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A FRAMEWORK FOR REDUCE CO_2 EMISSIONS AND ENHANCING ENVIRONMENTAL SUSTAINABILITY PROTECTION USING IOT AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

In recent years, our environment is constantly changing and faces multiple problems, it is for this reason that is necessary to become increasingly aware of all problems that surround it. The parts per million of CO_2 in 2022 is 418 and the global temperature rise now 1.1 Celsius [1]. The whole world knew several disasters due to the increase in greenhouse gas emissions, these disasters are multiple like eat waves and flooding to be more intense and frequent than seen before. According to this study [2], even if all greenhouse gas emissions were halted in 2020, global warming would only be halted by around 2033. The IoT market, and specially M2M (Industrial IoT) sector, has been growing very rapidly for several years, at the same time, a crucial issue for urban planning has emerged: the need for a green economy that would make it possible to reconcile cities with the environment. The AI also makes it possible to rationalize agricultural operations, optimize yield and contribute to the reduction or elimination of insecticides and chemical products by detecting the proliferation of diseases or insects as early as possible. The purpose of this article is to give a state of the art on the use of IoT and AI to enhance environmental sustainability, propose a secure solution based on IoT and AI to reduce and optimize the time of waste collection in smart cities and the CO_2 emissions.

Keywords*: CO_2, Internet of Things, Artificial Intelligence, Environmental Sustainability, Architecture*

1. INTRODUCTION

In November 2022, there will be an international conference of the United Nations on climate change, multiple actions are taken over years. Based on the Organization for Economic Co-operation and Development (OECD), 25 climate actions are listed until 2025, these actions focus on 5 highest-emitting economic sectors, agriculture, buildings, electricity, industry, transport, and are organized according to 5 policy levers, invest, regulate, tax and subsidies, led by example, and inform and educate.

The following list shows some examples of these actions related with IoT and AI:

- ✓ Improve productivity sustainably through innovation, to lower emissions and feed a growing population: Production of similar or higher amount of food with fewer inputs can help reduce emissions, these productivity improvements will be sustainable if they are supported by regulations and efforts to prevent forest clearing. Increase the productivity requires both the adoption of existing technologies and techniques and the encouragement of innovation.
- ✓ Educate planners and contractors on how to construct and maintain green buildings: This action is based on personnel awareness of green buildings, this is essential not only for construction, but also for pollution and waste reduction systems and air quality and renewable energy installations.
- ✓ Create conditions that increase accessibility and maximize use of transport capacity: This action insists to use more car sharing, studies show that car sharing can provide the same flexibility as private cars but will reduce CO_2 emissions. The use of eco-friendly ways like walking or cycling can help reduce the CO_2.
- ✓ Make low-carbon transport the default for public sector decision making: The governments should invest in public transport, encourage

walking and providing good charging infrastructure. Integrating transport planning with land-use policy and promoting urban densification will bring jobs, goods, and services closer to people and reduce the need for commuting.

- ✓ Share knowledge about tested measures that reduce transport emissions: This action sensitizes everyone towards national and international cooperation to create a more effective political approach, this approach will make the necessary conditions for the introduction and intensification of decarbonization measures as rapidly as possible.

Governments spend 340 billion each year supporting the production and use of fossil fuels through direct subsidies and tax rebates, which is good news, because it shows that the money is available, but we need to ensure that it is channeled to the right places. Leveraging Artificial Intelligence and the internet of things (IoT) for a healthy planet can help maximize our current environmental protection efforts.

According to a 2018 report by Intel, 74% of 200 business decision makers in the environmental protection industry agreed that AI can help solve our environmental problems. Below some examples of use cases where the internet of things (IoT) and/or artificial intelligence can help to have an ecological world:

- ✓ Improve air quality: Air purifiers with AI can record air quality and environmental data in real-time and adapt the filtration efficiency, AI provides the ability to send alerts to people living in rural areas about pollution levels in their areas. Currently, several tools exist that can detect sources of pollution quickly and accurately, with the help of the use of vehicle data, radar sensors and surveillance cameras, AI plays a very important role to help reduce air pollution.
- ✓ Maximization of renewable energies: Renewable energies have been recognized as useful in safeguarding the environment from the dangers of fossil fuel exploitation. Integrating IoT and AI into existing practices can further maximize the value delivered by clean energy. This will help to make solar panels and wind turbines more efficient and above all economical. “Smart grids” will change the way of how electricity is generated and distributed to homes, offices and everywhere else. These networks, which are a cloud of connected devices, give energy suppliers a better understanding of energy consumption allowing them to optimize distribution in real time. Today, 8% to 15% of the electricity produced is lost in transmission lines. This phenomenon is called “line losses”. Widespread deployment of smart electrical systems should drastically reduce the amount of wasted energy.
- ✓ Sustainable agriculture: Soil pollution is a major problem we face today. Population growth, intensive agriculture and other activities are the cause. Every year around the world, thousands of people die from pesticide poisoning. Monitoring crops and soils, promoting production with low environmental impact are something achievable, with the use of IA/IoT. They have the potential to transform traditional farming practices, paving the way for safer and more consumer-friendly methods. With “intelligent” and “connected” sensors, growth can be constantly monitored. Parameters such as plant hydration and nutrition can be monitored in real time. The data collected can then be used to determine irrigation patterns and recommend the best watering cycles.
- ✓ Animals protecting: AI can gather data from ocean locations that are hard or impossible to reach and thus, help protect species and habitats. AI provides the ability to track and detect illegal fishing. Also, to monitor ocean conditions such as pollution levels, temperature, pH, etc, AI-powered robots can be used.
- ✓ Optimized waste management: To fight against the ecosystem’s pollution, more and more communities are using weak AI based mainly on data collected by the presence, movement, temperature, pollution sensors, etc. For example, the implementation of the waste treatment process based on decision support algorithms, which will provide recommendations to reduce environmental costs. AI can also be used to recover waste scattered in nature. Indeed, operators can install a smart camera with visual recognition that automatically identifies any non-compliant object when dumping dumpsters and sends an alert so that it is removed before incineration.
- ✓ Preserving biodiversity: AI could play an invaluable role for nature conservation initiatives. Advanced drone and satellite technologies used for detailed species observation generate huge amounts of very valuable data. They won't be of much use, however, without AI and its high-speed data processing capability, which can collect data

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faster than humans. This data then helps us to deepen our knowledge of the reasons for biodiversity loss and find solutions to address it.

- ✓ Water security: Scientists use AI to project water use in a particular geographic area and help make weather forecasts to make informed policy decisions. Satellite data with AI can also help predict weather, soil and groundwater conditions and identify droughts in advance.
- ✓ Weather and disaster resilience: AI-powered predictive analytics along with drones, advanced sensor platforms and similar tools can monitor tremors, floods, windstorms, sea-level changes, and other possible natural hazards.

2. IOT AND ARTIFICIAL INTELLIGENCE

2.1. Internet of things

Internet of Things, called also IoT, is the network of physical things, equipped with electronics, transducers such as sensors, connectivity, actuators, and software to capture, process, filter and exchange this data with other IoT items in the environment.

The Internet of Things represents a vision in which the Internet extends into the real world including everyday objects. Physical elements are no longer disconnected from the virtual world but can be controlled remotely and serve as physical access points to Internet service (Chahid et al.) [3].

The IoT has 5 layers, perception layer, network layer, processing layer, application layer and business layer.

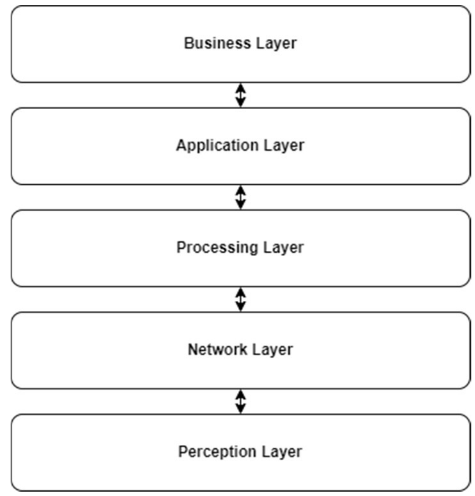

Figure 1. IoT Layers

The first layer is the perception layer, the lowest on the Internet of things architecture. It consists in perceiving the data of the environment. In addition, this layer is responsible for several operations, such as the management of data collection with a part reserved for detection by sensors, barcode labels, RFID tags, GPS... Its main objective is based on the identification of objects and the data collection (Chahid et al.) [3].

The second layer is called network layer, this layer receives the information and data from the perception layer, like the network and transport layer of the OSI model, collecting data from the lower layer and links it with the Internet From the network.

The processing layer is also called the middleware layer. it can store, analyzing and processing large amounts of transport data, also, it can manage and provide a variety of services. To manage this amount of data, it uses many technologies, such as databases, cloud computing and big data processing modules. The application layer receives information from the previous layer "middleware" and gives a more general management of the application presenting this information, and it depends on the type of device and their purpose.

The entire IoT system is managed by the business layer, including applications, business and business models, and user privacy.

2.2. Artificial intelligence

Artificial (made by human) Intelligence (power of thinking) is the study of machines which can sense, make decision and act like human beings. The meaning of intelligence is "the ability to acquire and apply knowledge and skills", in Merriam-Webster intelligence is defined as "the ability to learn or understand or to deal with new or trying situations". So, an intelligent entity must be able to acquire knowledge through various ways like by observations, learning from experience, reading information (data) and processing text, by discussing with others. It should be able to reason this acquired knowledge to make decisions, summaries, setting and following goals, understand text and images etc.

AI offers devices that are compatible with this technology the ability to solve complex problems with great precision. Below a non-exhaustive list of AI use cases in our current world:

- ✓ Virtual Assistance: To give digital and virtual personal assistance, several companies have built digital software like Cortana, Siri, and IBM Watson. All these software usually understand the voice instructions of the user and act accordingly. Cortana is introduced by Microsoft, Google Assistant by Google, and Siri by Apple [16].
- ✓ Robots are automated AI enabled machines which can work in an environment where survival of humans can be at risk. An annual international competition of robotics named RoboCup was started in 1996 [21] and in 2005 robots play Soccer without headbutting once.
- ✓ Self-driving cars are self-driving vehicles that can make real-time decisions based on road conditions, these cars are the most anticipated product soon. Some successful self-driving car tests have been done by Waymo, GM, Tesla, and Uber.
- ✓ Vision is the techniques to extract information out of digital images and use it like human visual system. Its widely used in object detection by robots, self-deriving cars, and medical diagnostics [9].

3. LITERATURE REVIEW

Till today, there is a lack of studies to map the digital transformation in the environmental sustainability domain, the purpose of this part is to present research trends and identify future research agendas regarding IoT and AI in the environmental sustainability domain.

Research on this subject can be grouped under 4 categories, pollution control, waste management, sustainable production, and urban sustainability, all these studies show how digital technologies, especially IoT and AI, are transforming the different aspects of environmental sustainability. It seems that the pollution control, is the area that had the highest number of research, approximately 40 research, shared between CO_2 transmission, water treatment, climate change and air pollution.

In the CO_2 emission category, Huang et al. [4] present research that measure self-driving tour carbon emission flow and spatial relationship with scenic spots based on big data in China. In the same category, Chuai and Feng [5] used big data to measure carbon emissions in spatial distribution in China's Nanjing city, aimed at understanding and controlling air pollution, Other similar studies that involve big data were prevalent in the literature [6, 7-9]. Also, there were multiple studies on how IoT technology is being used to measure and control air pollution [10]. IoT sensors provide real-time monitoring information and show great potential as a tool to understand the PM2.5 plume movement with temporal variation and geo-specific location, which can lead to better air quality [11], In the same area, we find studies using mobile technologies for pollution control. Mihăi¸tă et al. [12] published a study focused on investigating real-time mobile air quality measurement through smart sensing units and data-driven modeling techniques that can be deployed to predict air quality accurately from the generated data sets.

In the waste management field, near 28 research was made in solid waste, food waste, Agri-waste, and E-waste. AI has been used in global warming, waste management, wildlife care, geographic information systems, environmental risk assessment, energy concerns, land-use planning, and geoscience [13]. In electronic waste or "e-waste", AI is used for collecting e-waste on demand from users [14]. Lu [15] present research to study used big data to identify illegal waste dumping cases from 2011 to 2017 in Hong Kong. In this publication, the author used big data in the form of two million waste disposal records generated from around 5700 projects undertaken in Hong Kong during 2011 and 2012. In a similar research, Lu et al. [16] applied big data to compare and analyze public and private entities' construction waste management performance. Other digital technologies such as IoT, cloud computing, and social media are also transforming the waste management arena [17, 19]. In same research, IoT was designed and used to treat food waste generated from the Asian Institute of Technology (AIT) campus community [20]. Sujata et al. [21] conducted a study in which, using the theory of planned behavior, the authors established social media's role in stimulating recycling behavior.

When in the domain of sustainable production, we can find various research on sustainable manufacturing and sustainable apply chain. A production system that relies on cleaner and sustainable mechanisms can reduce operating costs, improve profitability and worker safety, and reduce the environmental impact of the business [22, 23]. Smart and sustainable manufacturing is increasingly gaining attention in the literature and deals with green, energy-saving, sustainable production, and renewable energy consumption [24]. Sustainable production can allow manufacturers to reduce resource use, degradation, and pollution while achieving development goals [25]. Sustainable smart manufacturing has been advanced by digital technologies such as IoT, cyber-physical systems, cloud computing, AI, big data analytics, and digital twin [26]. In the literature, we found that digital technologies such as AI, big data, and IoT are sustainably transforming the manufacturing sector in terms of green manufacturing [27], zero-waste manufacturing [28], efficient manufacturing [29] as well as sustainable supply chain. For example, Kaur and Singh [30] conducted a study and proposed an environmentally sustainable procurement and logistics model for a supply chain driven by big data for reducing carbon emissions. Zhang et al. [31] proposed a cleaner production method enhanced by systematic integration of product life cycle management and big data analytics to overcome issues in cleaner production mechanisms.

Finally, 18 research was made in the urban sustainability field, shared between smart cities and urban sustainability cities. Sustainable urban development has been facing severe resource shortage, environmental pollution, and traffic jams. A smart city is considered an effective approach to deal with such challenges [32]. Thus, many cities are increasingly adopting specialized digital technologies such as big data and IoT to address issues related to the environment and society [33]. Digital technologies such as IoT infrastructure, cloud computing, big data, mobile Internet, and artificial intelligence are at the core of smart cities to enhance the environment, resources, and connectivity [34]. Osman [35] developed a big new data analytics framework for smart cities called the "Smart City Data Analytics Panel (SCDAP)" aimed at harnessing big data analytics applications for smart cities. The real-time air pollution data play a vital role in urban sustainability [36]. Kim [37] proposed an alternative methodology based on big data for correlating reported and experienced fine dust levels to help prevent air pollution in the context of a smart city in Korea. Honarvar and Sami [36] used big data to predict and monitor air pollution in a smart city context, which costs considerably lower than other expensive mechanisms.

Gohar et al. [38] proposed the architecture for an ITS (Intelligent Transportation System) based on big data analytics in the context of a smart city. Since 2017, the number of publications had constantly increased, we passed from 11 publications to 42 in 2019, but unfortunately, this number is going down since 2020 to reach 17 publications.

4. PROPOSED FRAMEWORK AND APPLICATION

The figure below shows the proposed architecture for our framework:

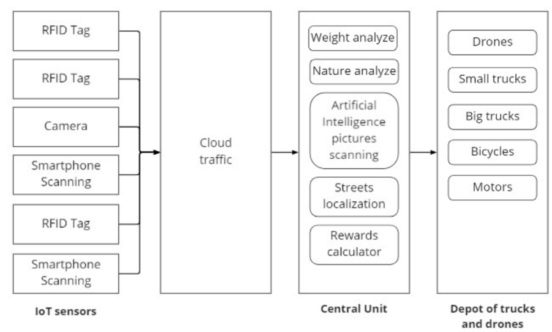

Figure 2. Proposed Framework

The main idea of our framework is to connect all IoT layers of the environmental sustainability, where the sensed data will come from the perception layer, main model and processing will be in the network layer, some important required services and additional information will come from the cloud and application layer where the data will be stored permanently. Also, the idea is to create a coupled cooperation between citizens and governments, so that citizens can cooperate to help with the collection of waste in an efficient and rapid way and for governments to reward its citizens by offering them reductions for example in taxes, reduction on household waste tasks, etc.

The proposed framework includes three types of sensed data which will be collected by collector sensor using AI, these types are:

- Images that come from digital cameras distributed in the smart cities or streets.

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- Sensed data that comes from smart public garbage container in the street using RFID tags.
- Data that come directly from smart phones devices of other users in case of signaling waste.

Deployment architecture of proposed framework shows in the figure 3:

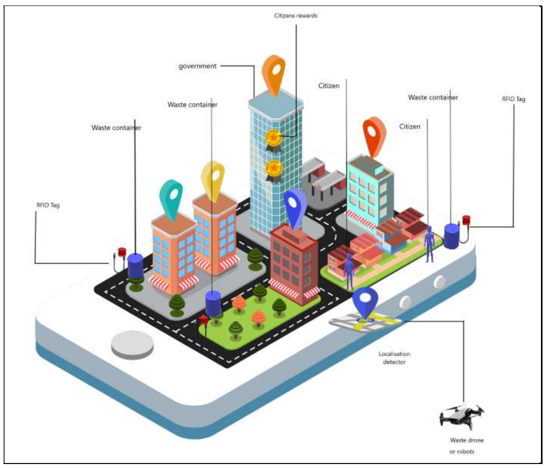

Figure 3. Implementing Framework in Smart City

In each public waste bins installed in the streets, the RFID tags will collect information on the waste thrown away by citizens, namely the weight of the waste, the nature (plastic, recyclable, household waste, date, location etc.), send this information to the central unit for processing. The central unit processes this data and begins a classification by nature of waste, calculates the evolution of the weight compared to a date interval to know if it is necessary to start a manual or automatic collection via drones and / or robots underground, with a small railway installation as for the trams to optimize collection and avoid daily truck movements, which will minimize CO_2 emissions.

It should be noted that what often happens is that recyclable waste stays in the garbage container for a long time because they are considered odorless, but unfortunately what happens is that the collection centers for this waste are often saturated, which sometimes blocks these garbage containers or in the event of overload, lets waste come out of these garbage containers and circulate in the streets, which makes it difficult to pick them up afterwards, so, our framework makes it possible to avoid these cases, to have real-time monitoring of the evolution of waste in cities.

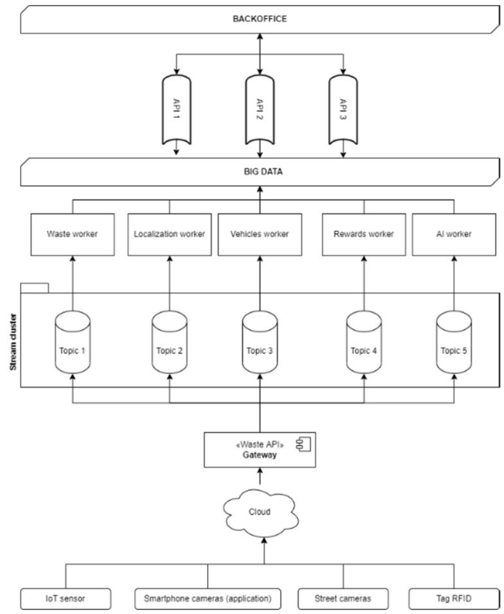

Figure 4. Modelling the Framework

- ✓ IoT Sensors: The sensors have the role of capturing the movements in the bins and measuring the weight of the waste, then sending this information to the "waste information API" to processing.
- ✓ Cameras: Public cameras will be installed in the streets to take pictures of publicly discarded waste such as plastic bottles, paper sheets and then send these photos to the API which analyzes this data.
- ✓ Smartphone scan: Citizens and via their smartphones, can scan the streets bottles barcodes for example if they have ones, otherwise they can just take pictures and send them to the central unit, sending via the application makes it possible to automatically send the location of the waste in order to know the exact location before the intervention via drones or robots.
- ✓ Waste API: This API will be responsible for managing all the information concerning the waste, namely the types of waste, the volume, the weight ... etc.
- ✓ Realtime events cluster: This component is like an orchestrator, it will contain the whole system events, these events are messages about the waste or / of the automobiles movements such as for example a new photo which arrives on the system, a robot movement or a drone for intervention, a

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notification by trash tags concerning overweight...etc.

- ✓ Waste worker: This worker will process all the waste type events received by the sensors and which are in the event cluster
- ✓ Localization worker: This worker will process all location-type events received by the sensors and which are in the event cluster
- ✓ Vehicles worker: The role of this worker will focus on vehicle type events, all equipment movements (robots, trucks, drones...etc.)
- ✓ Rewards worker: This worker is responsible for calculating citizen rewards based on their unique ID and trash movements
- ✓ AI worker: This component will analyze all the photos that come from the cameras and or sent by the citizens via the application in order to launch a scan and know the type of waste, the weight...etc.
- ✓ Bigdata: It is the engine of complex calculations on the forecasts for example, the reporting, the historization and the archiving of the data...etc.
- ✓ APIs: These APIs which will be used for the Backoffice part, and which will be used via the Backoffice to administer the system
- ✓ BackOffice: This is the application that will be used by internal staff to administer the system and citizens to know the rewards for example

Our framework is made in a way that allow citizens to notify the central unit using mobile applications by scanning the barcodes of bottles thrown on the ground for example, taking pictures with waste information's. these applications will send the exact location of the waste, which makes it possible to better manage the movements or the organization of the personnel responsible for waste collection. These notifications will be confidential via a unique citizen identifier, to allow governments to reward them via tax cuts or reductions on household waste taxes for example.

Since the study concerns Paris, capital of France, we used the method proposed by the French Ministry for the Ecological and Inclusive Transition published in 2019 by GHG information for transport services, to test our system and to measure the CO_2 emission, we used this formula:

$$EmCO_2 = W \times D \times EM \quad (1)$$

W = Weight in tons
D = Distance in kilometer
EM = Emission Factor in $KgCO_2/Km$

To analyze smartphone camera pictures, we used Deep Learning-based waste detection approaches presented in this research [39]. In this publication, new benchmark datasets detect-waste and classify-waste are proposed that are merged collections from the above-mentioned open-source datasets with unified annotations covering all possible waste categories: bio, glass, metal and plastic, non-recyclable, other, paper, and unknown.

Figure 5. Example EfficientDet-D2 predictions for diverse waste datasets. (Source: Sylwia M et al. [39])

5. DISCUSSION AND RESULTS

An estimated 400,000 tons, or 1/3 of the waste collected by the city of Paris in one year, waste produced only by businesses and businesses in the capital. By removing this non-negligible part in the calculation, the weight of waste produced annually per Parisian would be equal to 371 kg/person.

Based on these figures, we are therefore going to need 27.39 waste trucks which are refueled every day, and according to the formula, we therefore obtain 13.60 gCO_2/ t.Km per trucks, 372,504 for 24,39 trucks and 135 963,96 gCO_2/ t.Km the year.

Table 1: Trucks account for 38,1% of CO2 emissions (Source: Careza management & IT report "the calculation of CO2 emissions from rail freight and compares it to the road transport CO2 emissions").

Relevancy (%)	CO_2 emission (%)
Civil aviation	13,4
Railways	0,5
Water navigation	13,6
Motorcycles	1,2
Heavy duty trucks	26,2
Light duty trucks	11,9

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Cars	60,7

As we can see, trucks take a big share of CO_2 emissions into the air, they are ranked second after cars.

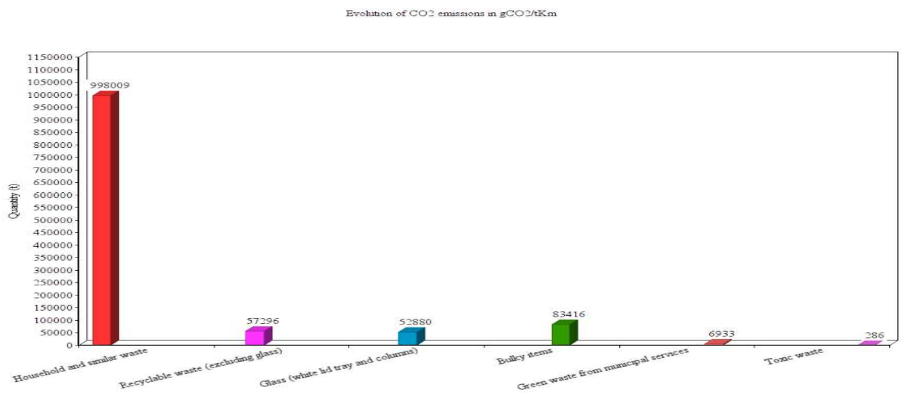

Figure 6. Evolution of CO_2 emissions in gCO_2/tKm by nature (Source: Careza management & IT report “the calculation of CO2 emissions from rail freight and compares it to the road transport CO2 emissions”).

Below is an overall report resulting from the voluntary contribution to recycling centers and home pick-up:

Table 2: The waste quantity by type and collection mode (Source: Careza management & IT report “the calculation of CO2 emissions from rail freight and compares it to the road transport CO2 emissions”).

Collection mode	Type of waste	Quantity (t)
Voluntary contribution to the recycling center	Bulky items	14 681
	Scrap metals	2 253
	Paper-cardboard	1 373
	Rubble	2 560
Home pick-up and deposit collection wild on public road	Bulky items	55 704
	Rubble	2 545

As we can see in the table 2, the amount of waste thrown away and recovered by Home Collection and deposit collection litter on public roads is important, so our framework will better optimize this litter and reduce CO_2 emissions by reducing the number of trucks and the frequency that these trucks circulate to collect this waste.

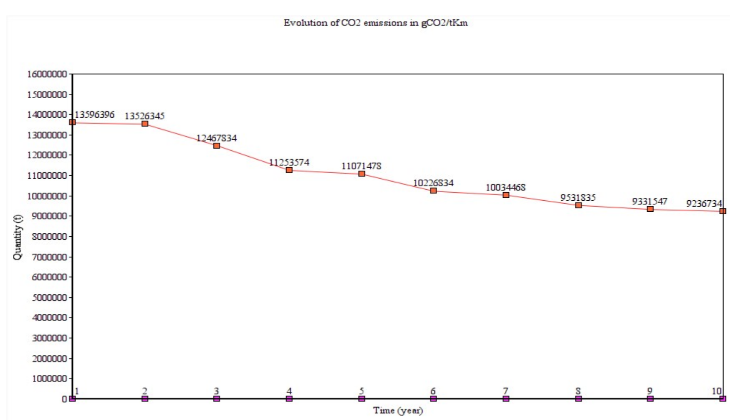

Figure 7. Evolution of CO_2 emissions by year (gCO_2/tKm).

The graph above shows the estimated evolution of CO_2 emissions per year, the curve down with time, the system optimizes the collection of recyclable waste based on the data received via IoT sensors, RFID tags and alerts sent directly by citizens via the smartphone application.

As advised by the ONU and based on results, our system optimizes waste collection, which minimizes truck movements and reduces CO_2 emissions by 3% each year.

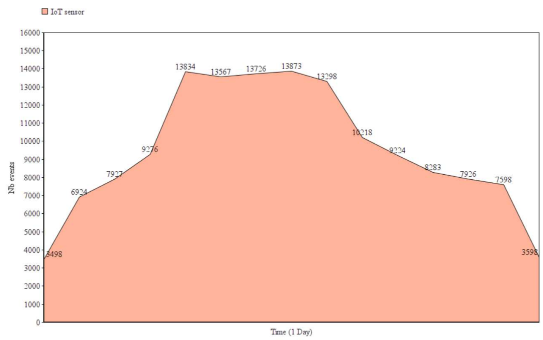

Figure 8. Number of received events by IoT sensors object types.

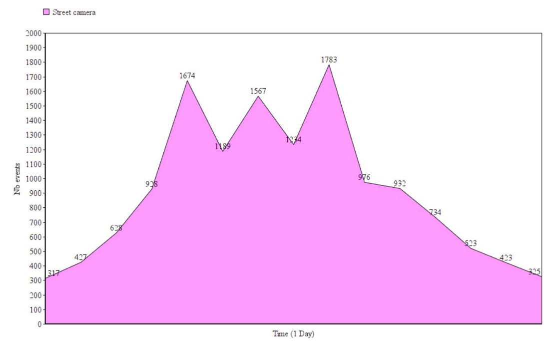

Figure 9. Number of received events by street camera object types.

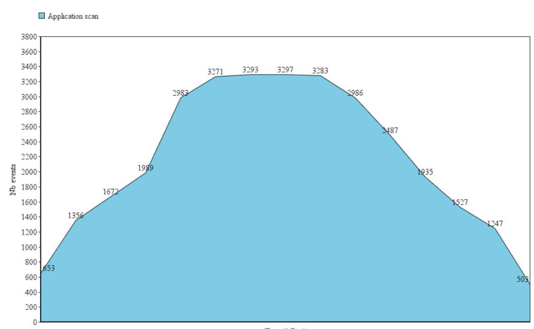

Figure 10. Number of received events by application scan object types.

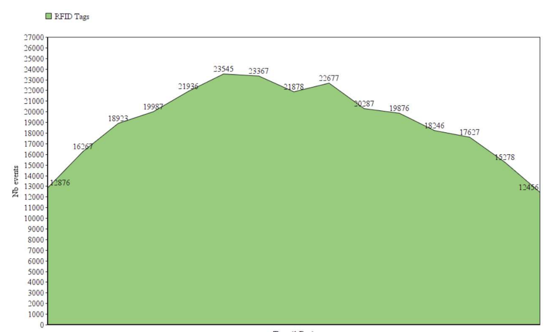

Figure 11. Number of received events by RFID tags object types.

Figures 8, 9, 10 and 11 shows the number of events evolutions, the number of events received by RFID tags is very important, it starts early in the morning with light traffic and begins to increase little by little. The number of events received by the IoT sensors comes second, because these sensors are installed on the waste bin collectors and allow movement to be detected during the day, after that there are scans sent by mobile applications by citizens, and the weakest graph is that of surveillance cameras detecting movements near waste bins.

According to the graphs obtained, the curves start with light values and continue to increase little by little, this rise is due to the traffic of people and waste during the day. This rise remains stable throughout the day and then descends at the end of the day because traffic and activity drop.

6. CONCLUSION AND FUTURE WORK

The main aim of this study is to propose a new model for enhancing the environmental sustainability protection using IoT and AI. An intelligent and robust framework is developed with IoT, and AI is proved to be a best system that helps to reduce CO_2 emissions and enhancing sustainability protection. With the use of connected objects, AI and waste detection methods based on deep learning, we have been able to build a system that will help reduce

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CO_2 emissions based on the use of environmentally friendly energies environment, the number of circulation of waste collection vehicles will greatly decrease, the collection will be controlled and better managed with the help of the installation of the underground infrastructure while encouraging and sensitizing the citizens through rewards to intensify the efforts to protect our environment. The current framework will be compatible with smart cities, it will allow a collaboration of citizens and governments to deal with pollution and to have a win-win model which allow all governments to respect the recommendations of the United Nations on climate change.

According to the results obtained above, our framework is robust to reduce the emission of CO_2 in the air, however, it has a non-negligible cost to install the infrastructure, a budgetary and energy cost because it is necessary to replace diesel with electricity. in our future work we will work on the framework to optimize costs.

Unfortunately, there is not enough research on this subject, there is a lack of models proposed to reduce CO2 emissions, our research, even with its cost limits, could be a solid basis for researchers to broaden their research and better optimize the model.

Comparing our proposed model with other studies on the subject of e-waste and based on the results obtained, we can say that all studies approve the role and the importance of the use of IoT and the AI to simplify waste collection in an automated way, but unlike other studies, our model focus on the CO_2 emission to reduce vehicle traffic and reduce the CO_2 emission, the other research are oriented towards solutions for reducing the time of collection and treatment of this waste.

7. FUTURE WORK

In the future, new research will be proposed to deal with the subject of costs, the study will mainly discuss the methods and the means to be used to reduce the infrastructure installation costs proposed in this research.

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