Intelligent Traffic Management System (ITMS) for the development of smart cities in Sri Lanka

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Abstract *- Traffic congestion in Sri Lanka is a pressing issue that leads to wasted time, financial burdens, and disruption of personal schedules. The inadequate road infrastructure, underutilization of various travel information sources, and transportation systems coupled with the increasing number of vehicles contribute to this problem. Despite the presence of two international airports, a railway system, and waterways for transportation, the populace predominantly relies on the road network, leading to consequential challenges such as traffic accidents, property damage, and environmental pollution. The objective of this research is to put forth and assess a smart system for managing traffic known as the Intelligent Traffic Management System (ITMS). This system utilizes technological progressions like Artificial Intelligence (AI), cloud computing, the Internet of Things (IoT), and data analytics to enhance traffic management and control. The objective is to optimize traffic flow, reduce wait times, alleviate congestion, minimize travel expenses, and mitigate air pollution levels. The proposed system employs machine learning algorithms to forecast optimal routes based on traffic patterns, vehicle classification, frequency of accidents, and weather conditions. The development and implementation of the ITMS demonstrate the potential of AI-driven solutions in addressing traffic-related problems and improving daily commuting experiences. In conclusion, integrating AI technologies into the ITMS presents a promising approach to mitigating traffic congestion challenges in Sri Lanka. By forecasting optimal routes and incorporating data-driven decision-making, the ITMS offers a solution to improve traffic management and alleviate the negative effects of congestion.*

Keywords—— ***Traffic Congestion, The Intelligent Traffic Management System, Artificial Intelligence***

I. INTRODUCTION

Have you ever wondered how a traffic light functions? Interestingly, artificial intelligence (AI) plays a crucial role in its operation. In Sri Lanka, the escalating volume of both rural and urban road traffic has led to numerous traffic-related issues such as traffic jams, accidents, and environmental pollution (Dharmaratne, Jayatilleke, & Jayatilleke, 2015). However, the application of AI, specifically programmatic AI, has significantly enhanced traffic management in both rural and urban areas worldwide, mitigating accidents and alleviating traffic congestion.

A. *Artificial Intelligence*

Artificial Intelligence encompasses a broad spectrum within the field of Computer Science-based topics where humans build smart machines with the use of human intelligence (Russell & Norvig, 2016). Artificial Intelligence (AI) refers to systems or robots that simulate human intellect and possess the ability to continuously enhance their performance based on the data they collect. Francois Chollet, a prominent researcher at Google specializing in Artificial Intelligence and the creator of the Keras machine learning library, highlights the connection between intelligence and a system's ability to extrapolate knowledge and effectively navigate unfamiliar circumstances through adaptation and improvisation. John McCarthy, renowned for his exceptional contributions to the fields of Computer Science and Artificial Intelligence, is widely acknowledged as the "father of Artificial Intelligence". In the mid-1950s, McCarthy introduced the term "Artificial Intelligence," providing a definition for it as the field focused on developing intelligent machines that can demonstrate cognitive abilities. McCarthy first used the phrase “Artificial Intelligence” in the middle of the 1950s and he did characterize it as “The Science and Engineering of making Intelligent Machines.” Artificially intelligent robots made their initial appearances in Science Fiction literature during the early 20th century. Notable examples of such characters include the unfeeling Tin Man from "The Wizard of Oz" and the humanoid robot, portrayed by Maria, in the film "Metropolis." The concept of Artificial Intelligence (AI) had deeply influenced scientists, mathematicians, and philosophers of the time, becoming firmly entrenched in their thinking by the 1950s(Anyoha,2017).

In 1956, John McCarthy and Marvin Minsky organized the Dartmouth Summer Artificial Intelligence Study (DSRPAI), which marked the significant milestone of the first official AI program being included. The software created during the Dartmouth Summer Artificial Intelligence Study (DSRPAI) is commonly acknowledged as the initial step in the development of Artificial Intelligence. While the trajectory of AI remains uncertain, this research underscores the substantial gap between the

current state of AI and its depiction in science fiction (McCarthy, J., Minsky, M., Rochester, N., & Shannon,1956).

B. Intelligent Traffic Management System

Despite the significant efforts to enhance and improve traffic flow in many nations, including several countries with advanced economies, traditional traffic lights continue to experience the following well-known issues.

a) They offer ineffective traffic control at intersections. This makes commuters who drive to work irrationally which in turn results in traffic congestion, pollution, more delays, etc.

b) They lack adaptability and cannot acquire intelligence. Currently, regardless of the volume of traffic or flow density, each route is given a certain percentage time frame to be green at intersections. By not allocating time in accordance with traffic congestion, this results in inefficient traffic flow. Some roads could be busier than others at certain times of the day, making it take longer to clear congestion. However, this feature cannot be offered by a conventional traffic light.

c) To eliminate needless waiting until the ongoing timer expires as described in the first two points, a signal that instantly closes once there are no longer any vehicles on the road in a junction and opens up the following road is required.

d) Some environmental conditions such as rain, fog, and the like, do not protect them. As a result, they might not function properly or be visible in these circumstances. Accidents and fatalities result from this.

e) They lack a system for granting emergency vehicles (such as ambulances, fire trucks, police cars, etc.) priority. Even before they reach the intersection, such cars require clever traffic signals to open the route for them.

Given the limitations of the conventional traffic management system, there exists a pressing demand to enhance its capabilities through the integration of intelligence for flexibility and adaptability. This advancement holds the potential to mitigate traffic congestion and bottlenecks, consequently leading to reduced travel times and lower environmental pollution. The original traffic management system was conceived several decades ago, catering to a significantly smaller volume of vehicles using the technology available at the time. With the exponential growth in vehicle numbers and the impracticality of expanding road infrastructure in many urban areas, innovative solutions are imperative, leveraging cutting-edge technologies to establish an intelligent traffic management system.

Hence, there is an imminent and compelling necessity to substitute the conventional traffic signal setup with an evolved framework: An Intelligent Traffic Management System (ITMS). This ITMS would offer a range of services unattainable by the conventional model, effectively addressing the aforementioned issues.

C. Research question

What strategies and mechanisms can be implemented through an Intelligent Traffic Management System (ITMS) to effectively minimize traffic congestion and address associated challenges in Sri Lanka, considering factors such as traffic flow optimization, route prediction, accident prevention, and environmental impact?

II.METHODOLOGY

This research aims to contribute to the understanding and advancement of Intelligent Traffic Management Systems (ITMS) by synthesizing insights from existing research articles. The methodology employed for this study involves a comprehensive literature review to gather relevant data, methodologies, and outcomes from prior studies. Reputable academic databases such as IEEE Xplore, ACM Digital Library, Research Gate, and Google Scholar were used to access a wide range of research articles related to ITMS. Relevant keywords, including "Intelligent Traffic Management System, "Traffic Control," "Smart Transportation," and related terms were used to conduct systematic searches. Selected articles were thoroughly reviewed to extract valuable data and insights. The Relevant information, including ITMS technologies, algorithms, case study details, challenges, and outcomes, was systematically extracted from each article. The credibility of the extracted data was ensured by cross-referencing information from multiple reputable sources. Articles from well-established conferences and journals were given priority. The synthesized data from the reviewed articles were analyzed to identify trends, patterns, and gaps in the existing literature. The credibility of each article's findings was evaluated based on the reputation of the publishing venue, the author's expertise, and the rigor of the research methodology. It is important to note that the methodology relies solely on existing research articles up to the knowledge cut-off date. This approach may result in overlooking recent developments or specific nuances not covered in the reviewed articles. The proper citation and crediting of the original authors of the reviewed articles were maintained throughout the research process to uphold ethical research practices and intellectual property rights. To enhance the validity and reliability of this study, a systematic approach to data selection, extraction, and analysis was employed. This included cross-referencing information and prioritizing articles from reputable sources.

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1. The *current traffic management system in Sri Lanka*.

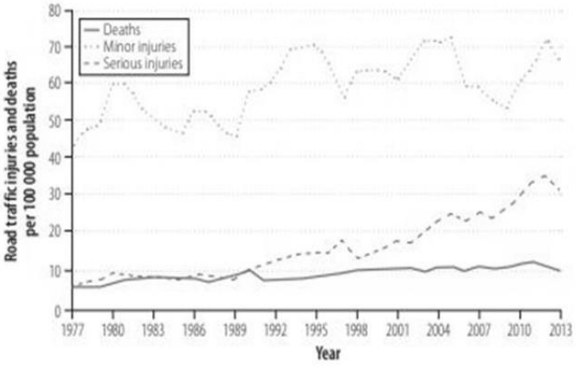
In the contemporary era, the Sri Lankan government employs a range of systems to address traffic-related challenges. These include the Advanced Traveler Information System (ATIS), Advanced Traffic Management System (ATMS), Advanced Public Transportation System (APTS), Emergency Management System (EMS), Transit Management Systems (TMS), Freight Management, and Incident Management Systems. The Advanced Traveler Information System (ATIS) incorporates diverse technologies like the Internet, telephones, cellular phones, television, and radio. This system is utilized by the traffic police department and traffic regulations consultants to effectively manage and regulate traffic conditions. It operates by monitoring traffic flow and promptly making well-informed decisions to ensure smooth traffic control. Advanced Traffic Management System (ATMS) refers to systems that facilitate vehicle movement through real-time information utilization. These systems are employed by traffic departments and law enforcement agencies to regulate traffic flow. The Advanced Public Transportation System (APTS) focuses on enhancing the operational efficiency of public transportation modes and boosting ridership by enhancing overall system reliability. Emergency Management System (EMS) is a field dedicated to managing risks and minimizing their impact. This system concentrates on addressing natural hazards that occur within the environment. These systems have been utilized thus far to manage traffic-related challenges.

Utilizing existing information flows more effectively is a significant challenge that underlies discussions about the market value of information. An illustrative instance is the SCOOT (Split, Cycle, and Offset Optimization Technique) system, renowned as one of the world's most successful adaptive traffic signal coordination systems. It optimizes signal timings across junctions within a network by leveraging comprehensive data and intricate calculations concerning traffic patterns in the area. Utilizing existing information flows more effectively is a significant challenge that underlies discussions about the market value of information. An illustrative instance is the SCOOT (Split, Cycle, and Offset Optimization Technique) system, renowned as one of the world's most successful adaptive traffic signal coordination systems. It optimizes signal timings across junctions within a network by leveraging comprehensive data and intricate calculations concerning traffic patterns in the area.

However, this valuable data resource remains underutilized, representing a pivotal aspect of the information value debate. A potential solution lies in extending access to traffic information providers. This proposition gains significance due to the widespread deployment of SCOOT systems, operational in over 130 locations across the UK, including cities, towns, and boroughs.

III.SYSTEMATIC LITERATURE REVIEW

Figure 3. The period from 1977 to 2013 witnessed fatalities and injuries resulting from road traffic accidents in Sri Lanka.



Source: Road traffic crashes, injury and fatality trends in Sri Lanka: 1938–2013 by Samath D Dharmaratne, Achala Upendra Jayatilleke and Achini C Jayatilleke 25 June 2015

Road accidents pose a significant public health issue, with preventable injuries placing a heavy burden on healthcare systems. Globally, road accidents rank as the tenth most frequent cause of death. Statistical reports and census data reveal that road accidents were a prominent contributor to mortality in Sri Lanka in 2020. According to the latest data released by the World Health Organization (WHO) in 2018, road accidents accounted for 3,590 fatalities, representing 2.82% of total deaths in Sri Lanka. The age-adjusted mortality rate was recorded at 16.37 per 100,000

population, placing Sri Lanka 96th in global rankings. Notably, Sri Lanka boasts one of the lowest road mortality rates within the South Asian region. Road accidents and the resulting injuries and fatalities have reached epidemic proportions in Sri Lanka. In 2019, the number of reported fatalities due to road accidents was 2,839, while injuries amounted to 24,611. Notably, pedestrians accounted for nearly one-third of the total casualties, while motorcycles and tricycles were involved in over half of the incidents. Low-income commuters and drivers were disproportionately affected, comprising 70% of road accidents. Motorcycle-pedestrian accidents were particularly prevalent, contributing to approximately 40% of pedestrian deaths. Despite improvements in car safety, the specific needs of vulnerable road users have not been adequately addressed. Additionally, around 10% of the fatalities occurred at railroad crossings.

Road accidents lead to substantial economic consequences for individuals, families, and the entire nation. These repercussions encompass not only medical costs but also the loss of productivity from individuals who have succumbed to injuries or are undergoing treatment. Furthermore, families often need to take time off from their employment or education to provide care for the injured. The financial impact of road accidents typically amounts to approximately 3% of the national income in many countries (Dharmaratne, Jayatilleke, & Jayatilleke, 2015).
The capital city of Colombo in Sri Lanka suffers a daily economic loss of approximately US$5 million due to traffic congestion. Residents of Colombo and nearby areas express frustration and view the congestion as a significant hindrance to their daily lives. The government is also subjected to criticism for what is perceived as its failure to adequately tackle the problem. Analysts attribute the root problem to inadequate planning and the authorities' inability to enforce traffic regulations. A traffic specialist, contributing to a local e-paper known as The Island, emphasizes the importance of strategic timing and efficient utilization of traffic lights as a crucial element in resolving the congestion problem. The impact of traffic congestion is not limited to individuals alone, as it also incurs costs for the transportation industry. Carriers and fleet managers report increased vehicle wear and tear due to prolonged idling in traffic, with engines running for up to four to five hours per day. Another contributing factor to traffic jams is police corruption. Some officers accept bribes, allowing drivers to park their cars in prohibited areas, leading to further congestion issues. (Colombo Telegraph,2021)

The constant influx of people moving from rural regions to urban areas poses a significant challenge to road infrastructure and transportation systems, pushing them to their capacity limits. As a result, managing traffic has become increasingly difficult. The severity of the situation is particularly notable in Asia, which is known for having some of the most congested traffic in the world. With the problem persistently escalating, city authorities are actively seeking effective solutions. Their exploration has led them to investigate a novel intelligent traffic management system that integrates artificial intelligence (AI) technology (Devanesan ,2020).

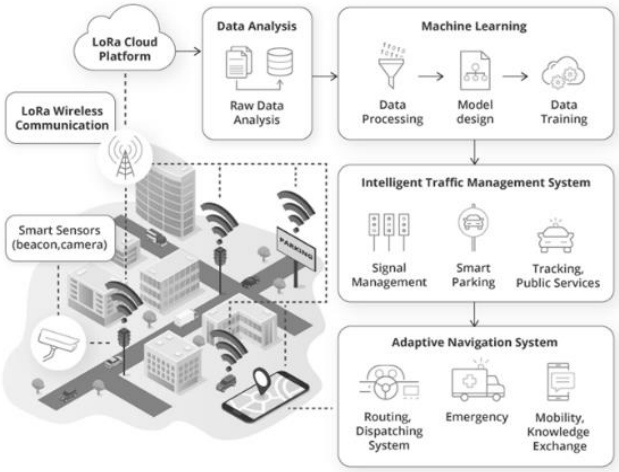


Figure 2.
Source: IEEE — The development of a Smart Town Traffic Management System that integrates LoRa and machine learning mechanisms

Intelligent traffic management systems are specifically developed to identify and monitor vehicles and pedestrians, as well as estimate safety indicators at intersections. The system incorporates object-tracking techniques to detect and track objects across successive frames, enabling the estimation of object trajectory and velocity. Additionally, the system has the capability to detect collisions and near misses. To provide a comprehensive overview, real-time dashboards are utilized to display extracted information from intersections alongside annotated video streams. The collected data plays a crucial role in fine-tuning traffic lights to optimize traffic flow at intersections and facilitate emergency service notifications. These notifications include essential information such as emergency response times, which are assessed and utilized to enhance intersection safety (Intel,2020).

Table 1. Main elements of an Intelligent Traffic Management System (ITMS)

Hardware	Software
IoT road sensors include: RFID (radio frequency identification) or AIDC (automatic identification and data collection) tags The Temperature sensors	Cloud computing and edge processing capabilities: I. The Traffic data platform/data lake II. Cloud-based traffic control systems III. Geographic information systems (GIS)
Air quality sensors	All supporting transportation apps
Connected CCTV cameras	Big data and predictive analytics
Connected traffic light systems	AI/ML: A. Computer vision B. Optical character recognition (OCR) C. Reinforcement learning
Smart toll gates / electronic road pricing gantry systems	Location-based services

Source: pruzhytska (2022). Intelligent Traffic Management Systems: 6 Key Features to Implement. [online]

A. The main capabilities of an Intelligent Traffic Management System (ITMS)

I. The video traffic detection system with the edge processing function

The Intelligent Traffic Management System consists of various sub-modules, including the surveillance footage system, the traffic control system, the computer control system, and the peripheral unit. The traffic control units within the system are specifically designed to effectively manage and regulate high-traffic roads. There is a surveillance footage system that has cameras deployed to monitor traffic alerts and traffic controllers to take action to prevent traffic congestion when the number of cars in a certain area grows. Traffic control units play a main role in the efficient management of traffic by facilitating seamless communication between senders and receivers. Peripheral units, on the other hand, handle sensor configuration, process the gathered data, recognize signals, and transmit responses to the control unit. The control unit itself is responsible for detecting traffic flow and establishing communication with other peripheral units (AumRaj, 2022). The elements of a modern Traffic management System consist of:

1. Connected CCTV camera with HD recording
2. The computer vision function for image detection and recognition
3. The edge chip for local video processing, reduced latency
4. Cloud connection + GPS-based communication to receive updates.
5. These settings allow you to:
   I. Detect incidents that will occur – car accidents, obstacles, illegal parking, inadvertent cyclists or pedestrians
   II. Send alerts to intelligent traffic management systems in seconds.
   III. Create or automate a series of subsequent tasks to be performed automatically.
   Follow-up actions
   A. Dispatch emergency services,
   B. Signals in traffic customization areas
   C. Control, reroute public transport, and provide information to nearby drivers.

Data analysis and the utilization of intelligent systems are employed to effectively manage congestion scenarios and implement control measures (Arai, K., Kapoor, S. and Bhatia, R.,2020). Technological advancements integrated within or near roads have a significant impact on enhancing the safety of drivers, passengers, and pedestrians. Through the utilization of sensors and cameras installed on roads, traffic lights, and strategic locations, real-time data regarding vehicles, driving conditions, and potential risks can be collected and transmitted. These technologies work in synergy to create more intelligent and secure road environments (Pagano,2016). For instance, the intersection collision avoidance system employs sensors to monitor traffic as it approaches hazardous intersections, promptly notifying vehicles through roadside signs. Given that intersection collisions contribute to approximately one-third of all accidents in the United States, field tests have demonstrated the effectiveness of such systems in reducing both the speed of oncoming vehicles and the occurrence of collisions at perilous junctions. Another example is the Dynamic Curve Warning System, which employs radar to measure the velocity of vehicles approaching curves. Electronic signs then display the safe speed at which the curve can be navigated, taking into account real-world conditions, subsequently facilitating a reduction in speed (A, Vidya, and Kaviyarasi, 2018). The Wildlife Detection System employs various detection methods, such as infrared technology, to identify the presence of large animals nearing the road. Once an animal is detected, a blinking sign is triggered to alert the driver (Zhang et al., 2023). These systems hold particular significance in rural regions, where the occurrence of

animal-related fatalities is nearly five times higher compared to urban areas.

Road weather sensors offer up-to-date data on hazardous conditions like frozen bridges, water on roads, upcoming rainfall, and fog. This information can be communicated to travelers through dynamic signs, highway advisory radios, and vehicle navigation systems (Mary G et al., 2022). One of the significant advantages of implementing edge data processing capabilities, coupled with live video, is the opportunity to leverage the collected data for various intelligent traffic analysis applications.

- Multimodal traffic volume analysis aims to understand the most commonly used transportation modes in the region and their average travel speeds.
- Traffic safety analysis utilizes pattern recognition to identify improper behavior of drivers and pedestrians in different areas, allowing for appropriate actions to be flagged.
- The response unit program generates alerts for police, ambulances, and maintenance crews after detecting an incident.
- Traffic analysis of origins and destinations facilitates the creation of improved traffic management plans and enables control updates for frequently traveled routes.

II. Pedestrian Detection and pollution analysis

The continuous collection and processing of real-time traffic data play a vital role in enhancing the efficiency and safety of pedestrian traffic. By analyzing the current presence of pedestrians and vehicles on the road, it becomes possible to improve the management of pedestrian flows and ensure their safety. Intelligent Traffic Management Systems offer three important capabilities: locating and mapping the system's applications, establishing connectivity with the external environment, and utilizing satellite navigation systems such as GPS to determine the precise location and velocity of objects at any given time (Šimunović, Bošnjak and Mandžuka, 2012).

Data regarding the location of pedestrians or vehicles can also be obtained through various means such as sensors installed in vehicles, on roadways, and even on pedestrian equipment. As an illustration, in Japan, tracking tags are incorporated into school backpacks, enabling parents to keep track of their children's whereabouts. In the context of safety, women in England who traverse hazardous urban areas utilize location-tracking devices discreetly embedded in their rings. These examples highlight the diverse applications and methods employed to collect location data for different purposes. The GPS device utilizes satellite data to approximate the location of the vehicle or pedestrian within a range of 3 to 6 meters (10 to 20 feet). (Šimunović, Bošnjak and Mandžuka, 2012).

The data collected is transmitted to the central system through either the Internet or the smartphone network. Valuable information for pedestrians, such as predicted vehicle movements and scheduled arrival times of public transportation, can be displayed using information displays. This is particularly beneficial for pedestrians waiting at bus stops. Additionally, voice announcements can be provided, which is especially helpful for individuals with visual impairments. To enhance pedestrian safety, both vehicles and roads are equipped with various systems. These systems enable drivers to detect and avoid collisions with pedestrians, thus improving overall traffic safety. For instance, sensors can be installed at crosswalks to alert drivers when pedestrians are crossing the road, ultimately reducing the number of pedestrian fatalities at such locations. Automobile emissions are a major contributor to the high levels of air pollutants, which have a significant negative impact on human health. Additionally, it aggravates cardiovascular issues and caused avoidable ailments, including respiratory disorders like asthma. The World Health Organization (WHO) reports that approximately seven million premature deaths occur annually due to air pollution, and numerous cities worldwide exceed recommended air quality standards. Air pollutants are categorized into primary and secondary pollutants (Zhang et al., 2022).

Primary air pollutants encompass a range of substances such as nitrogen oxides (NOx), sulfur oxides (SOx), ammonia (NH3), carbon monoxide (CO), benzopyrene (BaP), methane (CH4), and these pollutants are directly emitted into the atmosphere and contribute to air pollution (European Environment Agency, 2019). Ozone (O3) and nitrogen dioxide (NO2) are examples of secondary air pollutants. In urban areas, air pollution is a significant concern, largely driven by motor vehicle emissions. Maintaining acceptable air quality is a pressing issue for many cities. The Intelligent Traffic Management System plays a crucial role in addressing this problem by implementing various emissions, models and utilizing databases of emission factors. Efficient management of traffic flow can have a positive impact on reducing pollution. By optimizing traffic patterns and reducing congestion, individuals can save fuel, which in turn contributes to lower levels of pollution (AumRaj, 2022).

The Intelligent Traffic Management System has the capability to predict and anticipate instances of air pollution by analyzing specific conditions at certain locations, providing forecasts up to an hour in advance. In response, the system adjusts traffic signals accordingly, creating a slight delay for vehicles heading toward pollution-prone areas while allowing smoother traffic flow

and longer green lights for vehicles moving away from these areas. Each intersection makes independent judgments and communicates with the wider traffic light network to enhance the efficiency of vehicle movement, reducing time wasted at traffic junctions and improving overall traffic flow. Based on pilot testing conducted in Pittsburgh, the implementation of an Intelligent Traffic Management System in a city has demonstrated the potential to reduce travel times by up to 25% and decrease harmful emissions by up to 21% (Khanna et al., 2018).

According to a researcher from the University of Malaga in Spain, having a comprehensive understanding of the city and analyzing each vehicle, pedestrian, and bus is crucial for enhancing mobility and reducing emissions. This approach allows for the creation of an accurate map of the city and its traffic signals. By leveraging historical data and anticipating future changes, the computer can adjust traffic signaling to optimize traffic flow. Intelligent traffic control systems go beyond simply timing green lights; they also contribute to the development of cleaner and safer urban environments. These solutions provide real-time impact data, helping city planners accelerate their efforts to achieve zero-carbon transportation goals (Toutouh and Alba, 2022).

Such as:

A. Air pollution levels and air quality in the area

B. Carbon dioxide (CO2) emissions for each individual trip

C. Traffic volume and average speeds during different weather conditions

D. Impact on road infrastructure following natural disasters like hurricanes and floods

E. Analysis of unsafe driving behaviors, such as sudden braking or rapid acceleration.

Ultimately, the successful implementation of efficient and sustainable traffic management systems relies on the ability to collect and analyze significant traffic data using advanced analytics.

While this task may present technical challenges, it is achievable with the right approach and resources.

III. FINDINGS

By implementing an Intelligent Traffic Management system, countries have the potential to address numerous challenges associated with road traffic, including reducing human fatalities, alleviating road congestion, and mitigating environmental pollution, as indicated by the findings of the literature review. Sri Lanka, being a developing country, can leverage this concept to its advantage. With the right tools and a skilled workforce, Sri Lanka has the opportunity to unlock significant benefits from adopting an Intelligent Traffic Management System.

In addition to the aforementioned advantages, it is important to highlight some additional key points. Firstly, an Intelligent Traffic Management System can enhance the overall efficiency of transportation networks by optimizing traffic flow, reducing travel times, and minimizing fuel consumption. This can result in cost savings for individuals and businesses, boosting economic productivity. Furthermore, the system can contribute to improved road safety through the implementation of various safety measures such as collision detection, pedestrian monitoring, and intelligent signaling. By effectively identifying and addressing unsafe driving behaviours, the system can help prevent accidents and save lives.

Moreover, the integration of real-time data analytics and predictive modeling capabilities can enable proactive decision-making and enable authorities to respond swiftly to changing traffic conditions, incidents, and emergencies. This can lead to more effective emergency response times, reduced traffic disruptions, and enhance overall management of the transportation infrastructure.

Additionally, it is worth mentioning that the adoption of an Intelligent Traffic Management System can position Sri Lanka as a progressive and technologically advanced country in the transportation sector. This can attract investments, promote sustainable urban development, and contribute to the overall modernization of the country's infrastructure.

In conclusion, the findings suggest that Sri Lanka has the potential to derive significant advantages from implementing an Intelligent Traffic Management System. However, it is crucial to emphasize the importance of proper planning, investment in technological infrastructure, and the training of skilled professionals to ensure the successful deployment and operation of such a system.

IV.CONCLUSION

The Intelligent Traffic Management System (ITMS) emerges as a valuable innovation that addresses the limitations of existing traffic management systems and their associated web structures. The extensive data collection facilitated by ITMS enables improved forecasting and management of traffic issues. However, the successful implementation of ITMS requires more than just technological advancements. It necessitates strong policy frameworks, effective laws and regulations, appropriate sector coordination, and collaborative efforts.

Leading countries in technology and transportation, such as the USA, Japan, Russia, Korea, and China, have embraced ITMS with remarkable success. These countries serve as exemplary models for other nations aspiring to enhance their traffic management capabilities. Additionally, researchers continue to delve deeper into this concept,

striving to advance ITMS algorithms and expand their capabilities further.

The benefits of ITMS are diverse and impactful. One notable advantage is the reduction of traffic congestion, which not only improves the efficiency of transportation networks but also enhances the overall quality of life for citizens. By implementing intelligent algorithms and the real-time monitoring, traffic flow can be optimized, reducing travel times and minimizing delays.

Another crucial aspect of ITMS is it's potential to address environmental concerns associated with automobile emissions. Through efficient traffic management and control, ITMS can help reduce air pollution and minimize the carbon footprint of transportation systems. This contributes to a cleaner and more sustainable urban environment. The integration of road sensors and advanced detection systems enables ITMS to detect and respond to pedestrian presence, enhancing overall road safety. By implementing measures such as pedestrian detection, intelligent signaling, and collision avoidance systems, the risk of accidents and injuries can be significantly reduced.

It holds significant importance to note that the success of a smart and developed city relies not solely on a single technology, but on a comprehensive approach. While ITMS plays a significant role, other technologies and strategies, such as smart infrastructure, efficient public transportation, and sustainable urban planning, are equally vital for creating thriving and liveable cities.

Ultimately, the success of ITMS and the achievement of its full potential depend on human intellect and collaborative efforts. The continuous development and refinement of this concept, combined with visionary policies, investments in research and development, and the active participation of stakeholders, will pave the way for smarter and more efficient urban environments.

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