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ADVANCED SENSORS FOR SMART CITY ENVIRONMENTAL MONITORING SYSTEMS

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ABSTRACT:
THE RAPID INCREASE IN URBAN POPULATIONS HAS HEIGHTENED THE NEED FOR EFFICIENT RESOURCE MANAGEMENT, MAKING THE CONCEPT OF SMART CITIES ESSENTIAL FOR SUSTAINABLE URBAN DEVELOPMENT. SMART CITIES LEVERAGE INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) TO ENHANCE URBAN FUNCTIONS, INCREASE THE QUALITY OF LIFE, AND PROMOTE ENVIRONMENTAL SUSTAINABILITY. THROUGH ADVANCED SENSORS, INTERNET OF THINGS (IOT) DEVICES, AND DATA ANALYTICS, SMART CITIES GATHER REAL-TIME INFORMATION TO SUPPORT DECISION-MAKING BY MUNICIPALITIES, BUSINESSES, AND CITIZENS. KEY COMPONENTS INCLUDE SMART ENVIRONMENT, SMART TRANSPORTATION, DIGITAL ECONOMY, SMART GOVERNANCE, AND SMART LIVING. THIS PAPER EXPLORES VARIOUS DEFINITIONS OF A SMART CITY AND EXAMINES THE ROLE OF CUTTING-EDGE TECHNOLOGIES SUCH AS 5G, SMART ENERGY SYSTEMS, WASTE MANAGEMENT, AND BUILDING MANAGEMENT SYSTEMS IN IMPROVING INFRASTRUCTURE AND URBAN SUSTAINABILITY. BY ENABLING DATA-DRIVEN APPROACHES TO INFRASTRUCTURE, SECURITY, AND SUSTAINABILITY, THESE TECHNOLOGIES CONTRIBUTE SIGNIFICANTLY TO ADDRESSING URBAN CHALLENGES. ADDITIONALLY, THIS PAPER IDENTIFIES ESSENTIAL SUCCESS FACTORS, SUCH AS HOLISTIC DEVELOPMENT STRATEGIES, CITIZEN-CENTRIC DESIGN, GOVERNMENT SUPPORT, AND A FOCUS ON ENVIRONMENTAL SUSTAINABILITY, WHICH DRIVE THE EFFECTIVE IMPLEMENTATION OF SMART CITY PROJECTS. AS CITIES EVOLVE, THESE INNOVATIONS PRESENT OPPORTUNITIES TO OPTIMIZE RESOURCES, REDUCE COSTS, AND CREATE MORE RESILIENT, EFFICIENT, AND LIVEABLE URBAN ENVIRONMENTS.

KEY WORDS: SMART CITIES, ICT, SUSTAINABILITY, URBAN DEVELOPMENT, INTERNET OF THINGS (IOT)

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INTRODUCTION

With the increasing urban population, cities are facing many challenges and the effective and optimal use of resources is very important. What is a Smart City? According to the United Nations, about 55% of the world's population currently lives in cities, and it is expected to increase to 68% in the coming decades. Smart city is a framework that uses information and communication technology to develop, establish and promote sustainable development goals in order to solve the challenges of cities. A major part of this information technology framework is connected objects and machines with sensors that collect information and transmit it using wireless technologies and analyze it in real time. This data collection and analysis helps municipalities, companies and people make better decisions to improve their lives[1].Citizens use various tools such as smart phones, connected cars and smart homes to communicate with smart city platforms. Integrating devices and data with the city's physical infrastructure and services can reduce costs and improve sustainability in the city. Communities benefiting from the Internet of Things can improve energy distribution, simplify waste collection, reduce urban traffic and improve air quality. The smart city improves transportation and access to different parts of the city, improves social services and the sustainability of the city, and the voice of the community is heard in the smart city [2].

The main task of a smart city is to optimize city functions and create economic growth while improving the quality of life for citizens using smart technology and data analysis. In evaluating the intelligence of a smart city, services that are created using technologies are more important than the city's level of technology [3]. Several main features are used to determine the smartness of the city. These features include:

- Technology based infrastructure
- Environmental initiatives
- High performance public transportation system
- Feeling confident about urban planning and
- Convenience for people to live and work inside the city and use urban resources

The success of a smart city depends on its ability to build a strong relationship between government – including its bureaucracy and regulations – and the private sector. This relationship is necessary because most of the work that is done to create and maintain a digital and data-based space is outside the government. For example, the equipment related to the monitoring solution for busy streets can include sensors from one company, cameras from another company, and another server.

In addition, independent contractors may be responsible for analyzing data and reporting data to the city government [4]. In addition, this data can lead to the creation of an application development team that is hired to find a solution to the problems in the analyzed data, and if the solution requires regular updating and management, this the team can become part of the system. Therefore, the success of a smart city is more focused on creating positive relationships than creating a project [3].

Theoretical framework and literature review

What is a smart sensor and how does it work?

A smart sensor is a device that receives information from the physical environment and uses its internal computing resources to perform predefined tasks and then processes them before transmitting the data. Smart sensors allow for more accurate and automated collection of environmental data, with less error noise, among precisely recorded data. These devices are used to monitor and control mechanisms in various environments, including: smart grids, reconnaissance on the battlefield, exploration, and many scientific uses [5].

The smart sensor is also a vital and integral element in the Internet of Things (IoT); The Internet of Things is an environment in which almost everything is equipped with a unique identifier and can exchange data on the Internet or a similar network. The implementation of smart sensors is a part of a wireless sensor and actuator network (WSAN - wireless sensor and actuator network), whose nodes may reach several thousand nodes, each of which is connected to one or more sensors and sensor-hubs. Sensor hub) and separate operators are connected.

Computing resources are usually provided by low-power mobile microprocessors. A smart sensor consists of at least one sensor, a microprocessor and a communication technology. Computing resources must be an integral part of the physical design – a sensor that simply sends its data to be processed elsewhere is not considered a smart sensor.

A smart sensor has three components: a sensor that captures data, a microprocessor that computes the output data from the sensor through programming and communication capabilities. A smart sensor includes several other components in addition to the main sensor. These components include converter, amplifier, excitation control, analog filters and compensators. A smart sensor also includes software elements; these elements perform tasks such as data conversion, processing and digital communication for external devices [6].

How do smart sensors work?

A smart sensor connects a basic sensor array to computing resources that enable the processing of sensor input data. The basic sensor is a component that has a sensing capability. It can be used to sense heat, light or pressure. A basic sensor will often produce an analog signal that must be processed before it can be used. This is where smart sensor technology comes into play. The microprocessor inside the smart sensor filters the signal noise and converts the sensor signal into a usable digital format. Smart sensors contain internal communication capabilities by which they connect to a private network or the Internet. This feature allows the sensor to communicate with external devices [7].

What are smart sensors and what are their uses?

Smart sensors have numerous applications. They are widely used in industrial environments and are the driving force of industry 4.0. Factories often use smart temperature sensors to make sure machines don't overheat and vibration sensors to make sure machines aren't at risk of loosening due to vibration.

Smart sensors also provide the possibility of process control - for example, monitoring a process; For example, the process of producing a product and making adjustments that are needed in order to maintain quality or production goals. This work was once done manually, but smart sensors can be used to automate process control.

Smart sensors also play a key role in modern security systems. Thermal imager sensors can be used to detect the heat of the attacker's body. Similarly, devices such as smart locks, motion sensors and door and window sensors are connected to a common network. In this way, there will be multiple security sensors to work together to paint a comprehensive picture of the current security situation [8].

Conceptual analysis and its implications

Different types of smart sensors

There are five types of smart sensors that are used in industrial environments. Although there are many different sensors, each with a specific purpose, they generally fall under the following five types of sensors.

1. Level sensors: A level sensor is used to measure the volume of a tank. A car's fuel level gauge must be connected to the level sensor to show the fuel level in the tank.
2. Temperature sensors: A temperature sensor is a sensor that can measure the temperature of a part so that corrective action can be taken if necessary. For example, in an industrial space, a temperature sensor can be used to prevent machinery from overheating.
3. Pressure sensor: Pressure sensors are often used to monitor the pressure of gases or liquids inside a pipeline. A sudden drop in pressure indicates a leak or a fault in the flow control.
4. Infrared sensors: Some infrared sensors, such as those used in thermal imaging cameras or non-contact infrared thermometers, are used to monitor temperature. Other infrared sensors are optical sensors that are tuned to a specific frequency and can detect light in the infrared spectrum. These types of sensors are used in medical equipment, such as oxygen meters and electronic devices that are designed to be activated by remote control.
5. Proximity sensors: A proximity sensor is used to detect the location of a person or object relative to the sensor. In store environments, proximity sensors are able to track customer movements in the store [9].

How different are smart sensors from basic sensors?

Smart sensors include a built-in Digital Motion Processor (DMP), but basic sensors do not. A DMP is simply a microprocessor embedded in a sensor. This microprocessor enables the sensor to process its input data internally. This means normalizing the data, filtering out noise, or performing other types of signal shaping. In either case, a smart sensor performs digital data conversion processing before communicating with external devices.

A basic sensor consists of a sensor that is not equipped with a DMP or other computing resources that can process the input data. While a smart sensor produces data that is ready to use; the basic sensor output is raw and needs to be converted to a usable format. Smart sensors are generally preferred over basic sensors because they have native or built-in processing capabilities. However, in some situations, using a base sensor has more advantages. If an engineer designs a device and needs to have full control over the input data from the sensor, then using a basic sensor makes more sense than using a smart sensor. Basic sensors are also less expensive than smart sensors because they have fewer parts [10].

Smart city technologies

In smart cities, all components and objects are connected to each other, and this connection is completely dependent on technology. The key technology for turning a city into a smart city is connected, stable and resistant, and information is not only available, but also discoverable. The goal of a smart city is to provide smart services to its citizens, which can save their time and make life easier. Be them in the smart city, communication is also provided between citizens and the government, and citizens can give their opinions about how their city should be to the government. This goal cannot become a reality without technology. Using technology, officials are able to collect city information, and this information, when integrated with city operations, makes cities smarter and safer [11].

Information and communication technology in the smart city

The existence of a two-way communication channel is very important for a city to be smart, and in a smart city, information and communication technology plays the role of this

communication channel and creates a bridge between citizens and the government where citizens can interact with the government and in On the other hand, the government can develop the city in a way that is the choice of its citizens. ICT helps the government to analyze the demand pattern and thereby create a pool of resources to meet the demand online. The electronic medium of communication in a society helps create a collective intelligence that can be used to optimize resources with the help of analytics and deep learning [12].

Internet of things in the smart city

The Internet of Things is like the veins of a city that extends throughout it and connects different points to each other. All the devices that are part of a smart city must be connected to each other so that they can communicate with each other and make decisions that enable the management of the resources of a large urban population. The Internet of Things makes this possible and offers a complete paradigm of communication devices that provide intelligent solutions to everyday problems. All smart solutions in smart cities are based on the Internet of Things, which are sufficiently connected and intelligent and can make decisions about their performance [13].

Three ways to protect the environment by Internet of Things

IoT has a wide impact on environmental protection. Increasing productivity in production through the Internet of Things will help save energy, and big data with the help of weather monitoring systems will provide useful information about the environments that affect our health. However, IoT has interesting ways of addressing various aspects of environmental protection and climate change, and preventing deforestation and poaching [14].

IoT has a wide impact on environmental protection. Increasing productivity in production through the Internet of Things will help save energy, and big data with the help of weather monitoring systems will provide useful information about the environments that affect our health. However, IoT has interesting ways of addressing various aspects of environmental protection and climate change, and preventing deforestation and poaching.

Using real-time data to prevent deforestation

15% of the total carbon dioxide emitted is caused by deforestation. Rainforest Connection has a number of IoT projects underway that are designed to stop deforestation. They use mobile phone sensors to connect to tree trunks, which inform illegal entry and exit to the forest and hunting even from a long distance [15].

These sensors are sensitive to sounds such as saws or large vehicles in the unauthorized area and inform the authorities of illegal actions in the forest by creating an alert. Also, using these sensors by a number of organizations, a lot of data is shared, which is used to increase the protection of rainforests in certain areas.

Internet of bees

Another interesting way to use the Internet of Things to preserve the ecosystem is to track honey bees and monitor the conditions of hives. Bees play an important role in maintaining biodiversity in ecosystems, and recently their reduction has had serious effects on agriculture. Bee Corp offers an interesting solution to this problem using IoT technology. By placing a sensor inside the hives, beekeepers can use this technology to monitor the conditions inside the hive and track the health of the bees [16].

According to the company's website: "When the queen is healthy, the worker bees keep the temperature of the hive constant to raise the eggs. A drop in the temperature of the hive is a signal to the worker bees that the queen is laying eggs." Sensors inside the hive collect temperature data and send them to the cloud system for analysis through cellular networks. In this way, beekeepers will be informed quickly if there is a danger threatening the health of bees.

In Australia, research was conducted by the CSIRO Institute with the aim of improving bee pollination. To achieve this goal, researchers equipped thousands of bees with small sensors. These identification sensors work by radio frequency similar to an electronic tag and record the passage of bees from different points. This data allows farmers and researchers to identify the influencing factors in bee behavior and take action to eliminate the effective factors in reducing pollination [17].

Using sensors and smart cameras to stop illegal hunting

As mentioned, Rainforest Connection uses similar technology to detect sounds associated with poaching, such as the sounds of traps, guns, and vehicles in protected areas. In large, natural areas that are difficult to monitor, wildlife conservation organizations have installed motion-sensing cameras that detect rare species as well as poaching.

The RAPID project in Africa has equipped the rhinos with three smart devices including: camera, heart rate monitor and GPS. The combination of these devices means the protection of wildlife. When these animals are in danger, with the alarm of the device, their movements can be tracked and the recorded videos of the predators can be accessed. All of these tactics help rangers prevent poaching and protect creatures that are vital to biodiversity and ecosystem stability [18].

Sensors in the smart city

From an urban point of view, sensors are hidden but scattered components throughout the city and the essential part of any intelligent control system. The improvement of a process is done based on its environment, and in this regard, the process is equipped with different sensors to collect the data it needs. It then uses the appropriate variables to describe its environment and adjusts its functions accordingly. The availability of a large number of different sensors and the constantly evolving technology enable applications that were infeasible in the past due to high costs and limited access. Sensors are like transducers that convert parameters of a physical nature into an electronic signal, which can be interpreted by humans or can be fed to an autonomous system. These signals are for common sensors, including light, pressure, temperature, humidity and various other parameters [19].

Artificial intelligence in the smart city

The smart city is a digital revolution that generates a huge amount of data. This data is useless until it is processed and information is produced. Artificial intelligence is responsible for processing this huge amount of data and can create insights from this data [20]. Artificial intelligence allows machine-to-machine interaction by processing data and creating insights from it. In general, artificial intelligence can play an important role in urban planning, development and management in the development of smart cities with advanced security systems, traffic monitoring and waste management. Make communities safer and more livable and citizens experience a more comfortable and enjoyable life [21].

Block chain in the smart city

Block chain technology is new in the smart city concept and ensures data flow. Its integration in smart cities can connect all urban services while increasing security and transparency. In some ways, block chain is expected to impact cities through smart contracts, which help with billing, transaction processing, and facility management. Smart contracts are self-executing contracts where the terms of the agreement between the buyer and the seller are written directly in the line of code. They allow trusted transactions and agreements to be made without the need for a third party intermediary between different parties, making the process safer, cheaper and faster. Block chain can also be used in smart grids to facilitate energy sharing, a concept that is popular these days [22].

6 main axes of the smart city

1. Smart economy: The smart economy in the smart city describes all actions aimed at changing and strengthening the municipal economy.

Improving the overall business climate, the attractiveness of the city for startups, investors, businesses and elites, as well as the growth of the economy in an innovative and sustainable way to increase competition are among the most important goals of the smart economy. The use of (digital) technology and smart approaches leads to economic prosperity, which in turn creates stable and favorable conditions for all stakeholders. From the government's point of view, "smart economic development" is an important tool to actively use opportunities and provide conditions that support the creation and growth of jobs as well as new jobs.

2. Smart transportation: Smart transportation increases the efficiency and quality of urban transportation services in order to increase the use of transportation and the use of new transportation solutions, as well as increasing the movement of people through efficient transportation management. And targeted infrastructure investments are concentrated in the smart city. Achieving cheaper, faster and environmentally friendly transport as well as integrated multi-purpose transport is an important challenge for cities and communities. Supporting a mix of multiple public and private transport modes and adopting new forms of transport (e.g. electric vehicles, hydrogen vehicles, autonomous vehicles, bike sharing, car use or car sharing) is an important aspect of a strategy. It is a visionary in the smart city with an approach to enhance smart transportation.

To achieve a high-quality transportation service and ultimately improve the movement of people and goods within a city or community, while reducing environmental impacts, a customer-centric and inclusive approach for all citizens, businesses and visitors is required. It is necessary that this can be realized in the smart city by using smart transportation solutions [23].

3. Smart Living: Following a comprehensive strategic approach, Smart Living improves the quality of life of residents and visitors across all age groups and demographics in the Smart City. Facilitating livability and optimizing the management of the living environment are two aspects that must be considered jointly to maximize the benefits of the city government and its stakeholders.

Smart living focuses on improving social and digital interactions (e.g. the use of e-services, connectivity and social platforms), improving healthcare and elderly care (e.g. e-health), safety, housing conditions and smart buildings in the city. Smart is focused. In a smart city, new methods for civic and social interaction as well as new technologies (for example Wi-Fi-based Internet of Things or LPWA network technology) are used to improve access and experience of citizens in all areas [24].

4. Smart people: The goal of smart people in the smart city is to transform the way citizens interact - through information or providing services - with the public and private sectors as individuals or businesses. Creating social and digital equality through education is an important precondition for more efficient provision of information and services based on new technologies.

Smart People includes smart forms of education to facilitate career choices, job opportunities, vocational training as well as lifelong learning for all age groups and demographics. Cultivating talents is also an important aspect from the point of view of economic development.

Smart people solutions support the creation of an accessible and inclusive environment to increase prosperity and innovation in a city or community. Participation, open mind and creativity are aspects that are possible or cultivated by implementing the solutions of smart people in a smart city.

5. Smart government: The goal of smart government in a smart city is to strengthen communication and interactions between the government and all stakeholders - citizens, businesses and other civil society organizations - within a municipality.

By following a smart city strategy, a city government is in a unique position to improve the quality, scale and scope of services for citizens and businesses, using new methods, such as creating partnerships or financing, or with Implementation of new technology and innovation (for example for digital citizens or business services or public infrastructure management) can create "smart government". Following the "city as a service" model can help increase efficiency and effectiveness, as well as transparency and trust in the smart city [25].

6. Smart environment: Smart environment in a smart city describes how a city government manages the environment to improve the living conditions of citizens and visitors. In the smart environment, the use of new technologies and innovative methods supports the implementation of regulatory and cultural changes to facilitate sustainable standards and methods.

Reducing waste production, pollution monitoring and management, reducing greenhouse gas emissions, water management, achieving energy efficiency and accelerating local energy transfer are among the important goals of smart environment solutions. New standards of urban planning to improve efficiency and minimize harmful environmental effects, as well as create a resilient society, are other goals of smart environment [26].

Examples of smart city solutions

Emerging trends such as automation, machine learning and the Internet of Things are driving the adoption of smart cities. Theoretically, a solution based on the Internet of Things in a smart city can be considered for every area of urban management [27].

• Smart parking: For example, a smart parking meter using an app can help drivers find available parking spaces without long detours on busy city streets.

• Intelligent traffic lights: In the field of transportation, by monitoring traffic flows and analyzing real-time information, traffic lights operate in such a way that the least amount of traffic is created on the streets. Smart public transport is another aspect of smart cities. Smart transportation companies are able to coordinate services and meet passenger needs in real time, improving efficiency and passenger satisfaction. Car and bicycle sharing is another common service in a smart city.

• Smart energy: One of the most important goals of a smart city is to optimize energy consumption. For example, it is possible to control and integrate urban lighting, sensors and

actuators in order to optimize energy consumption and increase security in cities using the Internet of Things (IOT) technology, and it is also possible to use smart meters and smart grid technology to improve operations. maintenance and planning and supply of required energy and monitoring of energy outages [28].

• Smart waste management: One of the goals of using smart city solutions is to monitor and resolve environmental concerns such as climate change and air pollution. Wastewater management and sanitation can also be improved in a smart city. The use of trash cans connected to the Internet and fleet management systems equipped with the Internet of Things to collect and dispose of waste using hardware and software platforms and with the Internet of Things technology is possible [29].

• Smart building: Smart buildings are also often part of a smart city project. A smart home is a place that uses connected devices and the Internet for remote control and management of smart appliances and systems such as lighting, security, etc. By equipping the building with different sensors and connecting them with each other, it is possible to manage the space and safety of the buildings as well as the structural health of the buildings. For example, if there is a leak in the water network, this leak is detected by the sensor reduces costs and improves the efficiency of the water and sewage network employees [30].

Improving the sustainability of cities with smartness

Sustainability is another main aspect of a smart city, and smartness helps cities in improving the welfare of citizens and government efficiency in the coming years in urban areas, as well as improving the level of sustainability in cities. The high use of fossil fuels in cities causes the emission of greenhouse gases and has a destructive effect on the environment. The network of smart city technologies can reduce these harmful effects. For example, with the use of smart meters, energy consumption is reduced by 5-10%, and this optimal energy consumption has positive environmental effects [31].

The replacement of the public transportation system with electric vehicles from other aspects is in line with increasing environmental sustainability and not only reduces the emission of greenhouse gases caused by fossil fuels but can also be integrated with the municipal electricity infrastructure. Minimize the impact of charging batteries during peak hours of electricity use. In addition, with proper coordination, electric vehicles can be used to adjust the frequency of the city's power grid during power outages.

It is expected that as cities become smarter, the number of cars used in cities will also decrease. Self-driving vehicles can potentially change people's view of the necessity of owning a car, thereby reducing the number of cars on the road and, consequently, emissions .

Smart city challenges and concerns

• Participation of citizens: One of the challenges is the participation of citizens and making them eager to use smart city solutions. In addition to informing people about the benefits of smart city technologies, city officials can encourage citizens to use its facilities by promoting the use of open source information. Strengthening cooperation between the public and private sectors and citizens is the key to creating a smart citizen for empowerment and participation in the smart city. Smart city projects should include programs to make data transparent and accessible to citizens, often through an open data portal or mobile app. Access to smart city data enables citizens to understand the use cases of the data and can also perform personal tasks such as viewing their home's energy consumption, paying bills, and finding public transportation through a smart city app. to do efficiently [32].

• Privacy and security: Opponents of the smart city are worried that city managers will violate citizens' privacy and information security, and citizens' information will be at risk of being hacked or misused. Additionally, the presence of sensors and cameras may be viewed as an invasion of privacy or government surveillance. To address this issue, the collected smart city data should be anonymous and the information should not be personally identifiable.

• How devices connect to each other: The biggest challenge facing smart cities is connectivity. Thousands or millions of Internet of Things devices scattered throughout the city without a solid, stable and reliable connection will lose their efficiency, and as a result, the smart city will also be destroyed. While there is no one-size-fits-all solution, the development of LPWAN technology is well-suited for most applications and will increase efficiency. These technologies include LTE Cat M, NB-IoT, LoRa, Bluetooth and several others, all of which contribute to the structure of connected and smart cities. The advent of 5G is expected to be a turning point that will move smart city technology more rapidly into the mainstream and accelerate the deployment of new applications [33].

Smart environment

Smart environment means creating the necessary mechanisms for optimal and efficient use of natural resources such as water, wind and soil energy and reducing environmental effects in urban processes and reducing environmental pollution. In the smart environment, new technologies are used to preserve and protect the environment. Paying special attention to environmental issues, which in urban planning and activities and developments of big cities, will lead to environmental sustainability and, as a result, improve people's quality of life.

The following can be mentioned in relation to the methods of making the environment smarter [34]:

• Monitoring the quality and health of air, water and soil
• Early detection systems for floods, earthquakes, storms and forest fires
• Remote monitoring of different animal species
• Measuring the amount of pollutants, fine dust and suspended particles in the air
• Measuring the amount of pollutants produced by various factories and industries
• Controlling the amount of radiation and radio waves available
• Snow and rain level monitoring
• Monitoring soil moisture, vibrations and ground density
• Urban green space
• Municipal waste management

As mentioned, one of the areas of smart environment is urban waste management, which is discussed in this section [35].

Smart garbage collection

Due to environmental concerns, developed countries are more interested in waste management processes. But it seems that waste or garbage collection is still managed using traditional methods and the use of technology is not fast enough to make it efficient. In this regard, garbage collection will be done in a normal and normal way in such a way that garbage trucks start, travel the predetermined route and stop in front of each garbage can while moving and empty it. This scenario is almost the same in the most developed countries. The waste produced in different areas in a city is very different. Therefore, trash cans and trash cans across the city are not filled at the same rate. This is also true for different trash

cans on the same street. However, cities devote a lot of resources to collecting waste from all bins at the same time [36].

Managing multiple garbage trucks across the city and routing them to select each garbage bin is neither efficient nor optimized in terms of budget, equipment usage, manpower, fuel consumption, and time. This problem is not only limited to regulatory conditions but also the problem of service quality. Because the waste containers are not filled at the same rate, the bins end up emptying either half-full or over-saturated. In addition, garbage trucks cause traffic congestion and further indirect inefficiency of city municipalities.

The waste management system consists of a filling level measurement sensor that is connected to the trash can and measures the fullness of the trash can, and a communication system that transmits this data to the Cloud. The saturation level data is processed on the cloud and converted into meaningful information that is displayed on the user's screen. Management can see the filling level of all waste containers on the map on the dashboard. Software algorithms automatically select optimal routes. The sensor measures the filling level based on ultrasonic distance measurement technology. These sensors send location, temperature and filling level information to users. Using real-time data collected from sensors, managers can choose the optimal route for garbage trucks.

Also, drivers can access this app through their mobile phone/tablet using the internet. The real-time GPS assistant guides them to the predetermined route. As they are busy collecting waste from the bins, the management is also informed of the progress as the vehicle as well as the waste containers are tracked in real time [36].

Advantages of smart waste collection

In densely populated areas, the rapid generation of garbage usually leads to overflowing garbage cans. A smart waste management system empowers waste collection staff to know when it's full in real-time and prevent waste overflow. Some of the advantages of the smart garbage collection system are:

Reduction in collection cost

This solution significantly reduces the frequency of garbage collection and enables the municipality to save on fuel, labor and fleet costs. It has been seen that this solution has reduced the operational cost of municipalities by 80%.

Without moving the bucket

Using this solution, managers as well as drivers of waste collection trucks can see which waste bins have not been emptied and which should be emptied. Thus, no bins will be left unturned, protecting residents from diseases caused by bacteria, vermin, and insects that grow from garbage.

Reducing the accumulation of waste in trash cans

One of the bad effects of overfilling trash cans is air pollution, which causes lung diseases and many health problems by absorbing pollutants from the lungs to other parts of the human body. Another adverse effect is on waste collection workers, and the risk of collecting and handling overflow waste can cause them infection or chronic diseases. The smart garbage collection solution prevents these problems by providing the possibility of tracking the filling status of each trash can and planning for this issue in time.

Waste generation analysis

A smart waste collection solution is not limited to allowing managers to set the routes of waste collection trucks. The solution also features advanced data analytics through which waste collection managers can be informed of future waste generation and can plan resources accordingly.

Reducing CO2 emissions

Smart waste collection reduces fuel consumption, which ultimately reduces carbon emissions by up to 70%. This solution is actually financially beneficial and reduces the environmental impact a lot [37].

RVM device

RVM device is one of the examples of smart environment. This machine accepts used (empty) beverage containers and pays the user. These machines are popular in places with mandatory recycling laws or container return laws. In some places, bottled beverage companies fund a center to pay people who recycle the containers. Additional funds are used for general environmental cleanup. In other places, such as Norway, the government has mandated that the seller pay for recycled bottles, but left the system to private industry.

The recycler places the empty bottle or can into the receiver aperture. The system is a type that allows the user to import containers at once. (An alternative system found in many older machines is one where the user opens the lid by hand and places an empty container in the container. When the lid is released and closed, the process continues). Bottle or can after that, the auto-rotate bottle/can is then scanned by a versatile directional UPC scanner, which scans the beverage container's UPC. Some systems use the container's shape, embossing, material, or other identifying parameters to match the container to the database in addition to or instead of the barcode.

Once a container has been scanned, identified (matched against a database), and determined to which company a container belongs, it is processed and typically crushed to reduce size, prevent liquid leaks, and increase storage capacity. (For disposable containers). Refillable containers are collected and sorted by hand before being returned to the bottling company.

Smart waste separation

Separation of waste is one of the main challenges in the field of waste management. Waste separation is done manually in recycling centers. If waste separation is not done correctly, it can have many environmental effects [38].

Separation of smart waste from the source

Smart bins equipped with artificial intelligence are used in the separation of smart waste from the source. For example, Clean Robotics has presented a smart trash can called TrashBot that automatically separates different types of waste from one another. Artificial intelligence and robotics are revolutionizing waste and resource recovery. Clean Robotics has developed an autonomous system that uses robotics, computer vision and artificial intelligence to identify and separate landfill waste and recyclables. It does this more accurately than humans, captures high-quality data for waste, and allows staff to know when it's full. The trash bin produced by this company has the ability to separate waste with all kinds of sensors, cameras, metal detectors, and motors that are embedded in them, and one of its main goals is to change the manual waste separation methods and do it automatically at

the source. Also, based on studies of the amount of waste produced, this company provides various analyzes such as the amount and type of waste of a building, region or city. Cloud connectivity allows individual units to learn from the global TrashBot fleet and become smarter over time. The possibility of displaying advertisements or notifications on the screen of this device is also one of the other features considered for it.

Clean Robotics offers an intuitive dashboard where users can monitor trash bin capacity, track waste types, and make informed decisions.

Advantages and opportunities:

- Forecast deviation, cost and savings
- Audit of requested and exported waste.
- Full status and TrashBot for custody operations
- Customizable artificial intelligence for compliance
- Granular data for decision making insights

Smart waste separation in recycling centers

Manual waste separation can also be done intelligently using robots equipped with artificial intelligence. Today, most of the separation of garbage and waste materials is done by human power, which is a dangerous and exhausting task. But with the help of robots, the waste separation process can be done automatically. For example, AMP Robotics' artificial intelligence robots can pick up about 80 to 100 objects per minute. This is while a human can pick up between 60 and 80 objects in one minute. But this number is stated in an ideal state and the average amount of removal by humans for each person is 40 times per minute. In waste separation, robots are not the most important part, but the artificial intelligence that guides these robots is very important. The vision system used in these robots can recognize and differentiate different objects according to factors such as color, chemical constituents, etc. Designing the vision system in such a way that sat provides the possibility to separate all the materials and objects that are placed in the trash or recycling bin. Even if these materials are crumpled or dirty, they can be distinguished and separated with the help of this technology [39].

The pioneering AMP Neuron platform uses computer vision to process millions of images to map complex material flows. Neuron to continuously improve the accurate identification and classification of paper, plastic and metals based on color, size, shape, opacity, form factor, brand and more, to collect text and store data about each item it understands. It uses deep learning. A global neural network of unique depth and breadth enables automation to accurately recycle recyclable materials, eliminate contaminants, and ultimately create high-value raw material for resale in the global supply chain. The captured data also enables recyclers to optimize their operations, increase recycling rates, and process raw materials needed so that manufacturers of packaging, containers, and other goods can meet recycling content goals And reach the society's vision for a sustainable and circular economy [40].

Discussions and Conclusions

Today, thanks to the Internet of Things (IoT), living in smart cities is no longer an unattainable dream. Since 2008 when the term "smart city" was coined by Cisco or IBM until today, there have been many developments in the field of city management. Urban planners, tech companies, and governments have been developing cities with the idealistic vision of collecting and analyzing data.

But can smart cities really be considered a sustainable solution to urban problems? In this section, we will examine the different definitions of smart cities, their goals and benefits, and introduce some examples of the smartest cities in the world.

A smart city is a city that uses information and communication technology (ICT) to increase operational efficiency, improve the quality of government services provided, and thus raise the level of well-being of society. Below are the three definitions of smart city and the common points of these definitions.

Standard definitions of smart city

According to the ITU-T standard, the smart city is an innovative urban space that tries to increase the quality of life and improve city services by using ICT and other tools. In addition to meeting these goals, a sustainable smart city must meet the needs of current and future generations in various economic, social, environmental and cultural aspects.

Smart city according to SAC standard: Smart city uses information and communication technology as a tool to serve citizens. This new concept helps in the simultaneous development of all urban sectors as well as the modernization of agriculture [41].

Smart city according to the definition of GSM: the concept of smart city uses the participation of the government and mobile phone networks in order to improve the quality of life of citizens. This solution creates many benefits for businesses and citizens. In a smart city, data obtained from equipment and infrastructure are collected and processed, and important decisions are made based on them in different urban areas [42].

In all three definitions presented, three principles are essential for every smart city.

1. Ability to communicate: Different devices in smart cities must have access to the Internet so that they can share information with each other.
2. Data: Without data generation, devices will have a limited amount of information. Therefore, producing information (data, video, photos, etc.) is a necessity in a smart city.
3. Government participation: Without the support of the government sector, smart cities are the same as the Internet of Things. Although IoT has an interesting and growing market, to become a real smart city, the participation of the public sector is a necessity [43].

Objectives and features of the smart city

The main goal of a smart city is to optimize urban activities and promote economic growth along with improving the quality of life of citizens. The value of a smart city is the efficiency of technologies, not their number. A successful smart city has a strong, technology-based infrastructure that enables environmental initiatives. In this city, public transportation is effective and efficient, and urban programs are carried out in a reliable and progressive manner [44]. Some of the features of this city are:

- Smart environment

Smart cities are environmentally friendly and strive to preserve it and manage energy resources. Increasing the amount of green space, preventing deforestation and dealing with air pollution are among the measures that are taken in the field of creating a smart environment.

- Smart transportation

Intelligent Transportation System or ITS refers to a set of concepts and tools that are used in an integrated manner to improve the performance of the transportation system. Status control cameras, automatic car identification system, integrated and efficient public transportation, etc. are among the ITS solutions.

- Smart economy

One of the main components of smart cities is smart economy. Smart or digital economy means the use of ICT to produce products, services and business models. Making businesses and citizens smarter is very effective in creating a sustainable and smart economy.

- Smart governance

In the smart city, smartness is developed to governing and government institutions. Transparency in governance, effective use of information technology capacities for various events and development of infrastructure to interact with citizens are among the most important goals of smart governance.

- Smart life

The facilities of a smart life, such as electronic health, smart buildings, security, various educational and cultural facilities, etc., must exist in smart cities.

- Smart people

Citizens of smart cities should know how the data obtained from them will be used. People should know what the advantages of these cities are and how they can make the best use of them. In other words, citizens' digital literacy should be increased and people should become "Smart".

- Smart energy

Smart systems in a city should monitor and control the amount of energy consumption in different sectors. Information collected from different smart systems can increase energy efficiency by 30% in the long term. One of the ways to reduce energy consumption is to use the EMS energy management system [45].

What is an energy management system or EMS?

Introducing the dimensions of the smart city

Smart city technology consists of different dimensions and aspects and it is not possible to consider it as a comprehensive approach. Also, dividing the city into different dimensions helps the progress of each sector. Therefore, experts in this field consider 4 dimensions for this concept:

 Social and cultural dimension

This dimension refers to the use of information and communication technology to create a digital and knowledge-based city. Along with the development of various technologies, city managers should also create a culture of using them. As people's awareness increases and society becomes "knowledge oriented", participation in different sectors will increase and people's lifestyles and activities will change.

 Economic dimension

In the economic dimension, the goal is to reduce individual and social costs while providing better services. Among the most important achievements in this dimension, we can mention attracting tourists, expanding trade and international relations, saving energy and reducing the cost of urban transportation.

 Security dimension

An essential part of a smart city is the integrated deployment of city services and e-government. Smart warning systems, Special Forces and predicting future events are also related to this dimension. Therefore, the existence of infrastructure networks with suitable bandwidth is necessary to ensure the security of citizens.

 Environmental dimension

As it was said, the smart city is an environmentally friendly city, and as a result, preserving natural resources and the environment is one of its most important goals. Increasing electronic infrastructure in order to reduce traffic and volume of traffic, limiting

the use of fossil fuels, smart agriculture and saving renewable resources are among the goals of this dimension [46].

Getting to know the four main steps in making cities smarter

Smart cities take four important steps to improve the quality of life and create economic growth through a network of connected devices and technologies. These steps are as follows:

- Data collection. Collection of required information and data is done by sensors and in real time.
- Data analysis in order to obtain the necessary insight for decision-making, the collected data is carefully examined.
- Data transmission of the results of the investigations will be sent to the control center to make the necessary decision.
- Necessary measures of useful information communicated and the results of surveys lead to making decisions for better city management, improving the quality of urban life and greater satisfaction of citizens.

How smart city technologies accelerate the process of urbanization

Currently, about half of the world's people live in cities, and this amount is expected to reach more than 65% by 2050. As a result, one of the goals of future cities should be to speed up the urbanization process [47].

The role of the Internet of Things in the smartening of cities

The Internet of Things provides opportunities for cities to use information to control traffic, reduce pollution, make better use of infrastructure, and ultimately provide citizens with a safe and clean city.

It can be said that the Internet of Things has an unlimited role in a smart city. Because it offers solutions in every sector from construction to education and health. These solutions lead to the transformation of traditional elements into their advanced and intelligent type and speed up the process of urbanization [48].

Introducing the best wireless technologies needed in smart cities

Currently, the best and latest wireless technology for the smart city is the 5G Internet. High speed, connection stability, coverage and security of 5G internet are all that a functioning smart city needs. Of course, the development and progress of high-range and low-power networks (LPWAN) almost solves the need of a smart city [49].

Introducing the main parts of a smart city

Smart lighting

Currently, the lighting system is used in cities to illuminate the paths and ensure the safety of citizens. The intelligent lighting system is equipped with sensors to collect data. By analyzing the obtained information, it is possible to improve the efficiency of services and manage energy consumption.

Smart parking

Nowadays, parking lots are an important part of urban space. Therefore, you should make the most of this space. Space management, convenient payment, advertising, car parking guide, etc. are just some of the features of using smart parking in the urban space. As a result, the volume of urban traffic is reduced and citizens' time and money are saved.

Smart farming

Problems such as lack of food and the importance of saving water consumption caused the emergence of the concept of smart agriculture. But it is possible to have smart urban agriculture for maximum use and optimization of urban spaces. With existing modern methods such as aquaponics, hydroponics, etc., agriculture can be done with very high quality in containers or on the roofs of buildings in the smart city.

Smart waste management

One of the main challenges of every metropolis is managing the huge amount of waste produced. In a smart city, an intelligent waste management system is used, which has the least harm to the environment and increases the health level of the society by disposing of waste and recycling valuable materials. In addition, this system minimizes human intervention.

Smart building

In order to clarify the importance of smart building, it should be said that without smart buildings, you cannot have a smart city. Because buildings are the constituent parts of a city, and to build a smart complex, each part needs to interact with the other. These buildings are responsible for the intelligent management of energy, waste, urban space and environmental protection [50].

Essential elements in the success of smart cities

The results of studies and reviews of different smart cities show that the following 7 elements are common among successful smart cities:

- Focus on comprehensive development of the city, as opposed to regional development
- Citizen-oriented approach
- Aligning the development program with government plans and benefiting from their support
- Long-term perspective
- Prioritizing environmental sustainability
- Participation of public and private sectors
- Development of extensive databases and platforms

Smart city and how to earn income

A smart city can be considered a platform for sustainable income generation. In addition to saving and reducing costs for the city and citizens, different parts of the smart city can be used to earn money (Li, 2019). For example, with smart agriculture, quality products can be harvested anywhere in the city, and even rooftop space can be used to generate income.

Various smart cities use innovative solutions to generate revenue. For example, we can mention the Kansas City kiosks. Kiosks with maps, city information, etc. have been installed in the streets of this smart city. These kiosks generate income in several ways. Selling tickets for various events, renting advertising space, and using people's data and analyzing and selling them to other businesses are some of the ways to earn money from these kiosks, while buying and installing them did not cost much [51].

Another way to generate income is simple and its implementation only requires data management. Nowadays, many people voluntarily put their information on different websites. The desire to do banking, fill out forms and even change license plates online is increasing day by day. Many are willing to pay for doing things this way and reducing traffic. But even if these services are provided completely free, it is possible to make money from them. To

achieve this goal, the government must manage the information and turn it into usable and useful data that can be presented to others for sale [52].

Introducing the smartest cities in the world

Currently, there are many smart cities in the world. The following list includes ten examples of the smartest cities in the world:

1- Kansas, Missouri, United States
2- Dubai, United Arab Emirates
3- London, England
4- Hong Kong, China
5- Vienna, Austria
6- Tokyo, Japan
7- Amsterdam, Netherlands
8- Oslo, Scandinavia
9- Singapore, Singapore
10- Barcelona, Spain

The integration of Internet of Things technology into smart waste management will usher in a new era of efficiency, sustainability and innovation. For the transition from traditional methods of waste collection to intelligent management of urban waste, the impact of the Internet of Things is undeniable. Through the use of smart bins, sensors, data centers and advanced analysis in waste management, a new approach is created that optimize collection routes and improve resource allocation. The environmental effects of the Internet of Things in smart waste management are significant that by minimizing unnecessary collection traffic, reducing fuel consumption and promoting recycling, waste management systems can contribute to a cleaner and more sustainable environment [53].

The shift to a circular economy powered by IoT-enabled technologies will ensure that waste is seen as a valuable resource rather than a heavy environmental burden, promoting resource recovery and reducing reliance on raw material consumption. In addition, the financial benefits of using the Internet of Things in smart waste management are significant. International experiences of the Internet of Things in intelligent waste management serve as bright points of using this technology and show the transformative potential of connected devices and data-based decision-making [54].

At the international level, cities and countries have welcomed the power of the Internet of Things in waste management, and significant successful experiences are emerging. From crowded metropolises to remote towns, international experiences of the Internet of Things in smart waste management have provided brilliant results in reducing costs and preserving the environment.

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