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RESEARCH ARTICLE

Public Safety in Smart Cities: An Experimental Study to Monitor and Record Vehicles' Movements

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ABSTRACT

This research addresses the critical issue of enhancing public safety in smart cities, with a particular focus on industrial cities in Saudi Arabia. Despite the advanced infrastructure and high safety standards in industrial cities, there are safety challenges, particularly the vulnerability of residential properties to burglaries during holidays and extended breaks. To mitigate these risks, the research proposes leveraging existing infrastructure to implement surveillance systems that monitor vehicle movements using RFID technology and smart sensors, thereby enhancing safety, supporting law enforcement in crime detection, and protecting local communities. The study also acknowledges the reduced social interaction often associated with the heavy reliance on technology in smart cities, emphasizing the need to foster social connections alongside technological advancements. A proposed vehicle monitoring solution is introduced, capable of detecting and identifying registered and unregistered vehicles while recording movement data in urban areas for subsequent analysis. Future research is recommended to expand this concept, focusing on real-world implementation with real-time connectivity and cloud-based services integrated into secure and certified database systems.

Keywords: Public safety, Intelligent transportation systems, Smart traffic sensors, Smart cities

1. Introduction

The monitoring and management of vehicle movements have become critical for addressing incidents such as stolen cars or vehicles involved in dangerous activities. Advanced surveillance systems equipped with technologies like RFID, license plate recognition cameras, and GPS tracking are essential tools in this process. These systems enable authorities to monitor the movement of vehicles in real time, detect anomalies, and identify vehicles of interest based on predefined criteria. Modern public safety systems are now more efficient due to advancements in high-speed internet, IoT, and integrated surveillance technologies. The 3D urban security surveillance network consists of mobile phones and GPS devices. Urban public safety surveillance produces a large amount of spatiotemporal data, especially video, photographs, remote sensing images, vector maps, and operations data ([15], p. 36). This information has multi-level, multi-temporal, multi-dimensional, along with multi-modal characteristics, in addition to rich temporal, geographical and semantic information.

The multidimensional nature of public safety surveillance data, which includes multiple modalities, results in a single phenomenon being represented in multiple ways. Additionally, many systems display a combination of shared variance in lower-order features and high-level semantic relationships. The traditional method of collecting individual data cannot solve the problem of collecting heterogeneous and common data related to the same event in the process of detection, investigation, and early warning of urban public security. It is therefore important to carry out a comprehensive analysis of the relationships between the different data units. This involves establishing connections between different data modalities to facilitate multimedia recovery of the same object.

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This capability is essential to facilitate accurate, rapid identification and early warning of public safety cases in urban areas ([22], pp. 4371–4386).

The impacts of demographic expand, due to the displacement of the population regarding to modern centres, continue to be an obstacle for cities. The UN points out that currently 54% of the world's population lives in urban regions along with it is predicted that by 2050 this will rise to 66% [33].

The accelerated expansion of the urban population along with unplanned urbanization processes have generated complicate cities that face rising challenges. This leads us to reorient, rethink, and re-manage our city systems to adapt to current needs, through new sustainable development models, plans as well as techniques [30].

Regarding to this, the digital city model emerges that looks to solve the challenges of the contemporary city through interconnected intelligent systems, based on Information and Communication Technologies (ICT). Although, the concept of a smart city has been redefined in a differentiated manner in various reports and research by academia, consulting firms, along with government agencies [30].

Multiple definitions endorsed by technology companies and criticized by their detractors for being technocentric in nature, focus only on the use of ICT for data collection as support for city services. The most anthropocentric visions, on the other hand, also consider social and economic factors from an integrated perspective, where the citizen is the centre of development, thus extending the possibility of adapting this model to less developed cities that do not have the capacity to invest in technological systems. These different approaches converge in the recent definition of AENOR (2016: 7), which will be taken as a reference in this article [28].

According to this approach, defining a smart city, not referring to a fully technological and automated city, where the hyperconnected citizen loses human contact, thus nullifying their possibility of action and contribution to management, and limiting themselves to being a recipient of services. Rather, it is about the participation of an "intelligent citizen" who plays a fundamental role in the city's transformation process, since, through technology, a person interacts with the environment to provide rich data for decision making. Moreover, to collaborates in collective planning. That is, the incorporation of new technologies in urban governance provides tools and supports for the implementation of services to users for a more efficient management of natural and economic resources, through a participatory and interactive government [3, 6].

A smart city shall not lose its cultural along with historical specify due to the trend towards the homogenization of contemporary cities; on the contrary, it will determine and enhance the characteristics that differentiate it from other metropolises, as well as the comprehensive vision that will delimit its objectives and strategies. To achieve this, governments must promote a culture of entrepreneurship within their territories, valuing technological development and the sense of local innovation. Thus, from the human capital itself, it will contribute to the production of knowledge and search for solutions that address the true challenges of the city, avoiding importing international models that are incompatible with its characteristics and needs [5].

One of the first questions when demonstrating the topic of the smart city is to create whether it is a fashionable concept or could be considered a lasting model, since in recent years it seems to be exhausting its value and wanting to adapt its definition to resemble to other city models. In this sense, the dispersion of definitions on this concept shows that there is no specific direction in the objectives of cities towards the use of technologies. Meanwhile, the concept of a green city, which has a global definition that circularly articulates the economic, social, and environmental pillars, is adopted by governments due to the understandable objectives it represents to increase the quality of life in cities. Indeed, the Sustainable along with Integrated Urban Development Strategies (EDUSI) proposed by the European Parliament as well as the Council of the European Union (2013), and financed through the European Regional Development Fund (ERDF) in the period 2014 to 2020 address similar aspects to digital cities, prioritizing inserted assesses to face economic, environmental, climatic, social and demographic challenges towards a sustainable and resilient city [24].

The prime disadvantage of multimodal retrieval techniques is the demand to analyse along with develop relationships among multimodal data and understand the retrieval between different types of data. Despite the research on multimodal retrieval of multimodal spatial data with common spatiotemporal features and rich semantic information has not received much attention in recent years, research on multimodal retrieval of texts, images and of traditional videos is growing rapidly. With the birth of 3D public safety surveillance networks in urban areas, object acquisition methods for multi-modal public safety surveillance need to be examined to quickly detect, specify along with alert public safety incidents. Moreover, the main emphasize areas of this research embrace, multidisciplinary spatiotemporal

dataset construction, spatiotemporal inventory methods, multimodal data mining along with multimodal information retrieval technology for urban public security surveillance ([17], pp. 1025–1025).

Additionally, many systems display a combination of shared variance in lower-order features and high-level semantic relationships. The traditional method of collecting individual data cannot solve the problem of collecting heterogeneous and common data related to the same event in the process of detection, investigation, and quick warning of urban public security. It is therefore important to carry out a comprehensive analysis of the relationships between the different data units. This involves establishing connections between different data modalities to facilitate multimedia recovery of the same object. This capability is essential to facilitate accurate and rapid identification and early warning of public safety issues in urban areas ([22], pp. 4371–4386).

Urban public security management is a modern concept. Cities are important indicators of a region's economic success because they are densely populated and possess physical and financial resources. As the urbanization procedure continues to accelerate the level of urbanization continues to improve, various public security incidents in urban areas pose serious threats to public health security. Based on existing theoretical results, this study integrates different research trends from a theoretical perspective, discusses the factors that increase public safety risks in urban areas, and discusses the importance of understanding security public relations, diversity management and risk management ([16], pp. 55–62).

The collaborative events organized through interdisciplinary laboratories and state-of-the-art technologies play a vital role in shaping the regional identity of Lima, Peru, at the local level. These efforts establish a coherent developmental trajectory that addresses the city's urban challenges comprehensively. By integrating advanced technology and multidisciplinary approaches tailored to Lima's unique context, the city can progress toward becoming a smart city. To achieve this, expanding ICT infrastructure and coverage is crucial and must be accompanied by educational programs in technology-related fields to increase citizens' e-participation and digital literacy. Moreover, Lima's economic growth should not be limited to the creation of private and exclusive markets. Instead, it presents an opportunity for local governments to collaborate with public and private sectors to foster human capital development through entrepreneurship, innovation, and technology. This approach will create new employment opportunities in key areas necessary for Lima's transformation into a smart, inclusive, and economically resilient city [10].

This project studies along with develop an automated public safety command and control system in the context of responding to public safety emergencies. On other side, the features of real-time control, local access, and automatic intervention, to enhance the capability of the emergency control system to control accident scenes and other situations, while taking advantage of the control processing challenges of the emergency control system, response control delays, command and control errors, and information retention in the responses of individual robots ([34], pp. 1675–1696).

In addition, an advanced network utilizing network technologies, remote sensing, real-time data transmission, IoT technology, communications along with artificial intelligence is used to provide remote monitoring along with control. These comprehensive decision systems can assist commanders respond to situations more quickly while improving the overall effectiveness of each automated component in terms of situational awareness, decision making, and intervention.

Despite ongoing research on integrating and sharing video resources for public safety, as well as new access options that meet basic standards, there is still enormous untapped potential in expansion and development projects. Despite efforts to enhance the integration of social video resources, the adoption of video surveillance for public safety, vehicles registration and tracking is currently dominated by law enforcement development, surveillance, and use. This highlights the great potential for future improvements and applications ([34], pp. 1675–1696).

Recently important topics embrace enhancing the performance of public security video surveillance tools, improving three-dimensional comprehensive prevention and control, enhancing the performance of public services, urban planning management and public security information, and enhancing citizens' capability to benefit ([34], pp. 1675–1696).

This paper shows an innovated idea to use the RFID technology to track vehicles movements in urban cities and record all vehicles getting in or out neighbourhoods to save their data on cloud servers for later access and deep analysis by authorized agencies. Optimistically, providing advanced technological tools to increase the level of safety in urban areas and assure accountability by collecting vehicles data and their registration information.

According to study by Hesham et al. [12], showed the emergence of smart cities aims to leverage technology for improving services and overall efficiency for urban populations. Recognizing the critical need for continuous and seamless urban monitoring, numerous studies have explored the development

of intelligent surveillance systems tailored for smart cities. While various research avenues have been pursued in this field, the diverse range of problems and solutions makes it challenging to discern prevailing trends and gaps without a systematic review. Therefore, this paper undertakes a comprehensive literature review on the subject, shedding light on current research trajectories, encountered challenges, and prospects within the realm of intelligent surveillance systems for smart cities. This review furnishes a compilation of referenced papers, thus facilitating advancements in the effectiveness, dependability, and resilience of these systems.

Recent study by Sha et al. [29], it delves into a comprehensive examination of intelligent monitoring and early warning systems for public safety devices within the context of smart city development. It adopts risk management theory as its foundational framework and combines it with practical considerations, specifically focusing on the establishment of a risk management framework for public safety amidst the backdrop of refined urban management. A representative case is thoroughly analysed to gain insights into how communities undertake preventive measures and control public safety risks, employing research methods such as surveys and interviews. The study encompasses the system design and robot application modules.

If the investment markets exist and the results of the investment market are improving, this study has an analytical method suitable for our topic that can increase efficiency and accuracy. The application state of the robot in the next section is useful for emergency commands of the main operating system and is recognized by the robot. The accuracy of this model is defined in four key areas: data communication, situational awareness, incremental decision making, and command and distribution. It describes the technical environment of the system, including the site system that runs the operating system of the system as well as the information provided for the deployment devices and the interface modules to be implemented. The creation and implementation of robot application models is described. Finally, based on the analysis of the results, the performance and development of the system are analysed and possible recommendations for future research are made [29].

A study conducted by Elvira et al. [9], shows new challenges intersect and overlap in crucial aspects including, Smart city managers, planners, Smart City Infrastructure Analysis, integrators along with organizations face remarkable political, technical with economic challenges as these privacy and security, Urban safety are hugely emphasized on research objectives that highlight information security issues and challenges faced by smart city infrastructure in personal data management and processing weaknesses which may arise. This article addresses multiple of these challenges, provides an excellent summarization of the related key literature, and develops a model for engaging with smart cities.

In fact, several crucial topics in smart city research are emphasizes on this study, encompassing citizen utilize along with acceptance of smart services; operational hazards to smart cities; privacy and security of mobile devices and services; smart city infrastructure, energy systems, and healthcare; and frameworks, algorithms, along with protocols that enhance security and privacy. In-depth investigation provides an insightful viewpoint on multiple crucial issues along with offers significant recommendations for further research. For scientists and practitioners planning future research, the study's findings can serve as a helpful foundation and point of reference.

Otherwise, a study by Laufs et al. [18], revealed that smart cities technology is frequently praised as the answer to a number of urban problems, including waste management, transportation, and environmental protection. However, security and crime prevention concerns are frequently overlooked. Researchers seldom explore the adoption of new smart security technologies, and they also rarely consider how new smart city security can affect traditional policing and urban planning practises. In order to determine how closely these novel interventions align with more established security intervention functions, this systematic review examines current research on new "smart city" security technology.

We created a list of security solutions for smart cities after a thorough literature search and make many adjustments to the conceptual status quo in the area. At the end, we suggest tools to classify security interventions in smart cities: those that employ new sensors but conventional actuators, those that aim to make older systems smarter, and those that add wholly new capabilities. The significance of interventions for the wider area of urban security and governance is then evaluated after a detailed discussion of these issues.

2. Materials and methods

The research problem is improving public safety in smart cities. Industrial cities in Saudi Arabia are very developed and their infrastructure considered to be suitable for this research. Now, these industrial cities continue to be reimagined and face challenges in their implementation in different urban areas. Among the social problems associated with this concept, another

problem arises, which is the effect of residents of these industrial cities moving to their original homes and family reunification during weekends and holidays, which leaves their homes vulnerable to the risk of theft. Residents of industrial areas are often considered to have high incomes, which makes their homes a target for thieves and criminals. It is possible to benefit from the existing infrastructure in industrial cities to implement surveillance systems and monitor vehicles' movements to increase safety and protection. It can also contribute to supporting the competent authorities in localizing security and the ability to investigate and study in the event of crimes occurring. There is also the problem of lack of communication and social interaction in smart cities, due to the heavy reliance on technology and smart technical tools. This deficiency can cause a lack of social connections and low real social interaction, negatively affecting the social fabric of local communities. In this research, we are trying to provide a technical tool to increase public safety in industrial cities and resolve these raised concerns.

The main purpose of this study is to incorporate technological strategies and projects into their roadmaps allowing them to move towards a smart city model. This is done by applying smart sensors in creating a safer urban environment by monitoring and documenting neighbourhoods' traffic. The research also aims to advance towards industrial/smart city model that allows for the effective solution of aspects of mobility, environment, effective resource management, social cohesion, and public administration. The long-term goal is to unite and work collaboratively with other actors, such as educational institutions and private companies, to revitalize the country's technology and innovation ecosystem, creating competitive and innovative human capital, and new economies in entrepreneurial markets. This research provides a proposed tool for monitoring the vehicles movements without real data recording, there is a need for future works to expand the boundary of this research and apply it with real scenarios and actual cloud connections to certified protected servers and databases.

The research questions pertained to this study are:

2.1. How does the use of sensor-based surveillance systems affect the general level of security in public areas in smart cities?
2.2. How do various sensor types affect the precision and dependability of data collecting in this situation?
2.3. What possible privacy issues can arise from using sensor technology to keep an eye on public locations, and how might such issues be resolved?
2.4. How can the sensor data be efficiently used to better traffic management and urban planning for greater public safety in smart cities?

3. Results and discussion

In this research, a laboratory experiment was designed to validate the proposed solution approach. Description of all used parts in this experiment are explained in Table 1.

Table 1. Used parts for the research experiment.

Items	Parts	Purpose
1	Arduino UNO	Microcontroller mainboard
2	RFID Reader	Read RFID Tags
3	I2C 2 × 16 LCD Display	Display messages
4	Two IR Sensors Modules	Detect vehicles IN/OUT
5	Single RFID Tag	RFID Tags
6	9V Battery/or could be replaced with Power bank and USB cable	Power supply

Fig. 1 shows the design diagram of the proposed solution and other figures will be presented in this research for more details.

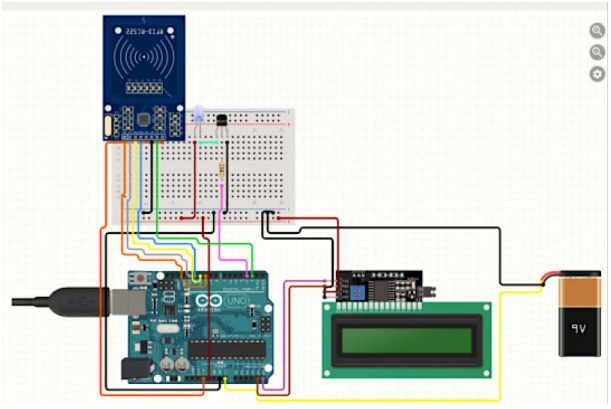

Fig. 1. Circuit diagram used for the research experiment.

The presented solution in this experiment is to monitor and record the cars movement from and getting out the neighbourhoods in the city. All neighbourhoods' urban layouts are designed with main loops so to get inside any of these neighbourhood, therefore, there is only one entrance for the loop and one exit as well. The entrance and exit gates can be exchanged depending on the cars directions since both gates allow cars to get in and out.

In this design, each entrance and exit will be equipped with bridges to since the cars movements and record the cars' information such as car plate numbers, registration number, Vehicle Identification Numbers (VINs), Owners, etc.



Fig. 2. A proposed model of vehicles' recording.

Fig. 2 shows the design of bridges that will be installed in all neighbourhoods' entrances and exits to record the cars' movement.

In this proposed model, all recorded information should be saved in a protected cloud server and only accessible by authorized users, however, using of cloud services is a next development stage and for future development. Cloud storage has been proposed in recent studies as it enables authorities to conduct in-depth analysis and make informed decisions at a later stage [14].

The parts explained in previous table were used to test the workability of the solution and used car toys as sampler of actual cars. Sensors were posted over the bridges and on all cars to establish the communication between them. In this experimental study, we are not focusing on collecting data from cars, however, we testified that TAG readers on bridges can communicate with each car passing the gates and this is evidence that cars' information can be extracted from the data sim card in each car and sent over the Internet to a protected and encrypted cloud server.

The Figs. 3 to 5 showed the experimental design, and how the signals can detect vehicles when passing a bridge to enter a neighbourhood or exit to a main road.

Moreover, in this proposed design, surveillance cameras would be employed to identify vehicles that either lack RFID chips or have malfunctioning RFID components. These cameras would capture the physical license plate numbers instead of RFID tags for all passing vehicles and transmit the data to certified cloud servers for subsequent analysis. The system would then cross-reference the captured plate numbers with the registered entries in the database. If a plate number is not found within the approved database, a warning message would be automatically sent to the appropriate authorities for further action.

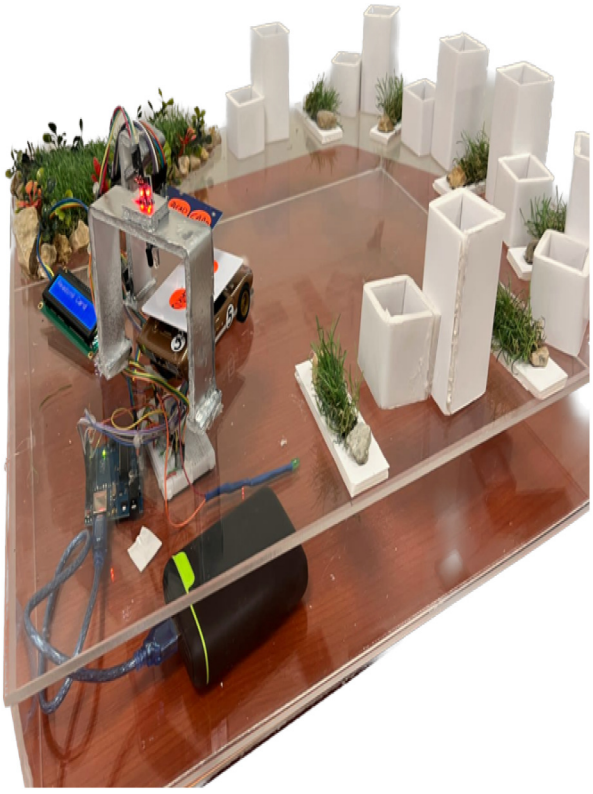

Fig. 3. A side view of the design with used parts for the research experiment.



Fig. 4. A top view of the design with used parts for the research experiment.

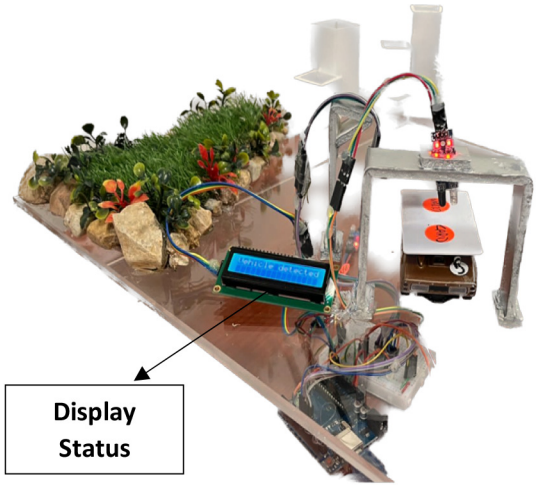

Fig. 5. A display unit used to show the status of crossed vehicles.

Table 2. The developed algorithm used in this research experiment.

Steps	Processes
1	System initializes itself and ready to detect the vehicles.
2	Once IR sensor detects the vehicle it sends the signal to the controller
3	Message is displayed at LCD "Vehicle detected".
4	Once vehicle moves forward, RFID reader scans the RFID card, installed at the vehicle.
5	System validates the vehicle's ID (with database).
6	If ID is validated, green LED blinks, and at LCD the message "Registered Vehicle" is displayed.
7	If ID is not validated, then the message "Unknown Vehicle" is displayed. To send a message that later analysis is required (as proposed using the surveillance cameras).
8	Now system goes back to its initial state and repeats the cycle for more vehicles detection.

As seen in Table 2, there is developed algorithm that describes the sequential processes of the proposed experimental solution.

The Figs. 6 and 7 show some of the programming codes used to initiate and control the sensors and show their conditions and loops in detecting vehicles.

4. Conclusion and future directions

The experiential work proved the effectiveness of the proposed solution. The design showed a security gate that can detect objects and identify registered or unregistered vehicles. The intention is to record the vehicles' movements in the city and send their information to a cloud server for later analysis. Unregistered vehicles will be video recorded to extract their information such as plate number for legal actions that could issuing a traffic or safety violations.

```
void setup () {
 lcd.init();
  lcd.backlight();
  Serial.begin(9600);

  pinMode(sensorPin1, INPUT);
  pinMode(sensorPin2, INPUT);
  pinMode(green_LED, OUTPUT);
  SPI.begin();
  mfrc522.PCD_Init();

  lcd.setCursor(0, 0);
  lcd.print(" Vehicle");
  lcd.setCursor(0, 1);
  lcd.print("Detecting  Sys");
  delay(3000);
  lcd.clear();
}
```

Fig. 6. Initiating the detection system.

```
void loop()
{
  digitalWrite(green_LED,LOW);
  sensorRead();
    if (senVal1 == 0)
  {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Vehicle detected");
      delay(1000);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Reading Card");
      delay(2000);
      lcd.clear();
      rfid();
}}
```

Fig. 7. IR sensors to detect vehicles passing the gate and read information.

The research answered the research questions with remarkable information. In the following section, the answers to these questions.

"*How does the use of sensor-based surveillance systems affect the general level of security in public areas in smart cities?*"

The proposed solution showed that vehicles will be recorded by each gate installed on all entrances across the city, thus, there is a possibility of high-quality tracking of all vehicles' movements in the city.

This will give the government authority to analyse the collected data in case of investigating a crime in a specified area. Areas can be identified based on geographical location and neighbourhood identifier and each entrance ID number.

"*How do various sensor types affect the precision and dependability of data collecting in this situation?*"

In this research, the RFID reader and cards were used to get information. As a proposed solution and for laboratory test, IR and RFID are acceptable. However, in the larger scale and to be used for long distance and send information to the server or direct interaction between monitoring system and vehicles, the use of GSM and GPS were suggested to detect the geographical location of each vehicle and detect vehicles' movements in a real time.

"*What possible privacy issues can arise from using sensor technology to keep an eye on public locations, and how might such issues be resolved?*"

In terms of privacy, the proposed solution gives the possibility of tracking vehicles' movements around the city hut the main goa is not tracking people. However, the collected information will be protected and can be seen by authorized government agency. There is a need to raise the level of awareness toward use of technology to serve security. In the smart cities, vehicles need to be smart and support IoT and allow data collections by authorized agencies for more protection. The high level of protection will benefit all citizens to low the crime rates and provide a quality of life.

"*How can the sensor data be efficiently used to better traffic management and urban planning for greater public safety in smart cities?*"

As shown in the proposed solution, detecting movements of vehicles and record their information will give the chance to authorized government bodies and decision makers to support the city with high traffic volume and where to use these controls and when to implement them to increase security in affected areas.

There are several challenges and future directions in this research. Despite the potential advantages of the proposed solution, it is constrained by several significant issues that will need more investigation in the upcoming years. The following list summarises the present research difficulties and potential future directions:

4.1. Cost factors

Cost-cutting initiatives are always considered to be the biggest problems. In order to obtain comprehensive coverage at a cheap cost, research works attempting to enhance the hardware cameras or are proposing algorithms and strategies to give high efficiency even with low-resolution cameras [25].

In addition to Dinakaran et al. [8] demonstrates future improvements to the IoT low-cost traffic monitoring system should include linking it to the cloud to include capabilities like plate number recognition and the ability to display online receipts [7]. In this research, the work was to minimize the cost by using RFID ships; however, the solution was perfect in a laboratory setting but in actual situation with higher bridges and fast movement of vehicles, there is a need for stronger equipment to assure sensors workability. Unavoidably, there is a need to use cameras in order to capture vehicles without tags installed or removed and send images of vehicles' plate numbers for later analysis.

4.2. Reliability and efficiency factors

One of the challenging issues is the calibre of the data collected by intelligent systems. As the algorithm is used to identify an event that is not entirely accurate itself, the question of the source's credibility also arises in relation to this obstacle [8, 27]. Thus, there is an issue with how the algorithm must be combined with the results of detection. Hence, the quality of clips could be enhanced by utilizing a diversity of image-processing along with computer vision techniques along with approaches to obtain the best stage of reliability [23] in addition to recommend utilizing diversified theoretical studies along with building resolution-invariant feature descriptors in future [4]. Installed sensors should work properly to detect vehicles in a trusted way and send accurate data to be registered on designated cloud servers. The whole process requires testing and validation before implementation and go-live stages.

4.3. Real-time analysis and prediction factors

Pereira et al., [25]; Tian et al. [32] mentioned that enhancing real-time analytical performance in surveillance systems for smart cities is crucial to preventing future catastrophic disasters. To help with this difficulty, strategies have been created by Pahal et al. [26]. Additionally, it is advised to forecast future occurrences in addition to analysing current or historical events [1]. This research provided a tool for collecting and storing data, however, there is a need to set clear operational rules and how the collected big data will be managed and analysed. It is a challenge for operators, and it requires full attention to avoid information overload and waste of resources.

4.4. Security and privacy factors

Security and privacy are one of the most underappreciated, yet remarkable difficulty encountered by smart systems. When establishing those systems for smart cities, it is crucial to recognize these barriers (Tian et al., 2018; [11, 21]). Additionally, the great reliance of monitoring systems in smart cities on shared information necessitates careful consideration of those systems' resilience to various threats [13]. People might think this kind of security will affect their privacy and freedom; however, the use of the proposed solution should be supported by the government and decision makers to prioritize the benefits of monitoring cities and assure their public safety.

Addressing privacy concerns while ensuring public safety requires robust data protection measures and public trust. All data collected should be encrypted to safeguard it from unauthorized access, and strict access controls must ensure only authorized agencies can view or manage the data. To enhance public acceptance, transparency initiatives should inform citizens about how data is collected, stored, and used, emphasizing that it is handled with strict confidentiality and solely for public safety purposes.

4.5. Infrastructure readiness factors

Although many cities have incorporated strategies and projects into their roadmaps allowing them to move towards the smart city model, since it is an emerging and still experimental model, it is not wise to optimistically generalize the results of adopting experiences of other cities. Which have different facts and points of view. Indeed, it is pertinent to further explore empirical knowledge of this concept, as there remain notable social and economic inequalities that lead to socially and regionally fragmented cities. However, there is a relationship between technological progress, innovation, and sustainable and integrated urban development.

Compared to countries in the Middle East region, Saudi Arabia is very developed in term of technological advancements [31], while some countries reflect low rates of innovation and development in the field of Information and Communications Technology (ICT), making it difficult to implement action plans and pilot projects for smart cities. Although the government initiatives to boost this sector are emerging, they need to unite and work collaboratively with other actors, such as educational institutions and private companies, to revitalize the country's technology and innovation ecosystem, and create competitive and innovative human capital, and new economies. Significantly, the integration of the existing monitoring systems, such as the Sawaher system and the Royal Commission monitoring system, with the proposed monitoring bridges would enhance the coverage and recording of vehicles on main roads and high-traffic areas. This integration could further expand the proposed solution outlined in this paper, leveraging the existing Sawaher system and drawing the attention of the Saudi Data and Artificial Intelligence Authority (SDAIA) to implement smart safety solutions across various cities in Saudi Arabia.

Conflict of interest

The authors declare no conflict of interest.

Author contribution

Dr. Ali Albar: Led the conceptualization, conducted the literature review, designed the research methodology, wrote the main sections of the paper, prepared the original draft, performed data analysis, and created visualizations.

Engineer Mirza A. Baig: Contributed to the experimental design, implemented the coding components, conducted data analysis and visualization, and was responsible for reviewing and editing the manuscript.

Both authors have read and approved the final version of the manuscript.

Data availability

The data that support the findings of this study are available on request from the corresponding author.

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