
  - ✓ The admin creates tours and integrates them to the drivers and the trucks.

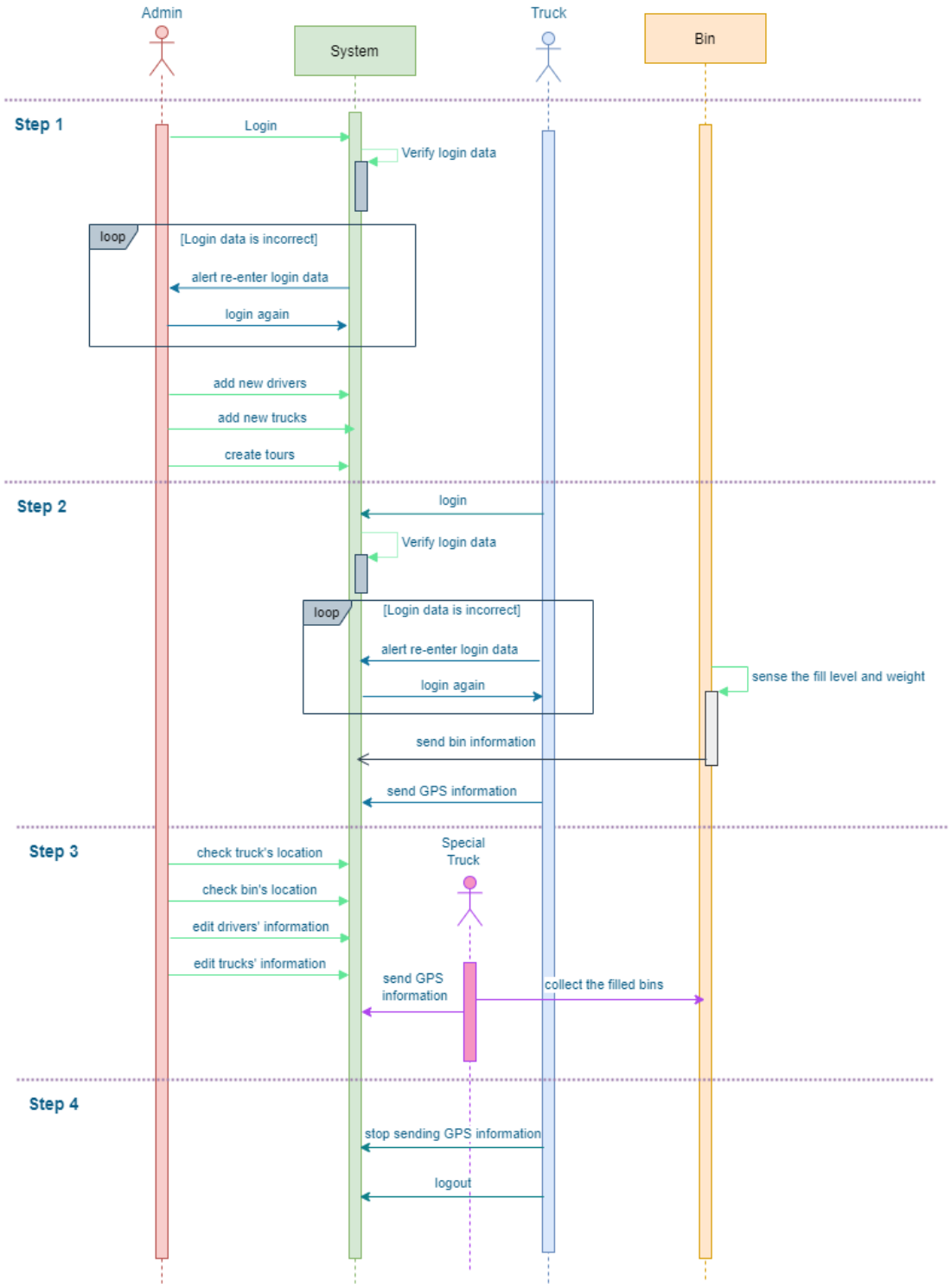
- **2nd Step:**
  - ✓ The track login to the system.
  - ✓ The track starts sending its location information to the system.
  - ✓ The bin senses its fill level and weight.
  - ✓ The bin sends the fill level and the weight;

- **3rd Step:**
  - ✓ The admin checks the track's location.
  - ✓ The admin checks the bin's fill level.
  - ✓ The admin edits drivers or trucks' information
  - ✓ If bin is full and there is no tour, the special truck start collecting only through the filled bins.

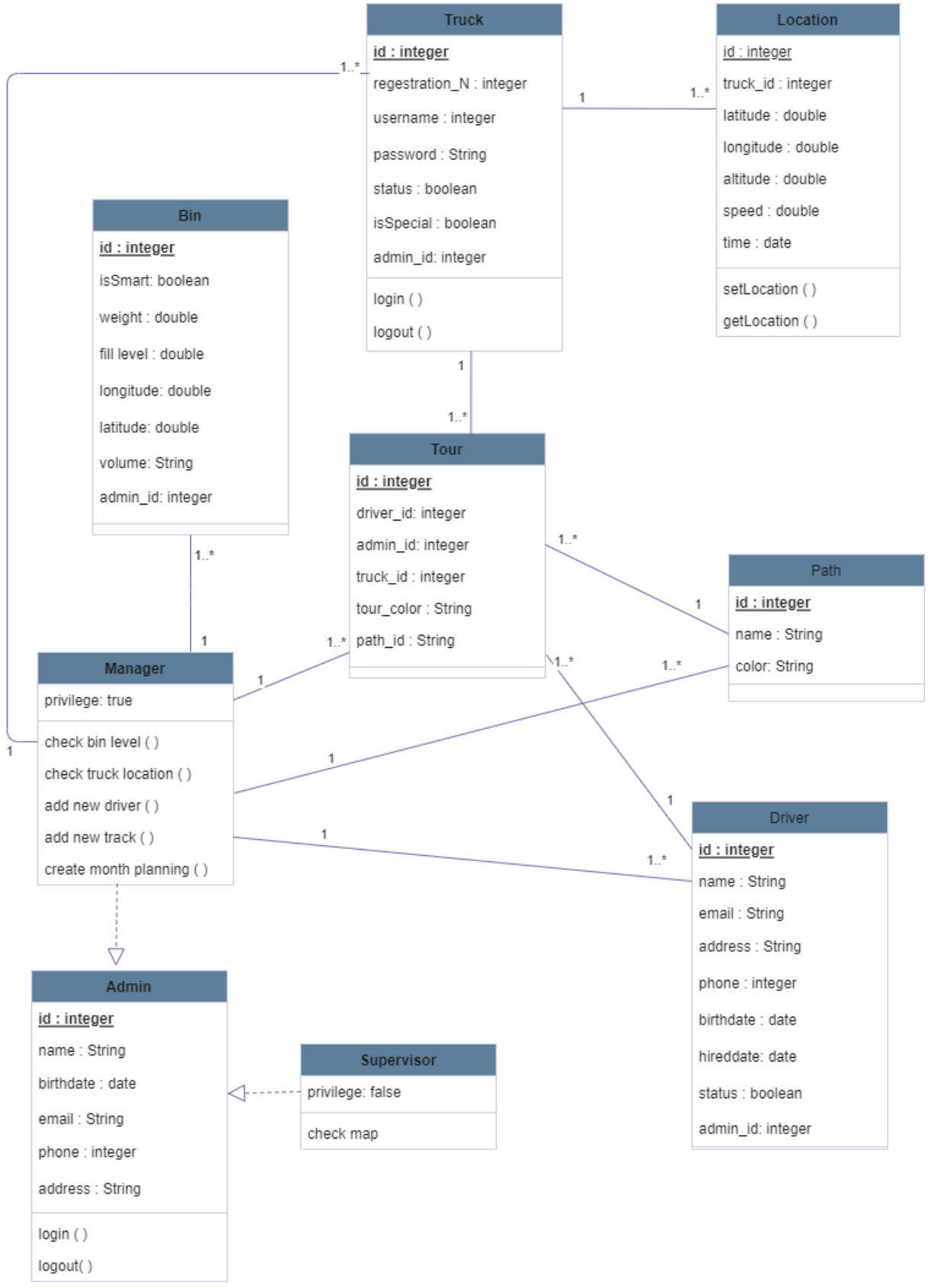
- **4th Step:**
  - ✓ The truck stops sending location information and logs out.



FigureIII.6 Use case diagram of the system



FigureIII.7 Sequence diagram of the system



FigureIII.8 Conceptual Class diagram of the system

The (figureIII.8) present a conceptual class diagram of the system, it consists of eight classes:

- Admin Class: it refers to the admins of the system, it has as attributes identifier, name and all the information of the admin.
- Manger and Supervisor Classes: both of them are children of the class Admin. The attribute *privilege* has false value for the Supervisor, and true for the Manger. The manager has the ability to create multiple drivers, trucks, tours, paths, and bins. But The supervisor has the ability to check the map only.
- Bin Class: it presents the bin, it has as attributes identifier, longitude, latitude, weight, fill level, volume and the admin id who created that bin.
- Truck Class: refers to the Truck, it has multiple locations (relation with the class location), it defines by identifier, registration number, username and password...etc.
- Location Class: it presents the location of the truck, identifies by the truck id and the location information (one location belong to one truck, and one truck has multiple locations).
- Driver Class: it refers to the driver of the system, it defines by identifier and the driver's personal information and the admin who added the driver to the system.
- Path Class: it refers to the path, it defines by the id, the name of the path, and the default color. It could be created by only one Manger.
- Tour class: it defines by an id, color of the path, driver id, truck id, path id and the admin id who created the tour (one truck, one driver and one path have multiple tours, one tour belongs to only one driver, one truck and one path).

III.6. Conclusion

In this chapter we introduced our solution and we described it in detailed, in form of different ways. At first we introduce our general architecture that show the actors of our system, then we described a detailed architecture, we introduced each component and how it works and we added some used algorithms and flowcharts. After, we introduced the smart bin's architecture and its functionality in form of pseudo algorithms and flowchart. Lastly we discussed the system functionality in form of use case, sequence diagrams and we described the system's structure by conceptual class diagram.

In the next section we are going represent the implementation of our system.

Chapter Four

Implementation

IV.1. Introduction

After detailing the architecture of the smart waste management system and describing the main concept of our solution in the last chapter, in this chapter we are going to focus on the implementation and the practical side of the project. We start the chapter by presenting the used tools in the project, both of Software and hardware tools. after we introduce the obtained results in form of screenshots and pictures.

IV.2. Software tools

In our project we used JavaScript, html and css programming languages for the frontend of the web dashboard, and php as language of the backend. But to make the development easier we used Laravel and Bootstrap frameworks.

IV.2.1. Laravel

Laravel is an open-source PHP framework, which is robust and easy to understand. It follows a model-view-controller design pattern. Laravel reuses the existing components of different frameworks which helps in creating a web application. The web application thus designed is more structured and pragmatic [35].

Laravel offers a rich set of functionalities which incorporates the basic features of PHP frameworks like CodeIgniter, Yii and other programming languages like Ruby on Rails. Laravel has a very rich set of features which will boost the speed of web development [35].

IV.2.2. Bootstrap

Bootstrap is a free and open-source web development framework. It’s designed to ease the web development process of responsive, mobile-first websites by providing a collection of syntax for template designs [36].

In other words, Bootstrap helps web developers build websites faster as they don’t need to worry about basic commands and functions. It consists of HTML, CSS, and JS-based scripts for various web design-related functions and components.

Bootstrap's primary objective is to create responsive, mobile-first websites. It ensures all interface elements of a website work optimally on all screen sizes.

Bootstrap is available in two variants – precompiled and based on a source code version. Experienced developers prefer the latter since it lets them customize the styles to suit their projects [36].

IV.2.3. Leaflet Library

Leaflet is the leading open-source JavaScript library for mobile-friendly interactive maps. Weighing just about 39 KB of gzipped JS plus 4 KB of gzipped CSS code, it has all the mapping features most developers ever need [40].

Leaflet is designed with simplicity, performance and usability in mind. It works efficiently across all major desktop and mobile platforms out of the box, taking advantage of HTML5 and CSS3 on modern browsers while being accessible on older ones too. It can be extended with a huge amount of plugins, has a beautiful, easy to use and well-documented API and a simple, readable source code that is a joy to contribute to [40].

IV.2.4. Flutter

Flutter is a free and open-source mobile UI framework created by Google and released in May 2017. In a few words, it allows to create a native mobile application with only one codebase. This means that the developer can use one programming language and one codebase to create two different apps (for iOS and Android) [43]. Flutter consists of two important parts:

- An SDK (Software Development Kit): A collection of tools that are helpful to develop applications. This includes tools to compile a code into native machine code (code for iOS and Android).
- A Framework (UI Library based on widgets): A collection of reusable UI elements (buttons, text inputs, sliders, and so on) that everybody can personalize for their own needs.

IV.2.5. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions

and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them [37].

IV.2.6. XAMPP

XAMPP is an abbreviation where X stands for Cross-Platform, A stands for Apache, M stands for MYSQL, and the Ps stand for PHP and Perl, respectively. It is an open-source package of web solutions that includes Apache distribution for many servers and command-line executables along with modules such as Apache server, MariaDB, PHP, and Perl. XAMPP helps a local host or server to test its website and clients via computers and laptops before releasing it to the main server. It is a platform that furnishes a suitable environment to test and verify the working of projects based on Apache, Perl, MySQL database, and PHP through the system of the host itself. Among these technologies [38].

IV.2.7. Ngrok

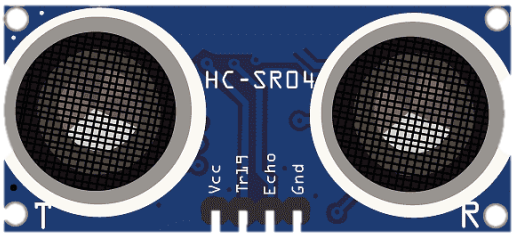
Ngrok is a cross-platform application that exposes local server ports to the Internet. Their website claims, “It allows the user to spend more time programming one command for an instant, secure URL to localhost server through any NAT or firewall” [39].

IV.3. IoT Material

In this section, we are going to introduce the hardware used tools in the project.

IV.3.1. Wemos D1 R2

WeMos-D1R2 is an ESP8266-12 based Wi-Fi enabled microprocessor unit on an Arduino-UNO footprint. That means the board looks and works (in most cases) like an UNO. Apparently several shields, sensors and output devices that are manufactured for the Arduino platform will work on the WeMos-D1R2 with the added advantage of built-in Wi-Fi [41].



FigureIV.1. Wemos Board

FigureIV.2. HCSR04 Ultrasonic sensor

IV.3.2. HCSR04 Ultrasonic sensor

The HC-SR04 Ultrasonic Distance Sensor is a sensor used for detecting the distance to an object using sonar. It non-contact ultrasound sonar to measure the distance to an object, and consists of two ultrasonic transmitters (basically speakers), a receiver, and a control circuit. The transmitters emit a high frequency ultrasonic sound, which bounce off any nearby solid objects, and the receiver listens for any return echo. That echo is then processed by the control circuit to calculate the time difference between the signal being transmitted and received. This time can subsequently be used, along with some clever math, to calculate the distance between the sensor and the reflecting object [42].

IV.3.2.1. HCSR04 Features [42]:

- Power Supply: +5V DC.
- Quiescent Current: <2mA.
- Working Currnt: 15Ma.
- Effectual Angle: <15°.
- Ranging Distance: 2cm – 400 cm/1" 13ft.
- Resolution: 0.3 cm.
- Trigger Input Pulse width: 10uS.
- Dimension: 45mm x 20mm x 15mm.

IV.3.3. HX711 Weight sensor

HX711 is a precision 24-bit analog-to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor.

The input multiplexer selects either Channel A or B differential input to the low noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, corresponding to a full-scale differential input voltage of ±20mV or ±40mV respectively, when a 5V supply is connected to AVDD analog power supply pin. Channel B has a fixed gain of 32. On-chip power supply regulator eliminates the need for an external supply regulator to provide analog power for the ADC and the sensor. Clock input is flexible. It can be from an external clock source, a crystal, or the on-chip oscillator that does not require any external component. On-chip power-on-reset circuitry simplifies digital interface initialization [45].

IV.3.4. LCD 16x2

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations…etc [46].

IV.4. Implementation of the system

In this section we are going to present the implementation of our system in form of screenshots.

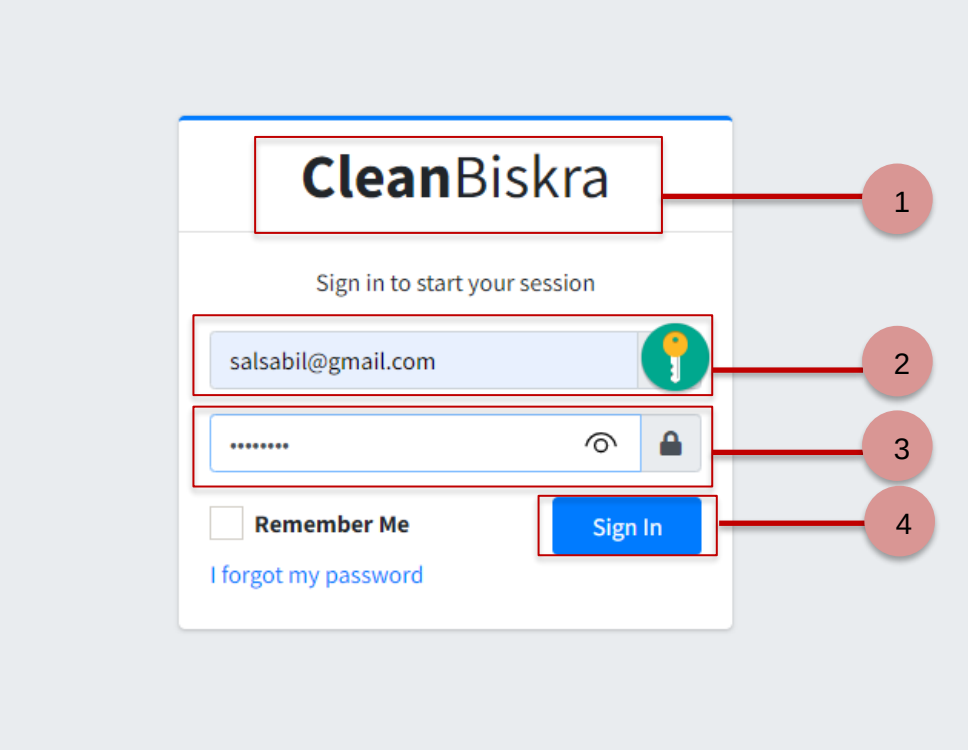
IV.4.1. Admin's Dashboard

The administration dashboard represented by a web platform.

IV.4.1.1. Login Page

First when we start our server, the first page appear is the login page (FigureIV.3.)

(1) We can see the logo "*CleanBiskra*" of the web site on the top of the login card, under the logo there is a short description says "Sign in to your session".
(2) Is an input for the email of the admin.
(3) Is an input for the password.
(4) Button for logging into the system.



FigureIV.3. Login Page

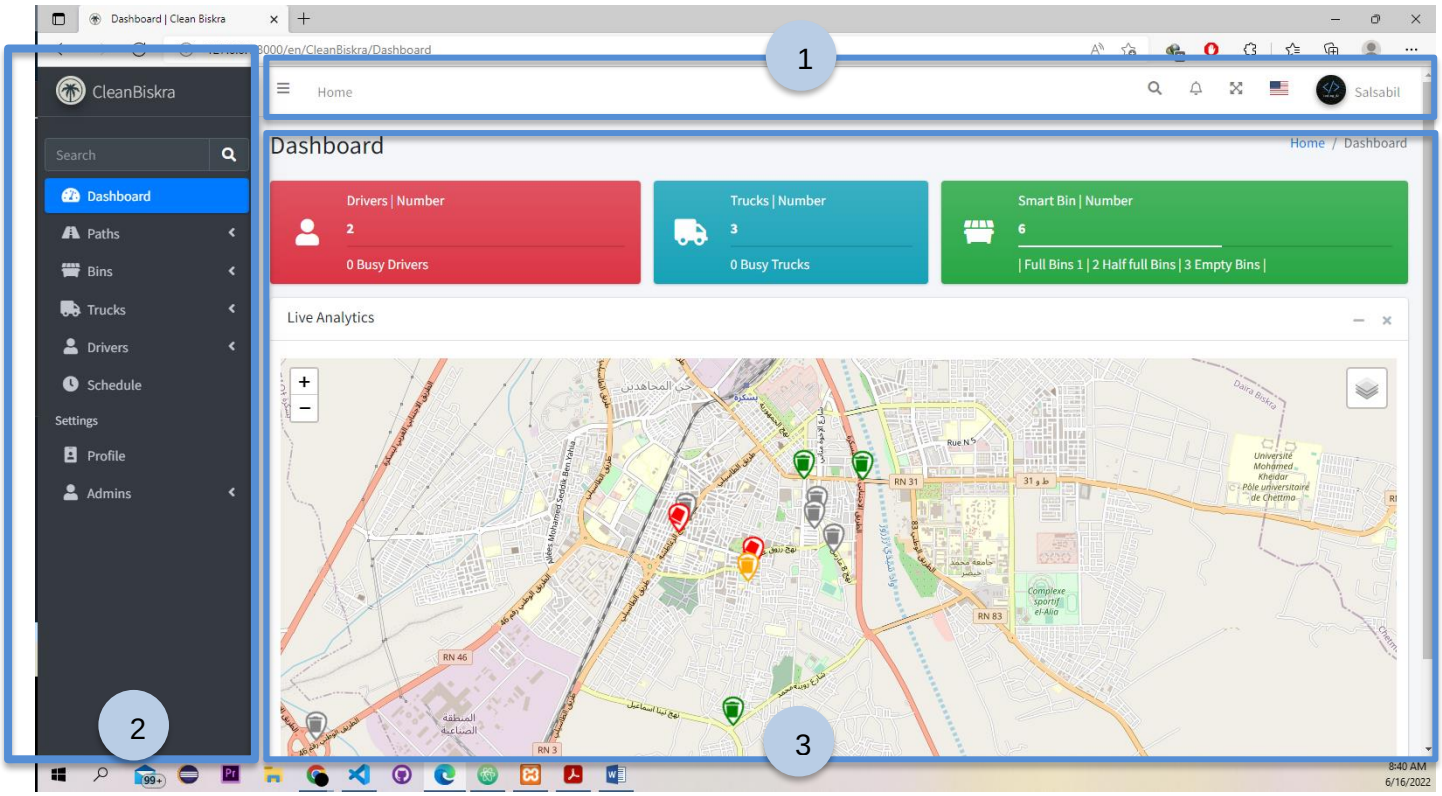
IV.4.1.2. Web site structure

The frontend of the web site is structured into three components:

(1) Navigation bar (Header) in the top of the page, it consists of (from the left to the right): a Hamburger menu button to slide the side bar in or out, a Home link to return to the home page, a Search button, a Notification dropdown menu, a Full Screen button, a Language Dropdown menu and a User Dropdown menu.

(2) Side bar on the left side of the page, it is structured into A website logo in the top, under that, a search input, and then a navigational links to the other pages of the website (Paths, Bins, Trucks…etc)

(3) Main content on the middle of the page.



FigureIV.4. Website structure

IV.4.1.3. Dashboard

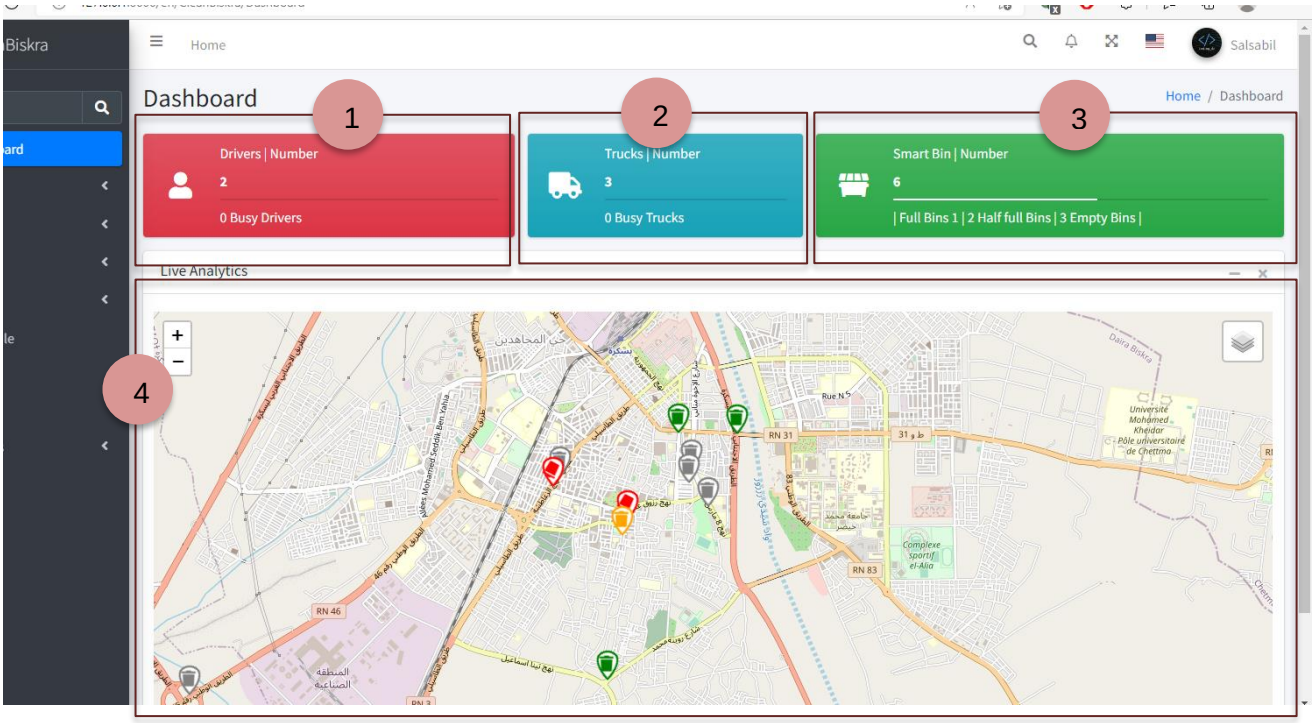
After login page, the dashboard page will appear, as we mentioned in the last chapter, the system has two types of admins: Manager and Supervisor, so there are two landing dashboard pages: one for the Manger which is structured as we described in (IV.3.1.2) section (FigureIV.4), and other for the Supervisor which displays only the analytics of the system (FigureIV.6), both of the pages contain the same analytics:

(1) Driver Number: it displays the total number of the drivers, and the busy drivers, also when the admin clicks on "*Busy Drivers*" phrase a modal will pop up, displays the id, the full name and the phone number of the Busy and Available Drivers (FigureIV.7).

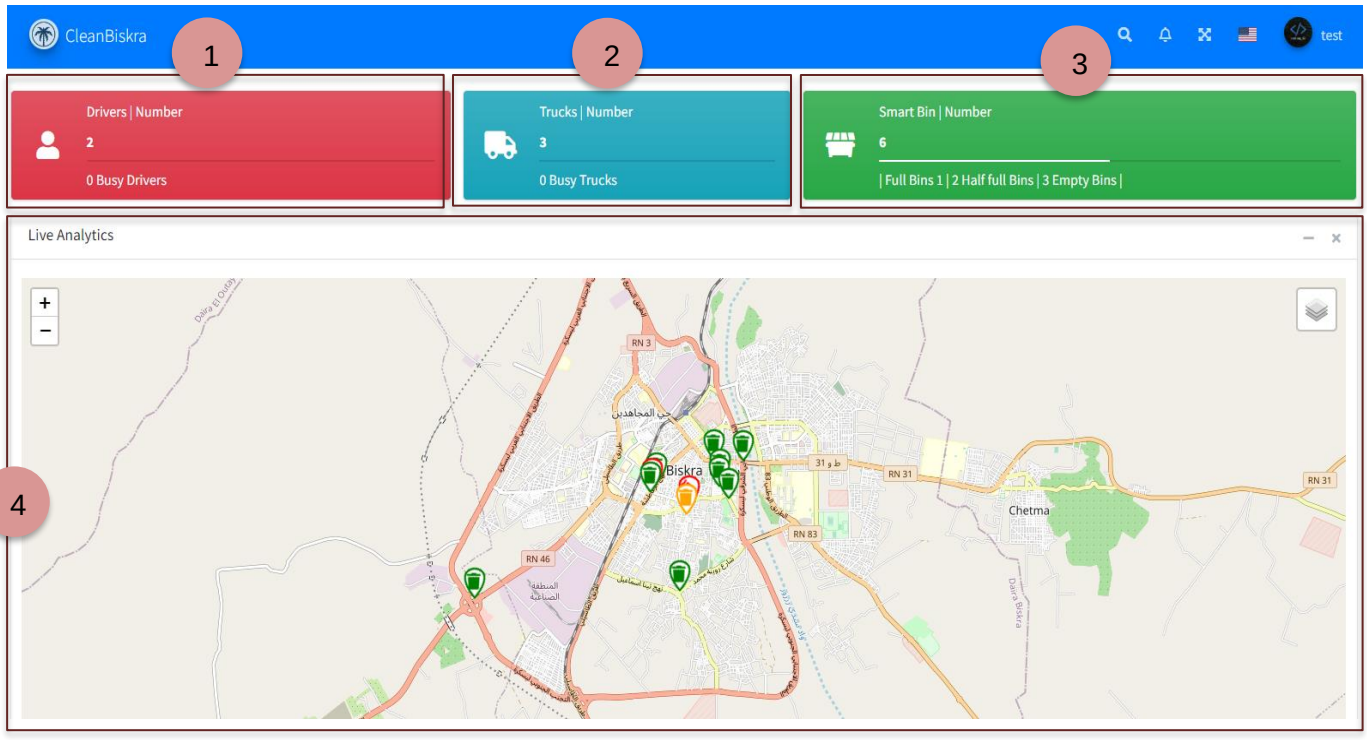
(2) Trucks number: it displays the total number of the trucks, when the admin clicks on "*Busy Trucks*" phrase a modal will pop up, displays the id and the Registration number of the Busy and Available Trucks (FigureIV.9).

(3) Smart bin number: it displays the total number of the smart bin, when the admin clicks on "*Full Bins*" phrase a modal will pop up, displays the id, the Longitude, Latitude, Fill level and the weight of the Full bins, the Half Full Bins and the Empty Bins (FigureIV.9)

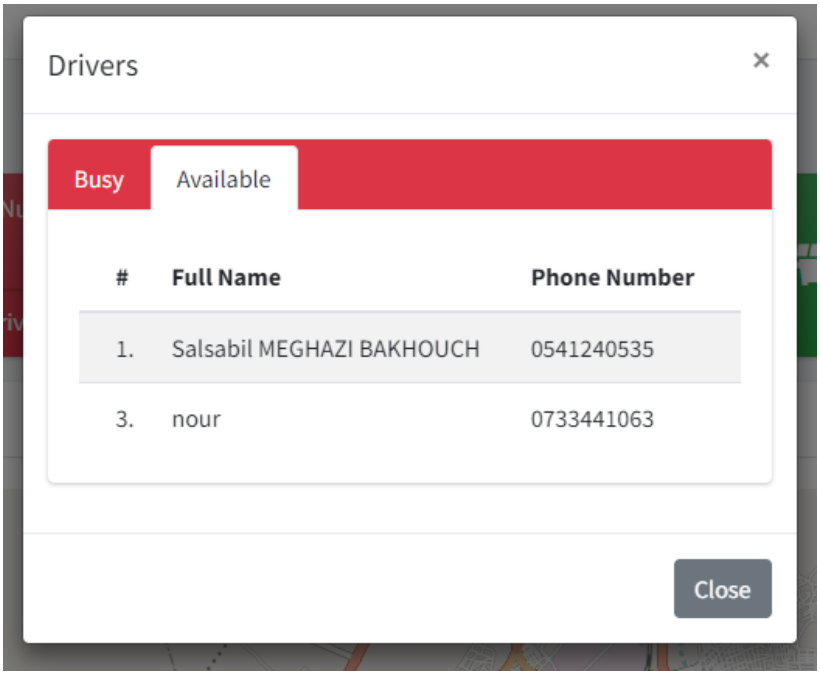
(4) Live analytics: it displays the real time data like all the bins with different colors, each color represents a different fill level of the bin, also when the truck start its tour or start collecting, the path of the tour will be showing on the map with the real time position of the truck.



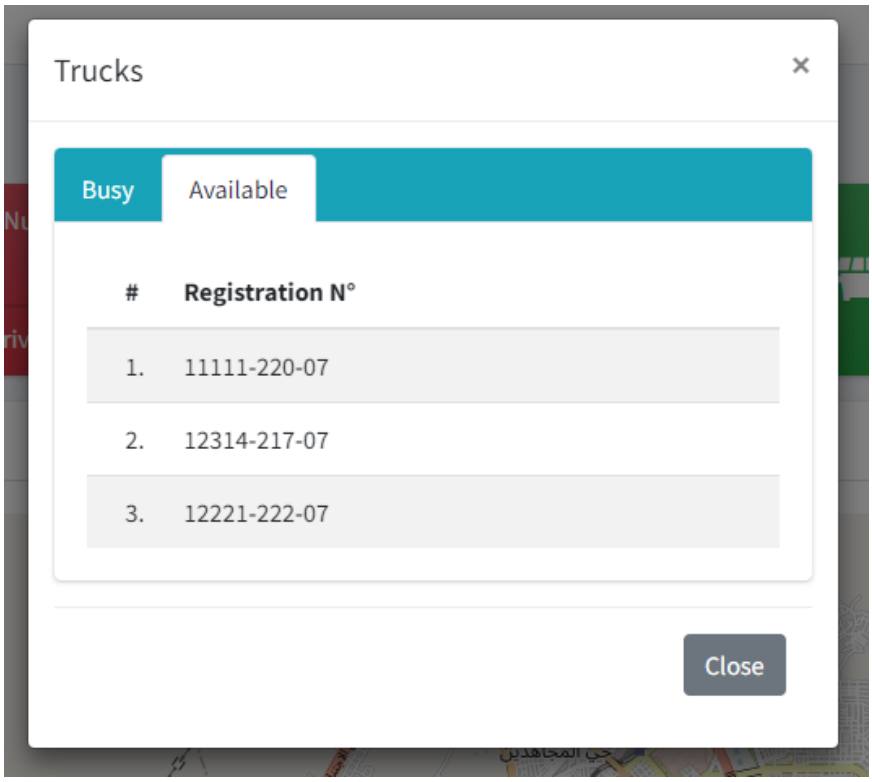
FigureIV.5. Dashboard Manger Page



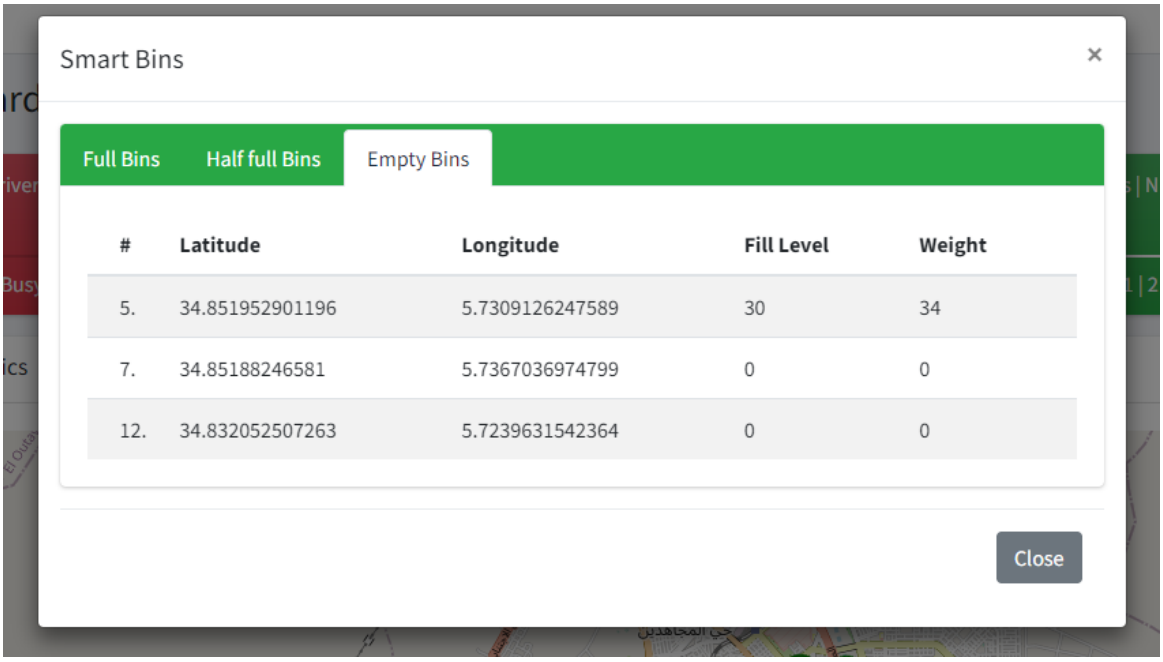
FigureIV.6. Dashboard Supervisor Page



FigureIV.7. Drivers pop up



FigureIV.8. Trucks pop up



FigureIV.9. Bins pop up

IV.4.1.4. Path pages

Path section consists of two pages Map Paths page and New path page:

- **Map Paths Page:**

  This page displays a map contains all the stored path on the database, (FigureIV.10):

  (1) Map of all the paths

  (2) Settings Dropdown for delete Path or add a new path. If the admin clicked on delete path a modal will show up (FigureIV.11), it contains all the existing paths, so the admin selects the path and then clicks on delete, the path will be deleted. If he clicked on add new path, the new path page will appear (FigureIV.12).

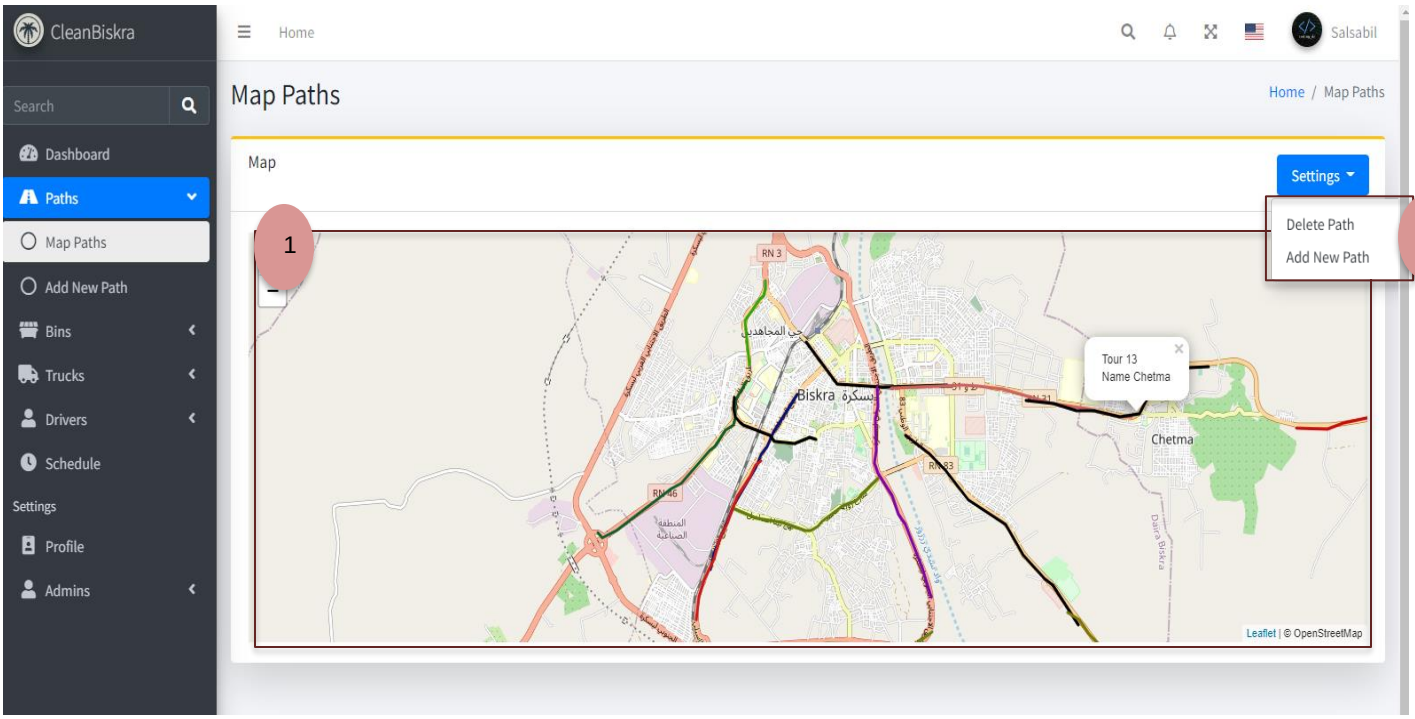
- **New Path Page:**

  This page enables the admin to add new path to the system (FigureIV.12):

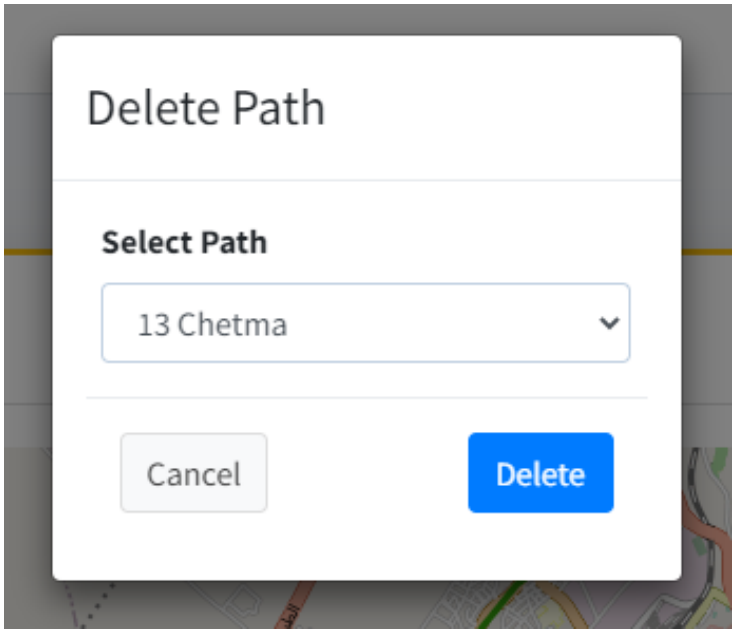
  (1) Is section composed from of two inputs: Color Path allows to select default color of the path and Path name.

  (2) It consists of a map, by default it has two markers green and red, represent the start and the end points of the path, the admin should click on the map multiple times to draw the path he wants to add.

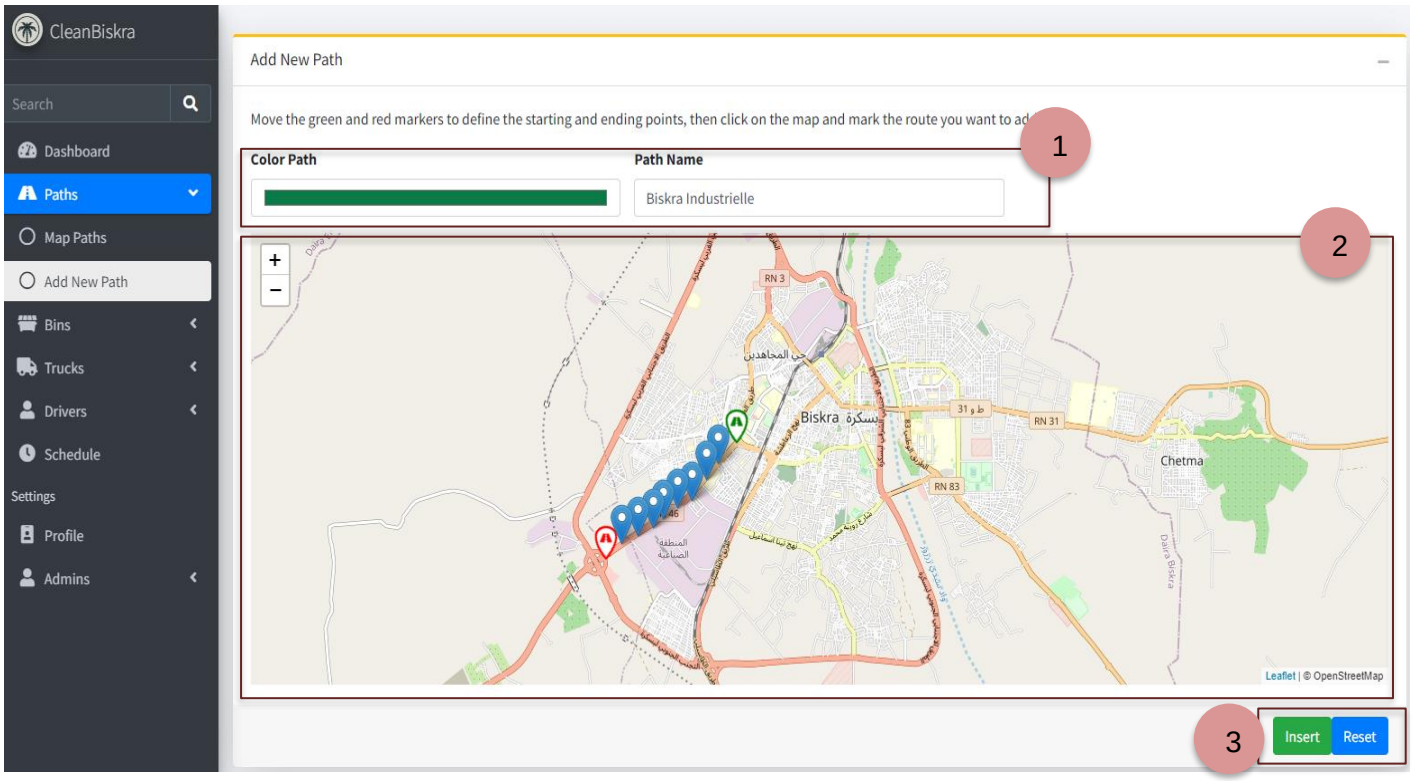
  (3) Composed by two buttons: Insert button to insert the path to the database and Rest button to return the map to the initial status.



FigureIV.10. Map of the Paths



FigureIV.11. Delete Path dialog



FigureIV.12. Add New Path Page

IV.4.1.5. Bins Pages

Bins section consists of three pages Map Bins Page, List Bins Page and New Bin Page:

- **Map Bins Page**

  This page displays a map contains all the stored bins on the database, with different colors "Non Smart Bins display in grey, Smart full bins in red, Half Full bins in orange and Empty Bins in Green "(FigureIV.13).

- **List Bins Page**

  This page displays a list of all the bins with their information (FigureIV.14):

  (1) Is options to export the bins' list, in form of PDF, CSV or print it, and it controls the table's visibility and show only the wanted information.

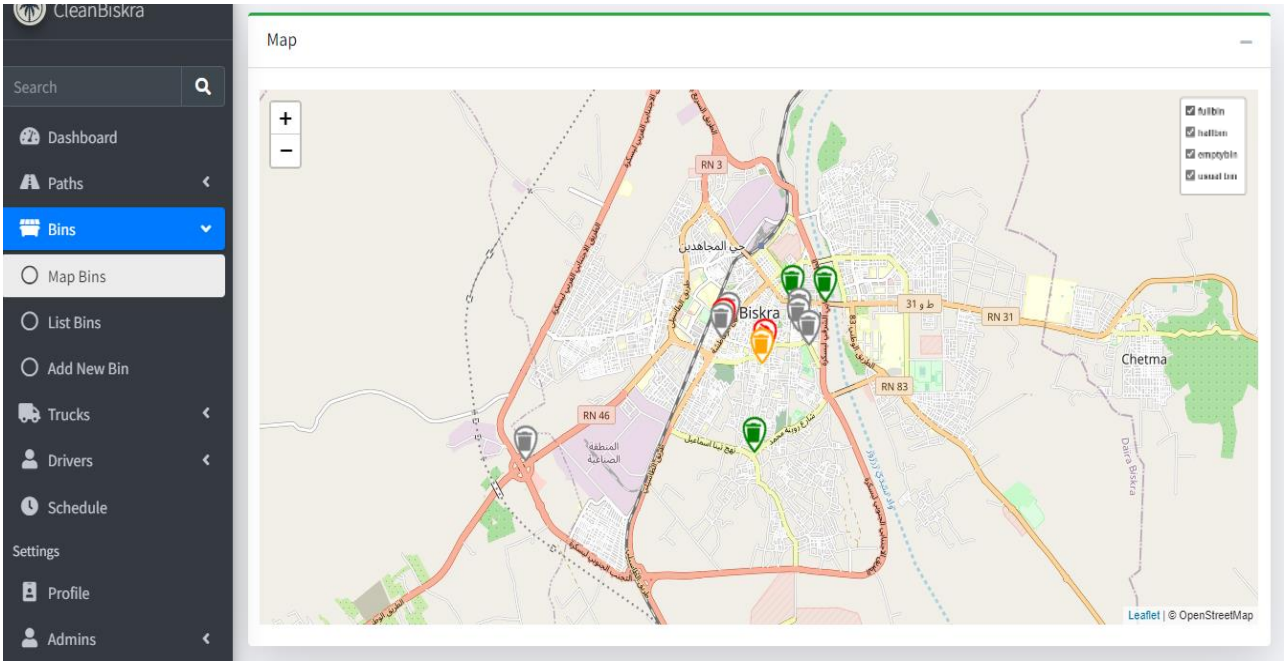
  (2) Is a table, it contains all the information of the bins: longitude, latitude, volume, total weight, (current weight and fill level if the bin is smart), and the last column display two values (icons), "X" if the bin is not smart, "right icon" if the bin is smart.

- **Add New Bin**

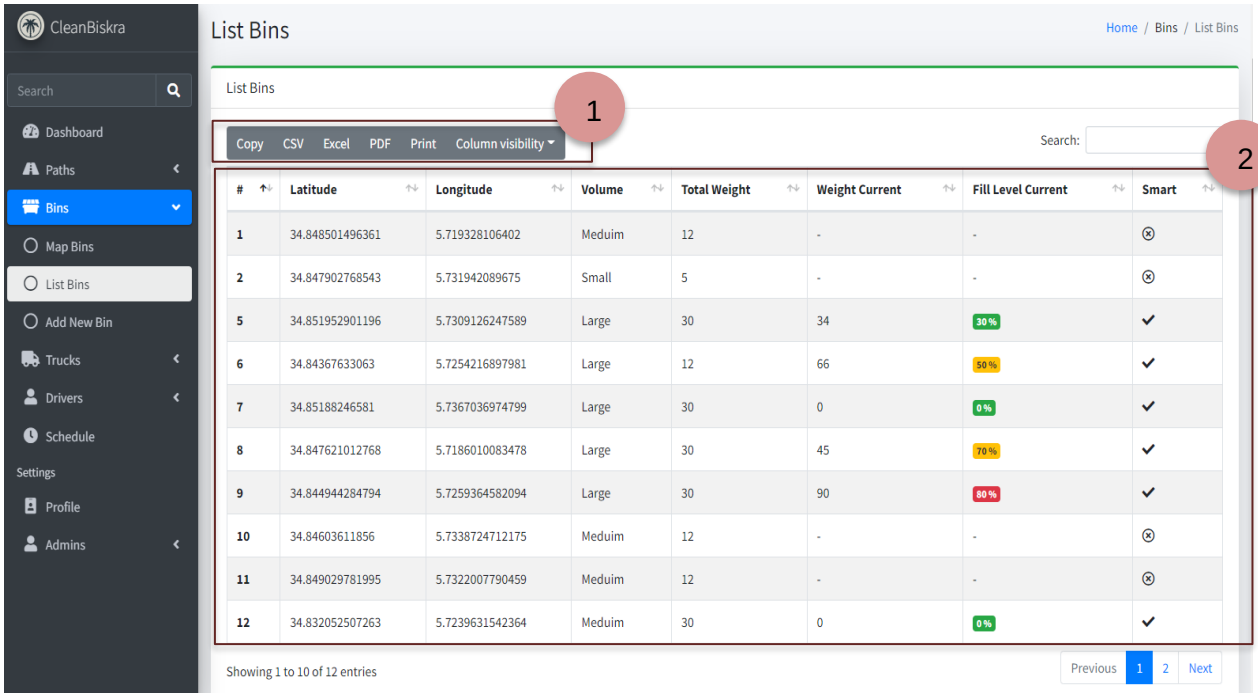
This page allows the admin to add new bin to the system, it consists of three sections (FigureIV.15):

(1) This section is a map, contains a draggable marker, it enables to select the exact position of the bin, while the marker is moving the longitude and latitude will be displayed on the location coordinates inputs on the section (2).

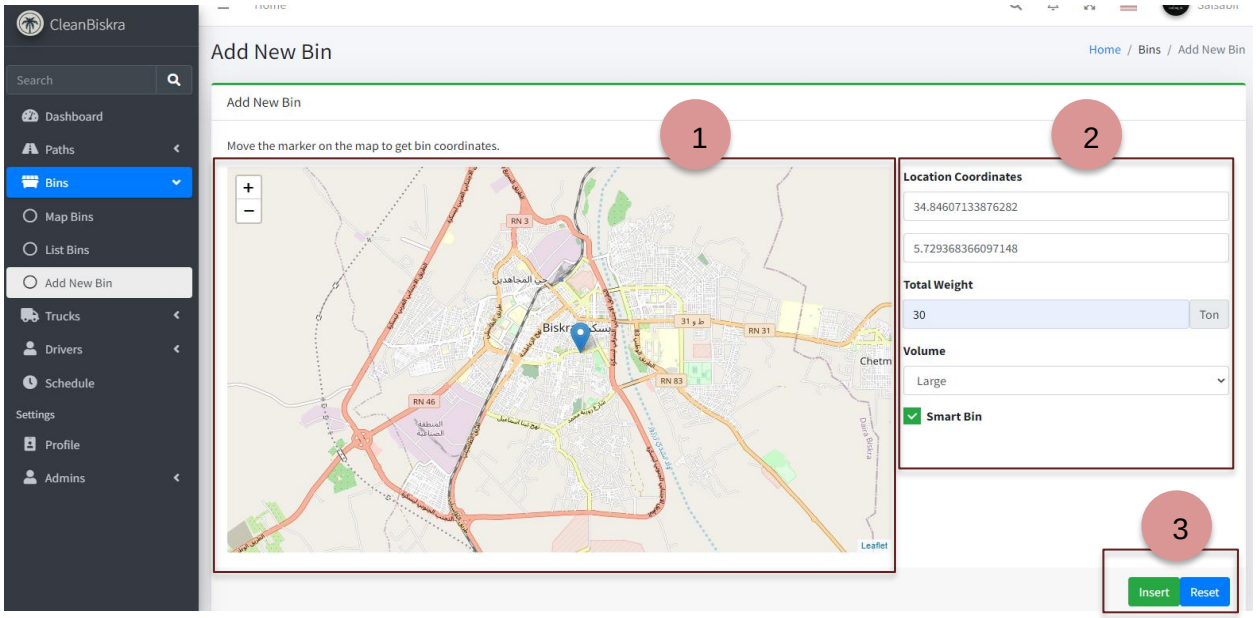
(2) This section is made up of four entries, two inputs for location coordinates, third input is for total weight of the bin, and the fourth entry is a dropdown to select the volume of the bin Large, Medium or Small, under that there is a check box to select if the bin is smart or not.



FigureIV.13. Map of the Bins Page



FigureIV.14. List Bins Page



FigureIV.15. Add new Bin Page

IV.4.1.6. Trucks Pages

Trucks section consists of two pages List Trucks Page and New Truck Page:

- **List Trucks Page**

  This page displays a list of all the Trucks with their information (FigureIV.16):

  (1) Is options to export the Trucks' list, in form of PDF, CSV or print it, and it controls the table to visibility and show only the wanted information.

  (3) Is a table, it contains all the information of the Trucks: The Registration Number, the Name of the tucks, the company of manufacturing, the type, the License plate, Expiry date and the status of truck (if the truck is online or not)

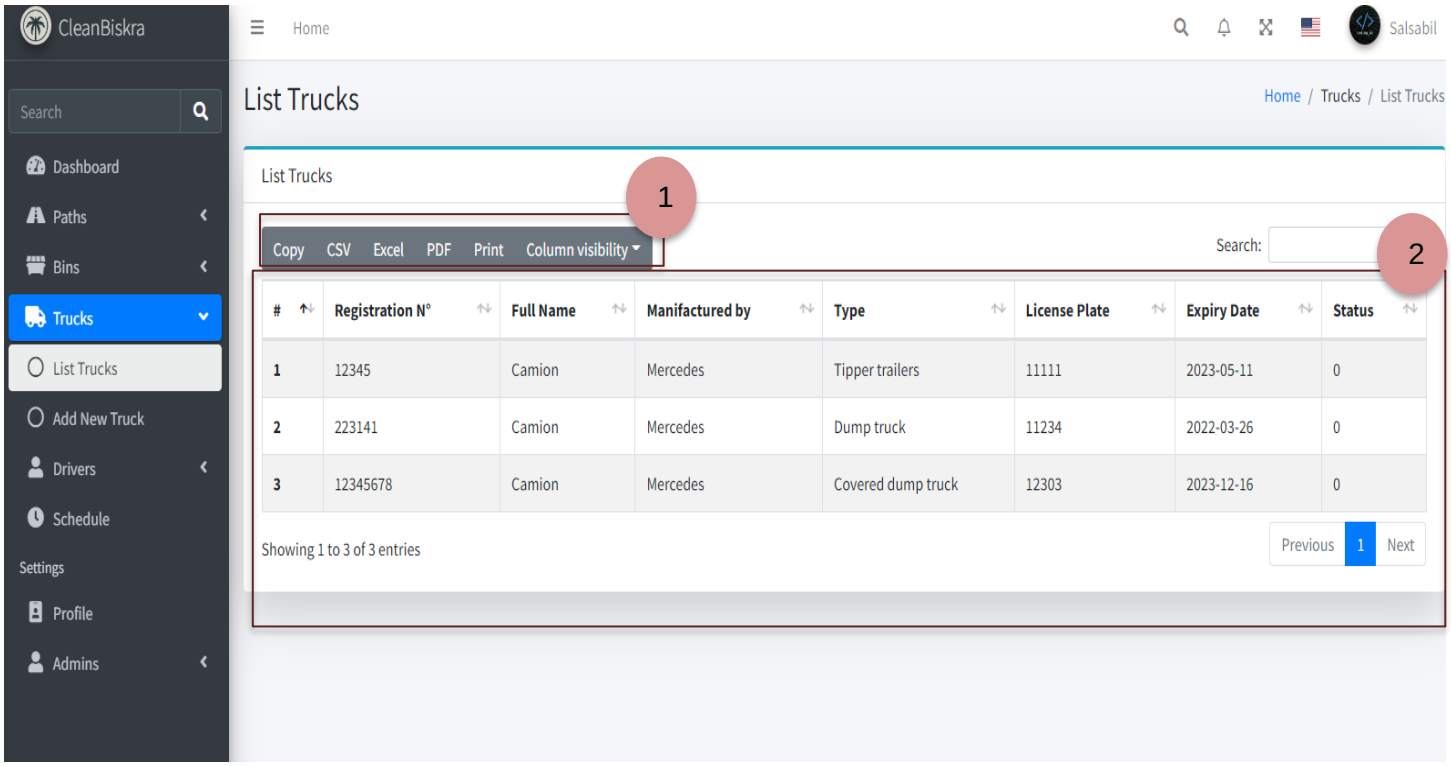
- **Add New Truck Page**

  This page allows the admin to add new truck to the system, it consists of three sections (FigureIV.17):

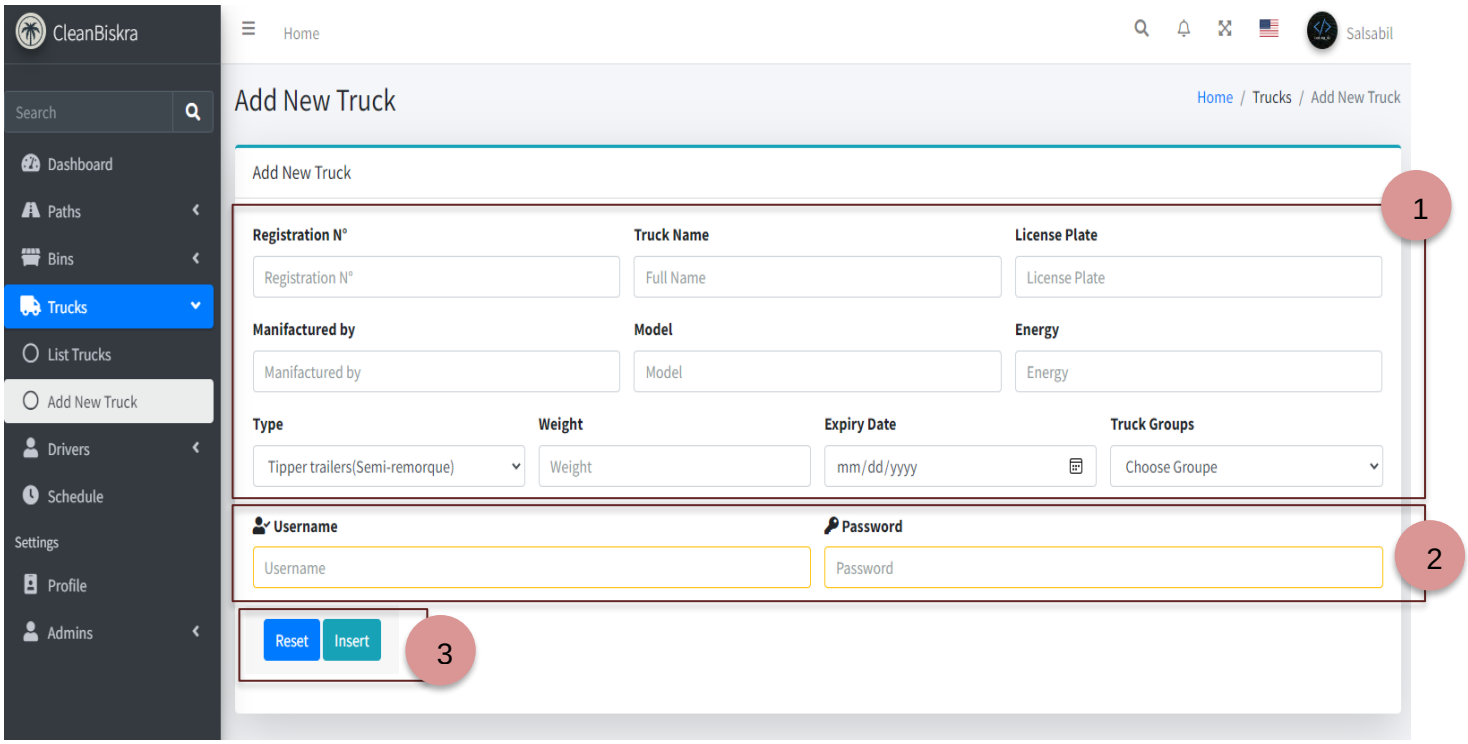
  (1) This section is made up of ten entries, the admin has to enter all the truck's information such as the registration number, license plate…etc.

  (2) This section formed by two inputs username and password, these inputs enables the driver to log into the truck's app.

  (3) This section consists of two buttons: Rest Button to reset all the fields of the form, and Insert Button to store the truck into the system.



FigureIV.16. List Trucks Page



FigureIV.17. Add New Truck Page

IV.4.1.7. Drivers Pages

Drivers section consists of two pages List Drivers Page and New Driver Page:

- **List Drivers Page**

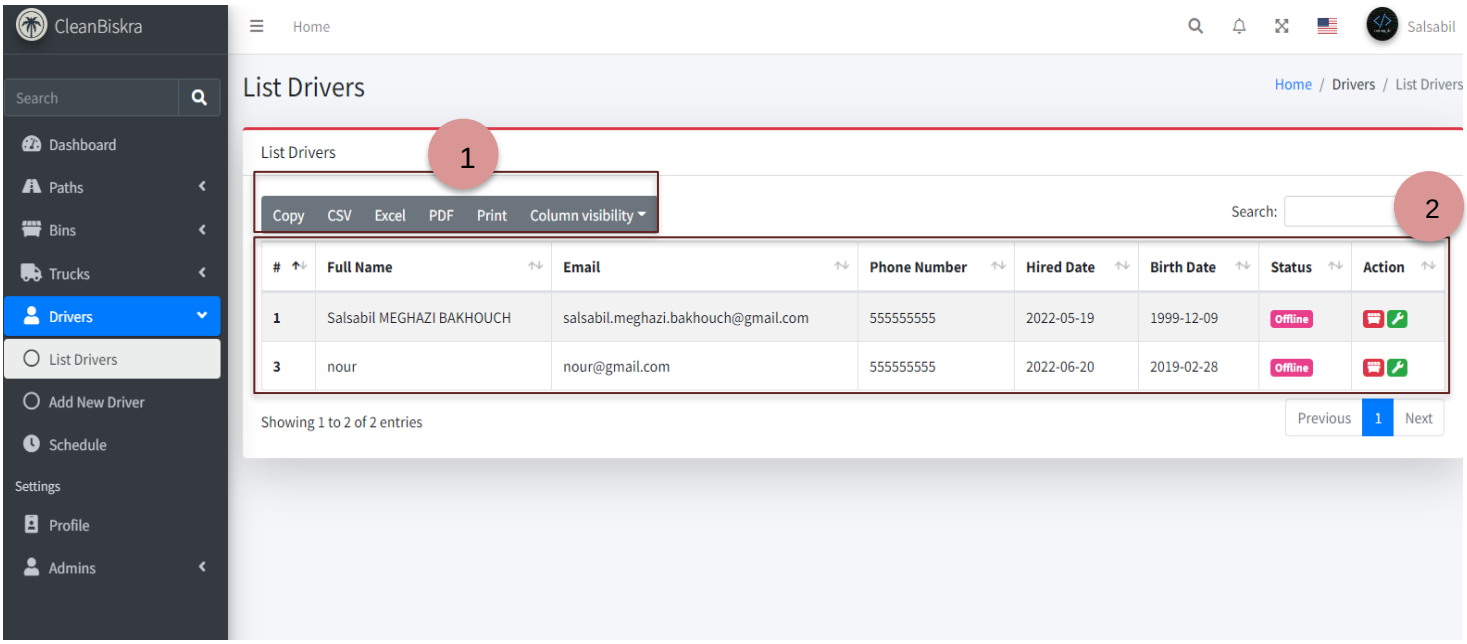
  This page displays a list of all the Drivers with their information (FigureIV.18):

  (1) Is options to export the Drivers' list, in form of PDF, CSV or print it, and it controls the table's visibility and show only the wanted information.

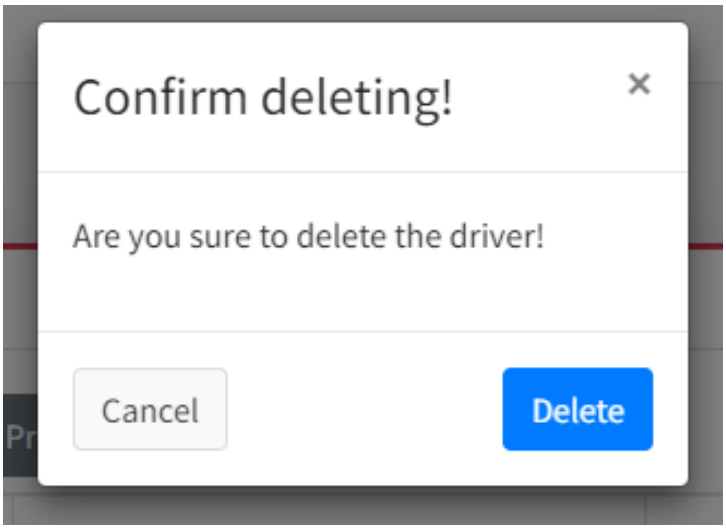
  (2) Is a table, it contains all the information of the Drivers: The Full Name of the driver, the Email, The Phone Number, the hired Date, the birth date and the status of driver (if the driver is online or not), and the last column is Action contains two icons: the red icon to delete the driver (a confirmation alert will pop up before deleting the driver FigureIV.19) and the green to edit the driver's information (a modal will pop up contain a form of the selected driver FigureIV.20).

- **Add New Driver Page**

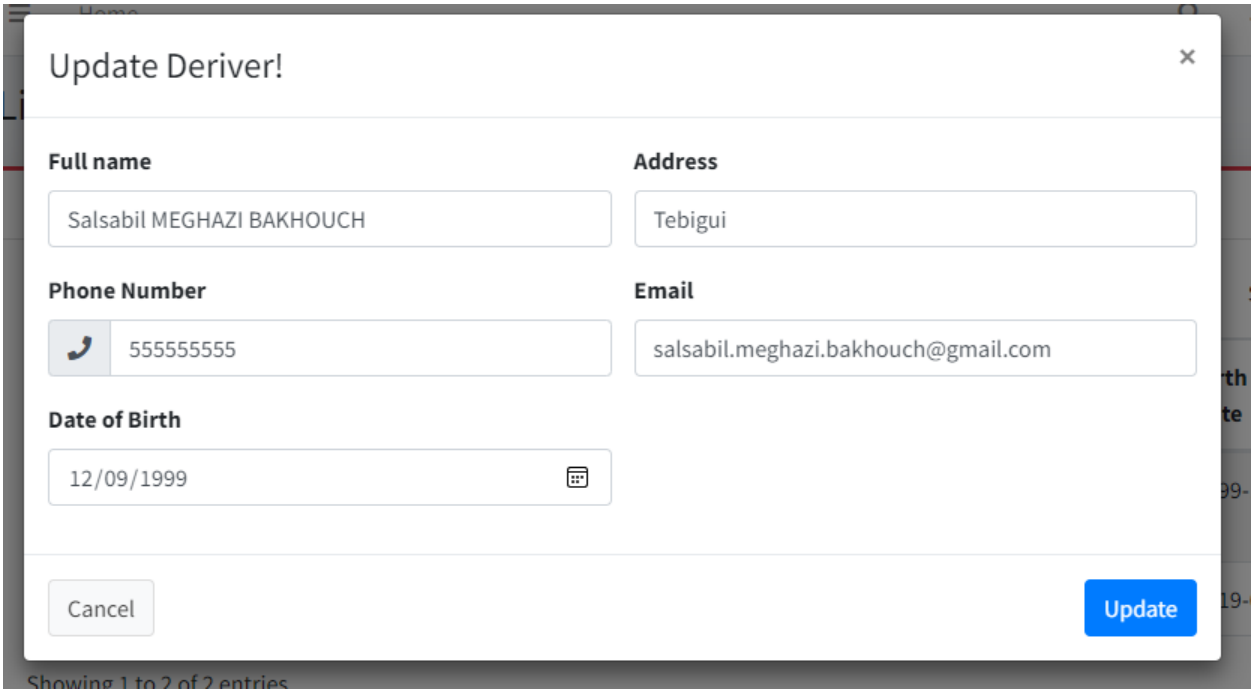
  This page allows the admin to add new driver to the system (FigureIV.21), it consists of a form of inputs to enter the driver's information: Full Name, Address, Phone Number, Email, Birth Date and Hired Date. The button Insert for storing the driver into the system, and the Reset button for resetting the form.



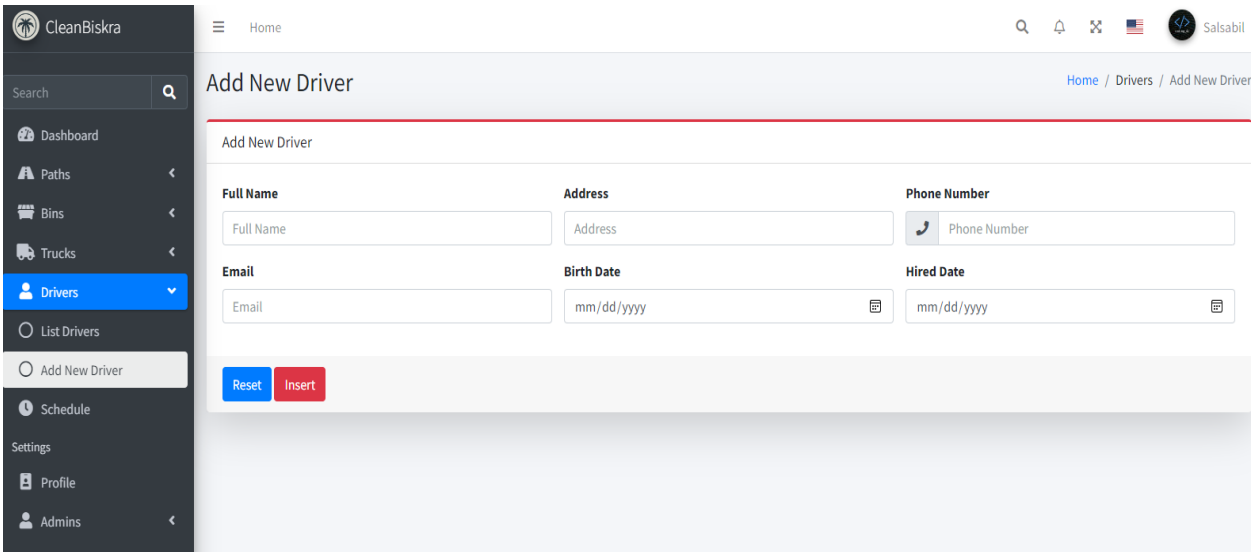
FigureIV.18. List Drivers Page



FigureIV.19. Deleting Confirmation alert



FigureIV.20. Update Driver's information Model



FigureIV.21. Add New Driver Page

IV.4.1.8. Schedule Page

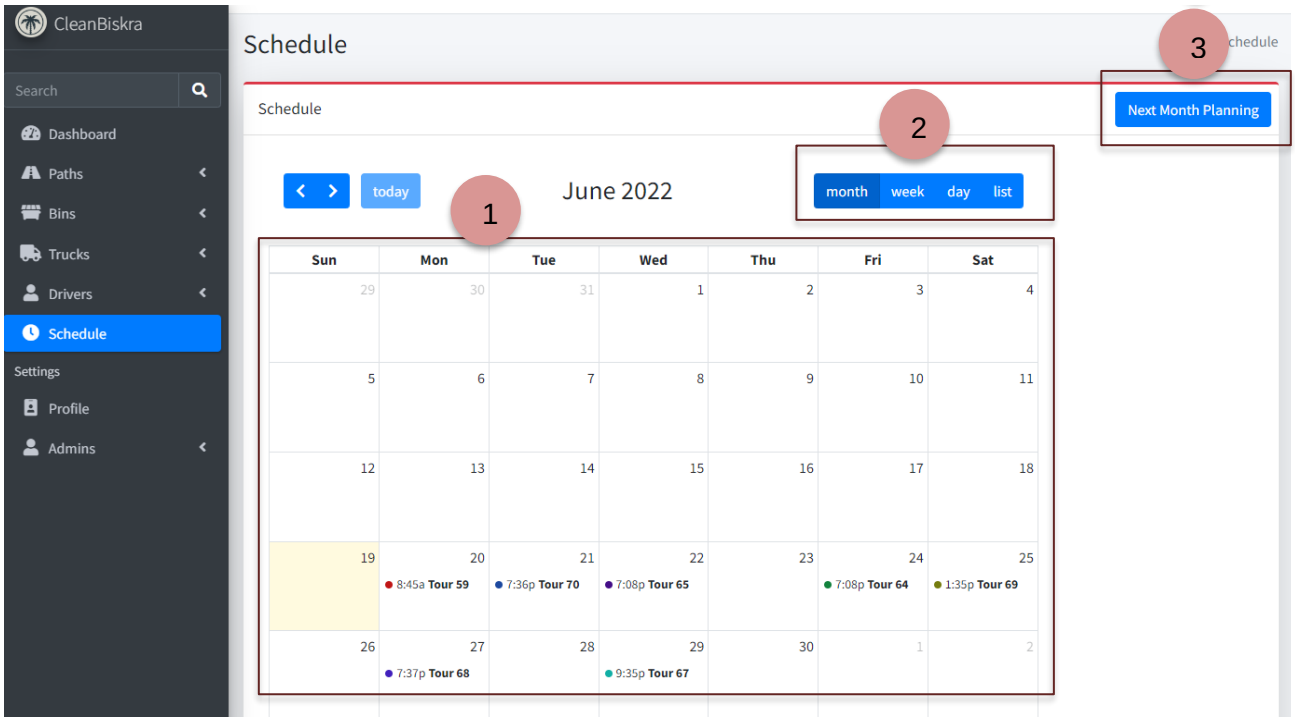
Schedule page is in form of calendar (FigureIV.22):

(1) It displays all the planning tours on the calendar, at their exact time. The admin has the possibility to edit the tour by clicking on it, a model will show up which contains the tour's information (FigureIV.23).

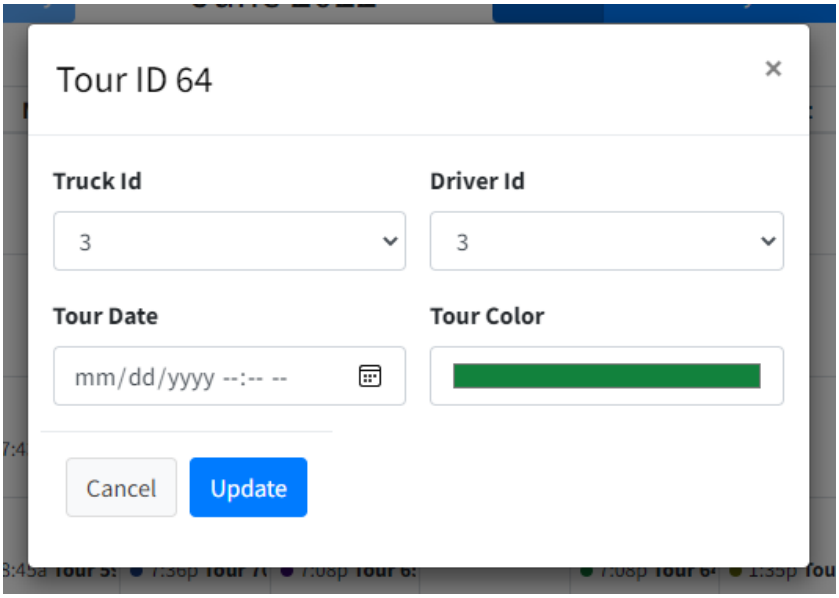
(2) Control buttons, they allow to select the calendar's type like month, week, or day or even the list of the tours of the week.

(3) It is a button named (Next Month Planning), it forwards to another page called Month Planning (FigureIV.24). This page composed of three cards Map, Calendar and Added Tours:

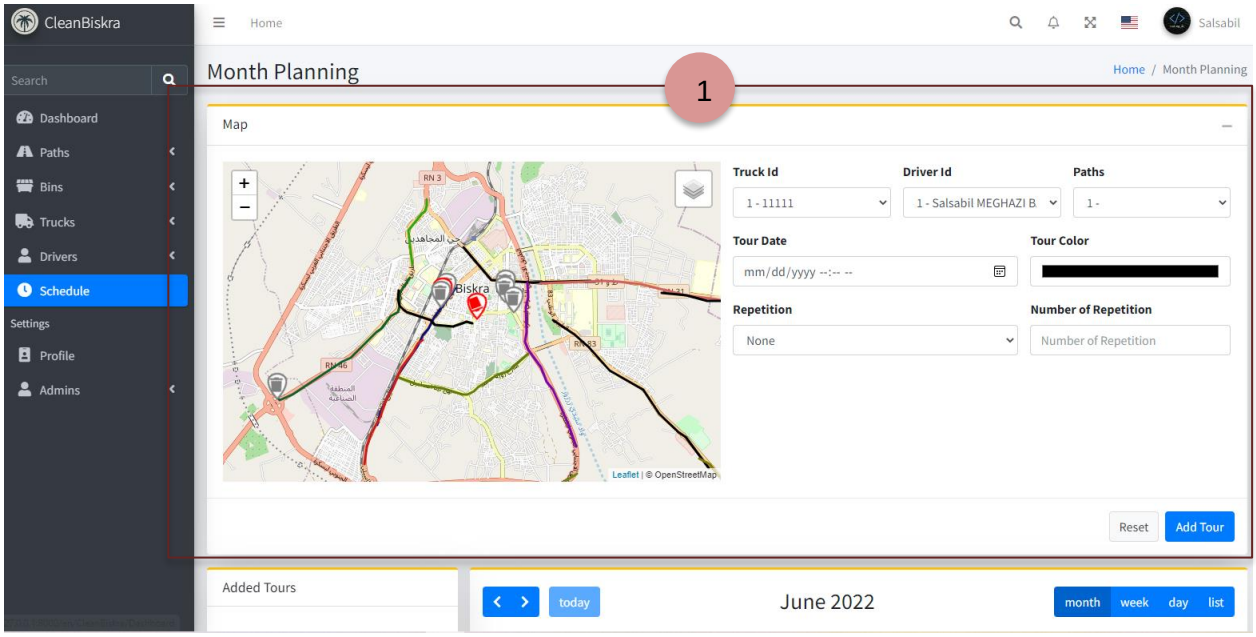
(1) Map card is made up of two components: Map, which displays the paths and all the bins on the map, and a Form which allows to enter the tour's information, after pressing the Add tour button, the tour will display on the calendar (2), and on the added tours list (3). When the admin finish adding all the tours, he can simply press on store schedule button to store the planning.



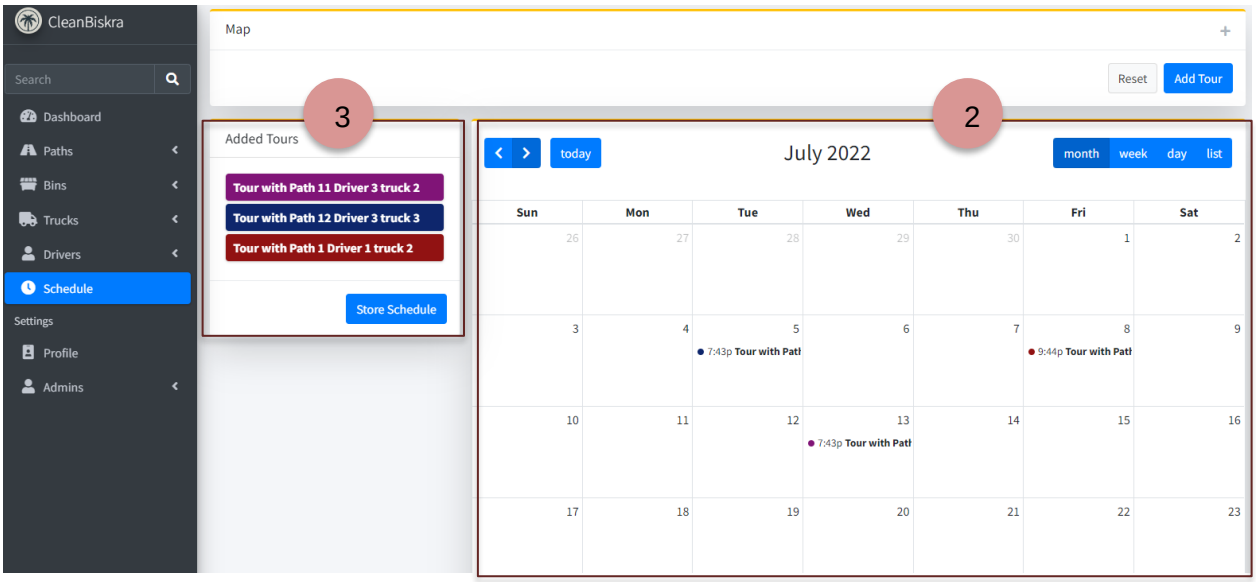
FigureIV.22. Schedule Page



FigureIV.23. Edit Tour Model



FigureIV-A- Map card (Month planning Page)



FigureIV -B- Calendar and Added tours cards (Month planning Page)

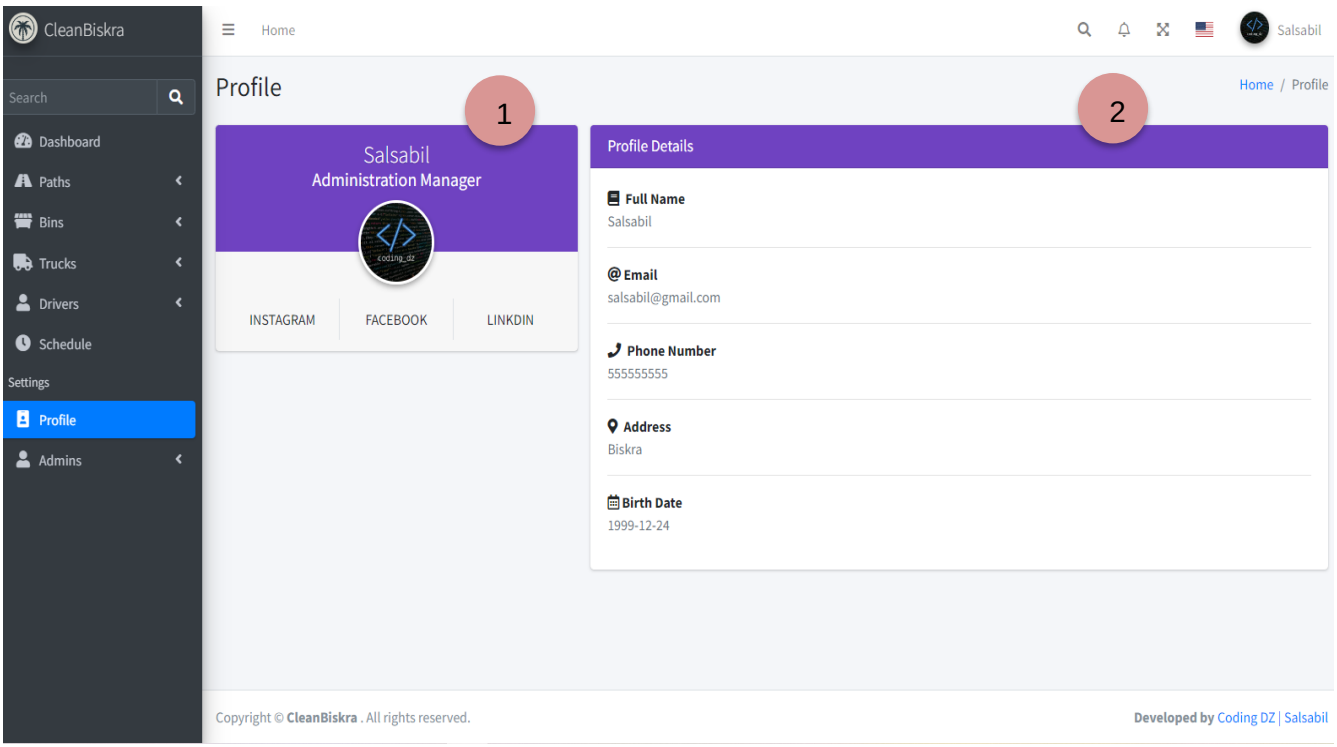
FigureIV.24 Month Planning Page

IV.4.1.9. Profile Page

Profile page contains all the information of the current admin

(1) This card shows the admin's name, grade, profile picture and the social media links.

(2) This card displays the Profile details like the full name the email, the date of birth, the phone number and the address of the admin



FigureIV.25. Profile Page

IV.4.1.10. Admins Pages

Admins section consists of two pages List Admins Page and New Admin Page:

- **List Admins Page**

  This page displays a list of all the Admins with their information (FigureV.26):

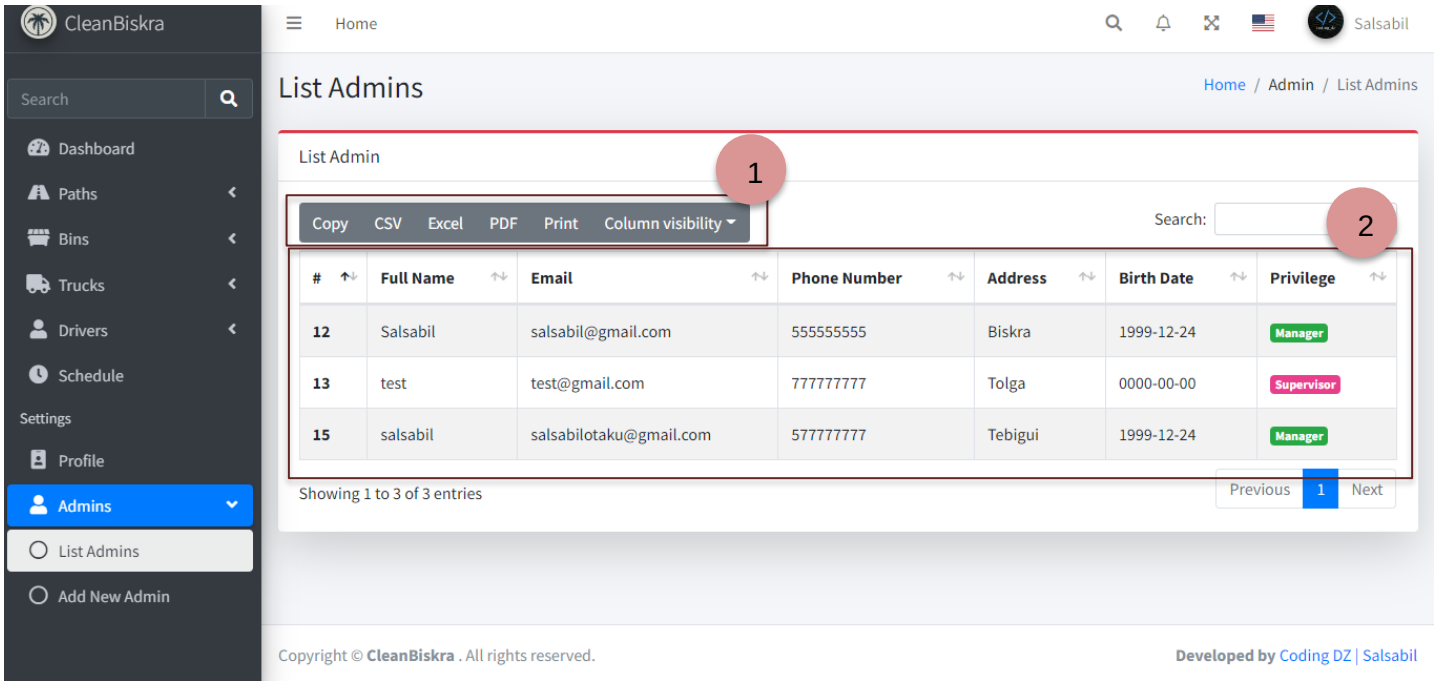
  (1) Is options to export the Admins' list, in form of PDF, CSV or print it, and it controls the table's visibility and show only the wanted information.

  (2) Is a table, it contains all the information of the Admins: The Full Name of the Admin, the Email, The Phone Number, the Address and the Birth Date. The last

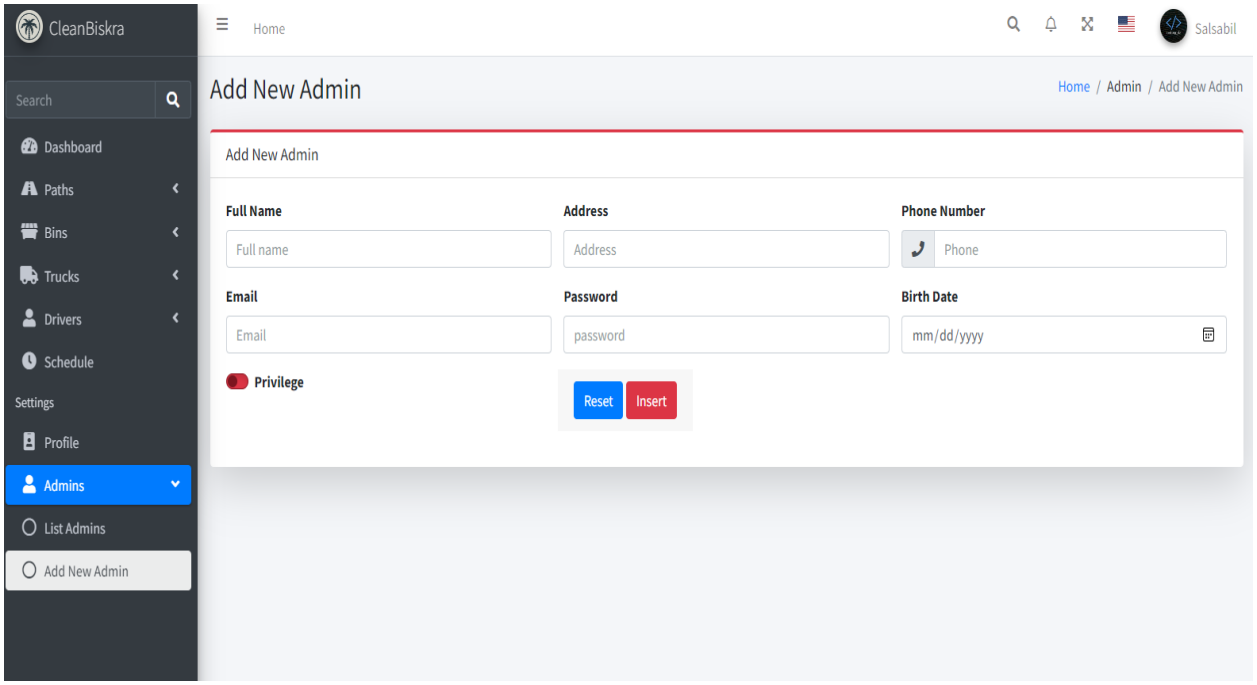
column contains the Privileges of the admins (if the admin is either a manager or a supervisor).

- **Add New Admin Page**

This page allows the admin to add new admin to the system (FigureIV.30), it consists of a form of inputs to enter the admin's information: Full Name, Address, Phone Number, Email, Password and Birth Date, and the last input is a check box to select the privilege of the admin (Red supervisor, Green Manger). It contains also two button: Insert Button to insert the Admin to the system and Reset Button to reset the form.



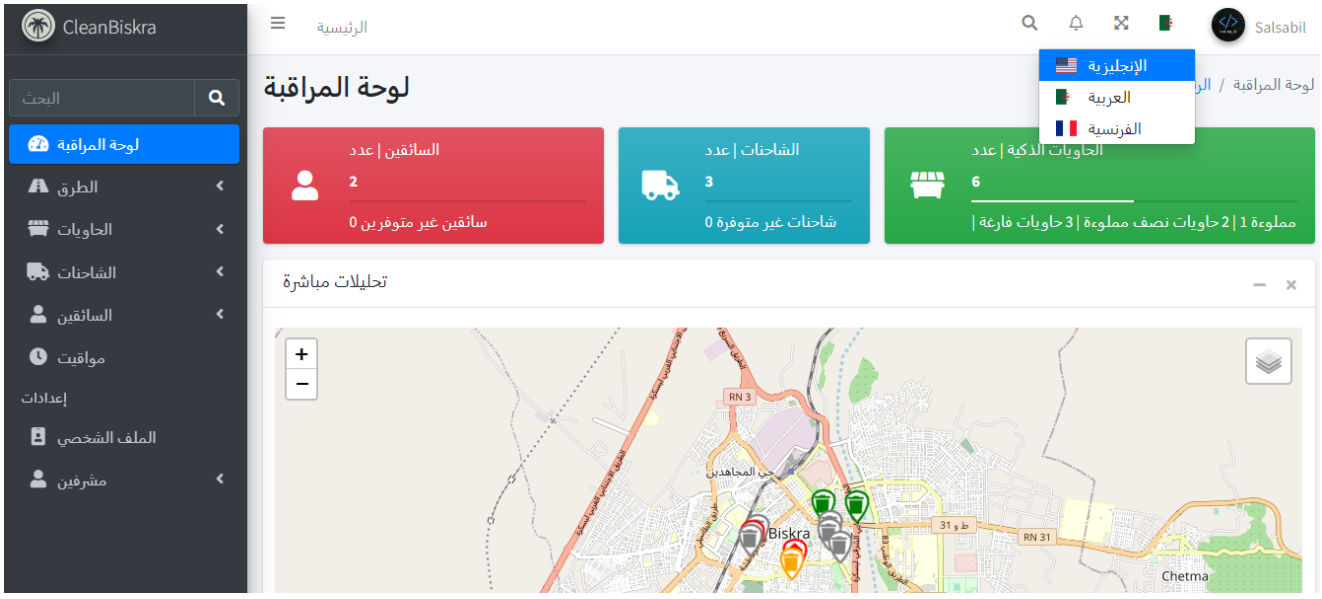
FigureIV.26. Admins' List Page



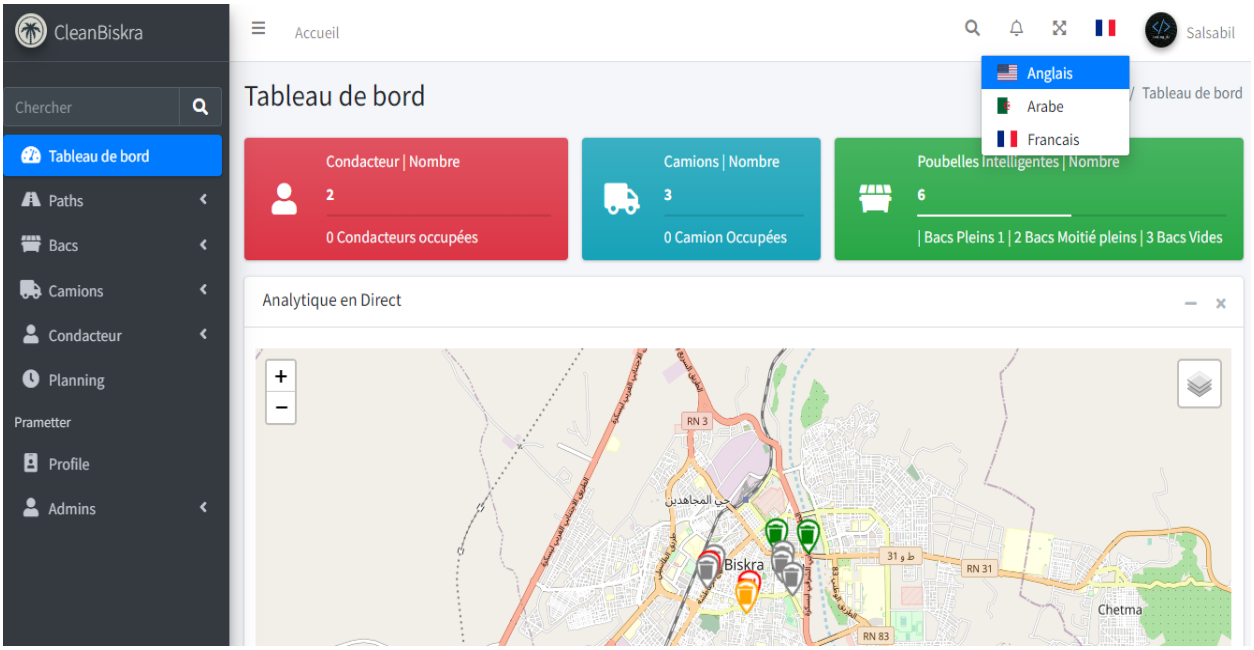
FigureIV.27. Add New Admin Page

IV.4.1.11. Language Support

The web site supports three different languages English as a default language, Arabic and French.



FigureIV.28. Dashboard page in Arabic



FigureIV.29. Dashboard page in French

IV.4.2. Truck Mobile Application

Truck mobile application is an application could be installed on the driver's mobile or on a tablet which is integrated on the truck.

IV.4.2.1. Login Screen

This page is the first page appears when the driver starts the app, it consists of two entries Truck username and password, and button under the inputs to Login into the app (FigureIV.30), once the driver logs in a notification will be sent to the admin.

IV.4.2.2. Set IDs Screen

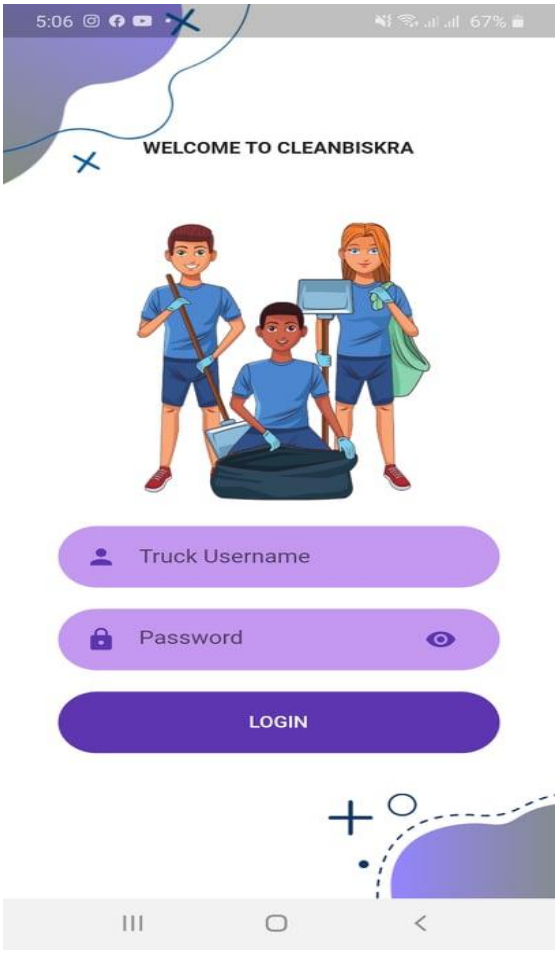
After logging in, this screen will show app (FigureIV.31), it is composed of two inputs for the driver's id and the tour's id, and a button to forward to the next screen.

IV.4.2.3. Start Tracking Screen

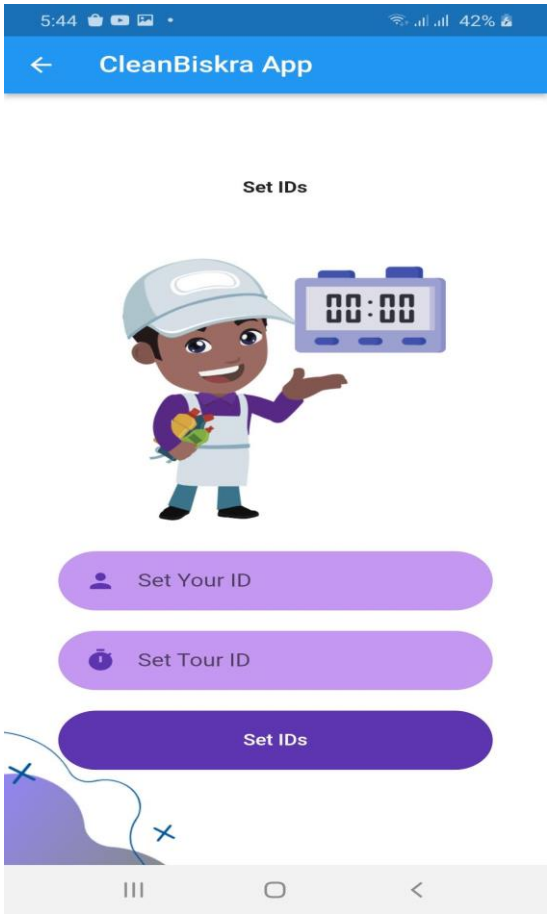
Start tracking screen is a basic screen contains two buttons: Start Tracking and logout. When the first button is pressed an access alert pops up to allow using gps of the device. The purpose of this button is to send a real time location to the web server, and it pushes to the Maps screen. The logout button stops tracking and return the first screen back (login screen).

IV.4.2.4. Map Screen

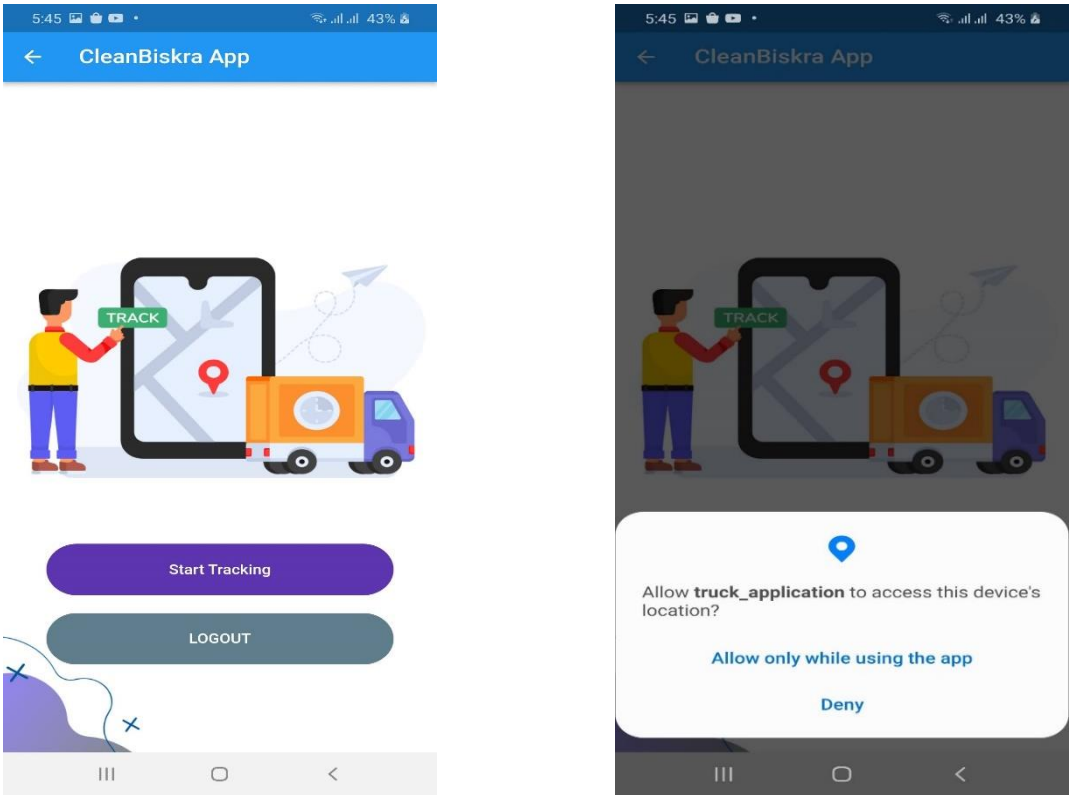
This page displays a map located in Biskra, it displays the current location of the track.



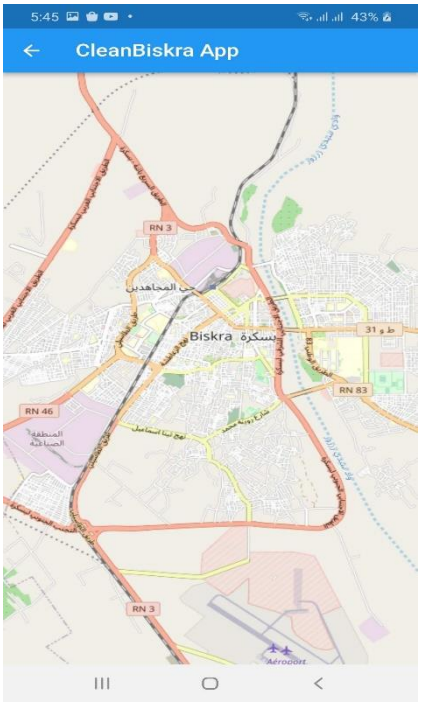
FigureIV.30. Login Screen



FigureIV.31. Set Ids Page



FigureIV.32. Start Tracking Screen



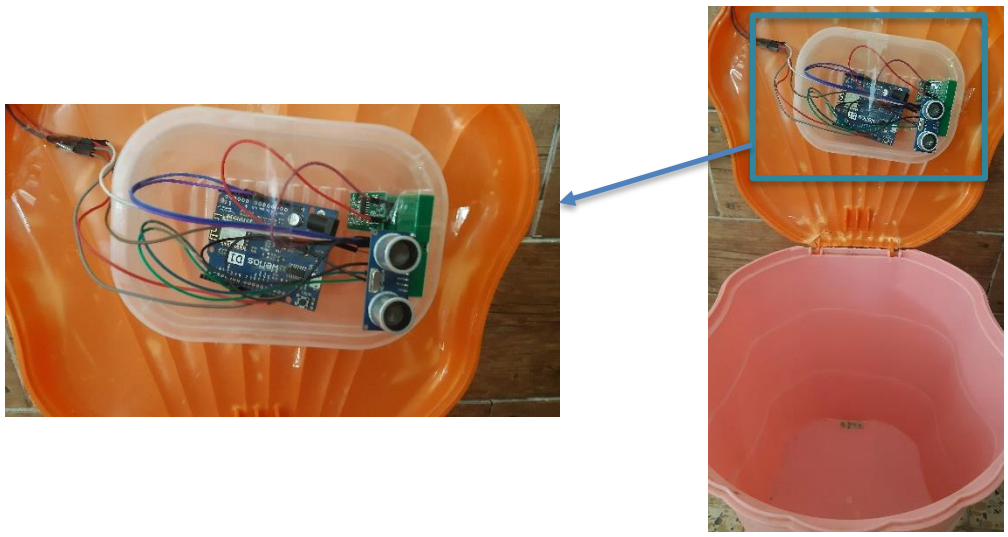
FigureIV.33. Map Screen

IV.5.3. Smart Bin Prototype

In this section we are going to introduce a smart bin prototype (figure.IV.34):

The IoT material are placed on the top of the dustbin, we used a breadboard to connect all the sensors to the microcontroller:

- The ultrasonic sensor (hc-sr054) calculates the distance with the next object first, and then he will be able to figure out the fill level of the bin, he sends the calculated data to the microcontroller in our case Wemos D1 R2. The microcontroller displays the obtain data on the LCD, and he send it also using the web connection to our cloud.
- The weight sensor (HX 711) get current weight level through the load cell which is placed under the bin, the retrieved data will be sent to the cloud.



FigureIV.34. Smart Bin Prototype

IV.3.2.1. Material Connection

In this prototype we used an HC-SR054 ultrasonic sensor, HX711 and Wemos D1 R2 (FigureIV.34):

First we placed the Wemos D1 R2, HC-SR04, HX711 and the lCD to the breadboard.

Then the pins are placed as follow:

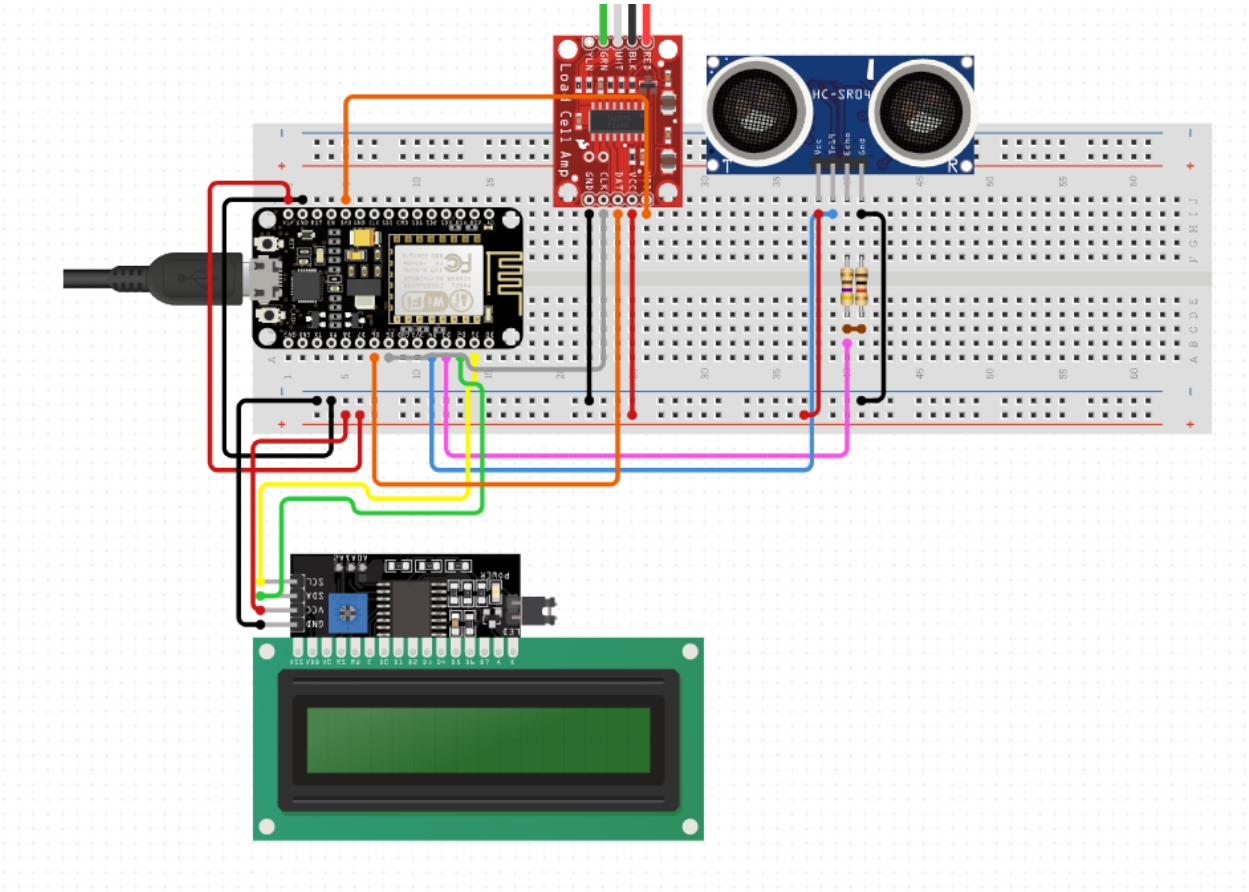
- Wemos D1 R2 :
  - GND to Bus GND.
  - Vin to Bus Vin.

- LCD
    - GND to Bus GND.
    - SCL to Wemos D1 R2 D1(SCL)
    - SDA to Wemos D1 R2 D2(SDA)
    - VCC to Bus POS

- HX711
    - GND to Bus GND.
    - VCC to Bus POS
    - CLK to Wemos D1 R2 D5
    - DAT to Wemos D1 R2 D6

- HCSR04
    - GND to Bus GND.
    - VCC to Bus POS
    - Trig to Wemos D1 R2 D4

Then we connected our microcontroller to a source power (we used batteries).



FigureIV.35. IoT Material Connection

IV.6. Conclusion

In this chapter, we presented the implementation of our solution, first we started by introducing the used tools software and IoT materials, after we presented the administration dashboard page by page, then we introduced the Truck Mobile Application, and lastly, we described the smart dustbin's prototype.

General Conclusion

Waste management system used to be a critical issue to all the countries around the world, as the human population keeps growing, so the waste keeps growing too, so for a cleaner environment we have to find the best management system, but in our city we can easily notice the trash and the litter are on the grown not on the bins, and the citizen have complaints, and they are not satisfied with the view, this assume that the classic waste management system is highly inefficient.

We proposed a new waste management system based on the internet of things. This system provides real time insights on the trucks movements and bins' fill level.

In our project, we developed a web dashboard for the admin which provide a real time analytics such as the current location of the trucks and the fill level of the bins, this data was presented on a map and in form of different ways, we developed also a truck's mobile application, which contains a gps module allows to retrieve the truck's location information such as the current position and the speed, and the app will notify the administration when the truck's tour get started. In addition, we've provided a dustbin prototype based on IoT, which allows to capture the current fill level and the weight of the bin.

Future Work

As future work, we would love to include an optimization route module to the trucks' application. Instead of driving along preplanned collection routes, optimization module helps to generate new collection path at the current moment, pass by all the full bins.

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