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INTELLIGENT TRAFFIC MONITORING AND CONTROL SYSTEM: AN INSIGHT

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Abstract: The Intelligent Traffic Monitoring and Control System (ITMCS) is a highly advanced solution designed to improve the efficiency, safety, and management of traffic flow in urban areas. This paper provides a detailed overview of the ITMCS, including its core components, operational principles, and the underlying technologies that enable its intelligent functionality. By integrating Artificial Intelligence (AI), Image Processing, Machine Learning (ML), Deep Learning (DL), Neural Networks, and Sensor-based Internet of Things (IoT), the ITMCS collects real-time traffic data, applies intelligent analysis, and makes informed decisions for effective traffic control and management. A comprehensive taxonomy of the different techniques employed within the ITMCS is presented, offering thorough explanations and examples for each method. Additionally, the paper explores the benefits and potential applications of the ITMCS, such as reducing traffic congestion, preventing accidents, and enhancing overall transportation systems. With its ability to revolutionize urban mobility and enhance citizens' quality of life, the ITMCS represents a significant advancement in traffic monitoring and control, leveraging the power of intelligent systems.
Keywords: Traffic Light, Adaptive, Synchronization, Priority vehicles, Traffic congestion, Traffic signals.

INTRODUCTION

Traffic Monitoring is the greatest worry in numerous nations, because of issues like congestion, globalization, abbreviated or thin streets. Inappropriate design in the flagging framework and aversion of traffic rules are influencing the traffic inflow and prompting clog. Gridlock at different interconnected intersections is prompting contamination and a worldwide temperature alteration that influences the inward city climate and long holding up hours in rush hour Gridlock is a costly arrangement for suburbanites because of high fuel utilization.

Traffic blockage is a bigger issue since it influences not only a major part of the population but also the economy as a whole, through delays in the transportations of goods and fuel usage, making a powerlessness gauge travel time [1]. Also, the traffic congestion can create medical

issues because of the gases produced via vehicles just as actual issues of conductors because of the measure of hours spent similarly situated inside a vehicle.

The numerous parts of human existence keep on getting altered by innovations and administrations towards smart vehicles and Intelligent-Transportation-Systems (ITS) [2]. ITS is an application to offer imaginative forms of assistance and offices identified with different methods of transport and traffic the executives. This will help the client with better education, security, organization, and better ways of utilizing the vehicle organizations. Intelligent automated frameworks are assuming control over the conventional functional techniques after the innovation blast. Intelligent traffic the framework gives a benefit by offering safe public transportation, severe disciplines on disregarding traffic rules, tagging framework computerization, and so forth. The high-level tech utilizations of IoT (Internet of Things), AI, Deep Learning, Computer Vision, regulated Artificial Intelligence (AI), and large information are giving constant answers for the traffic the issue [2].

The metropolitan administration and traffic signals are now in dire need of precise traffic detecting and forecasting with the arising ideas of brilliant urban communities and intelligent transportation frameworks. Most recently, the fast adoption of the Internet of Vehicles (IoT) and the rising inescapability of portable administrations have created exceptional measures of information to serve the traffic detection and expectation applications. However, the expanding intricacy and variety makes it essentially difficult to satisfy the calculation requests by the enormous traffic information. [3]. Fig.1 represents the synchronization of red lights.

Smart Traffic Monitoring and Control System might differ in advances applied, like vehicle route, traffic light control framework, programmed number plate recognition or camera to give security, synchronization of traffic lights. Additionally, prescient strategies are formalized to permit examination with reliable measurable information or we can say comparative analysis or new methods with the current one. Zhu et al. presented CAMABRL integrates a context-aware mechanism to mitigate the impact of neighboring agents and gather valuable information. The experimental datasets employed in the study consist of publicly available vehicle data and simulated pedestrian data, thereby enhancing the adaptability of the ATLC system [13].

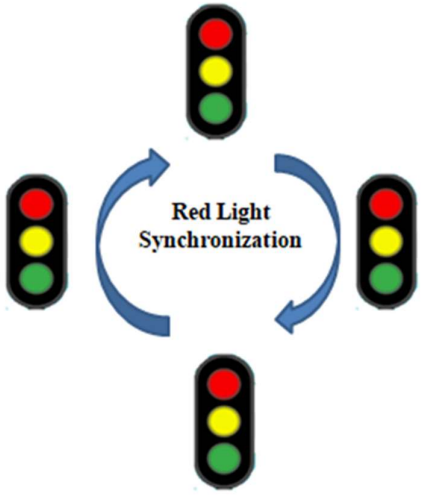

Figure 1 Red Light Synchronization

1.1 Motivation

There are no traffic decongestion initiatives such as synchronization among traffic lights in order to avoid multiple subsequent stops signals for the same vehicle in a short period of time in order to reduce Red-Light running and improve vehicle fuel efficiency. Traffic congestion also leads to death by getting stuck in emergency vehicles which aren't able to get right of way. Currently, there is no traffic monitoring and control to facilitate priority vehicles leading to a huge number of fatalities. The traffic rule violations in today's day and age largely go unchecked in India because of manpower and resources constraints. There is no detection of the vehicles prohibiting the passage of way to emergency vehicles and providing e-challan. All these problems related to traffic congestion come, so we plan to work on this problem and this paper tries to apprehend the congestion control problem and red-light synchronization in the current architecture of traffic monitoring and control systems.

The significant commitments of this paper are:

- Analysis of various techniques and identify the issues in the Traffic Monitoring and Control System.
- A detailed analysis of different traffic congestion problems and framework designed by various researchers in this field.
- In the existing solutions to identify the gap areas that could be utilized for future scope by the researchers for finding the solution related to Traffic Congestion.

This paper is organized in the following manner: Section 2 provides the literature review of strategies related to intelligent traffic monitoring and control systems. Section 3 enlists the taxonomy related to traffic monitoring systems. Section 4 gives the overview of different techniques used in implementation of intelligent traffic monitoring and control systems. Section 5 supplies the information on research methodology used while carrying out this literature survey. Section 6 gives some enlightenment on major discussion related to this literature survey. Section 7 discusses the gap areas that can form the foundation of future research. Finally, Section 8 contains the final conclusion of this review article.

Literature Survey

Till now, different strategies have been proposed for the Traffic Monitoring and Control System. The performance of these methodologies can be dependent upon major factors such as the congestion control, decrease fuel utilization, decrease holding up time, and prevent traffic law violation.

Englund et al. (2021) proposed smart traffic driver and control displaying are defined in addition to calibration and open research contests to help announce programmed vehicle performance and progressive driver support systems in traffic. Smart Cities and Communities (SCC) assign to an adhesive approach to advance a continuous prospect nation. The paper advertised the way Artificial Intelligence helps in explanation to the advancement of Smart Cities and Communities, and precisely for the upcoming supportive Intelligent Transportation System. The two main claims within Intelligent Transportation System (ITS) which are for Smart Communities and that are related to the safety of traffic and the challenges related to

environmental. Driver examination is an area for research that advances the involvement of the user in robotics based on smart vehicles [4].

Vlahogianni et al. (2014) target of TF is the expectation of not-so-distant future traffic estimates dependent on past traffic information [5]. Currently the availability of data and continuous viable commutation has raised the usage of AI and Machine Learning process for traffic prediction. In spite of the wide scope of Machine Learning calculations, there is no measure to figure out what are the most appropriate techniques and their hyper-boundary arrangements to move toward the distinctive problem of Traffic Forecasting and issues revealed in the writing [6] [77].

Lee et al. (2020) explained the rational significance of this work is to control the flow of traffic by balancing the load and congestion problem among bottleneck areas without human interferences or by using Artificial Intelligence methods [7].

With the help of the recordings of vehicles, the video vigilance of vehicles naturally kept the vehicles like emergency vehicles also, good vehicles, which helped us in coordinating the vehicles at the hour of crisis. The approach of Internet of Things (IoT) for the advancement of the endowment of modern life. It includes the field related to healthcare, sport, entertainment, industry, and many more [11, 80]. Mo et al. presents the distinguishing features of this approach involving the design of the state and reward functions, which enable effective coordination among agents and make use of measures such as phase duration and travel delay [79].

Table 1 Literature Review of Traffic Monitoring and Control

Ref	Year	Objective	Technology	Domain	Observations/ Evaluation
[11]	2018	System for detection of accidents and monitor traffic signals dynamically.	Video surveillance systems, Image Processing Techniques, Machine Learning	Camera, Sensor, Image processor.	Accident detection, criminal action detection, traffic law violation detection can be done.
[12]	2018	Classification of the current traffic based on Internet of Things (IoT).	Machine Learning, Intrusion Detection System (IDS).	Generic IoT devices, Healthcare devices.	Development of real-world use cases and datasets for the classification of Traffic research in IoT and other approaches.

[10]	2020	Solve the problems related to safety, security, blockage regulation and execution of traffic that provide a good experience.	CNN, Machine learning, Deep learning and AI.	IoT Devices, sensors.	To recognize the traffic sign, feature selection, security, privacy techniques and optimization etc.
[6]	2020	Forecast the traffic data on the basis of past data.	Auto-WEKA, SVM (Support Vector Machine), and RF (Radial Base Function), NN (Neural Networks), k-NN (k- Nearest Neighbour).	Generic IoT Devices	Find the best pair for outlining strategies and development for the Auto-ML process. To analyze the allowances of algorithms done by Auto-ML methods for Traffic Forecasting regression issue.
[7]	2020	Advancement in persistent circumstance implementation in movement and transfer executions and congestion removal in critical hindrance or traffic jam areas.	Traffic Prediction is used to create a simulator. For measure the accuracy means absolute percentage accuracy (MAPA) used.	Semiconductor, Machine Learning Protocols.	The patterns of traffic changes are inevitable in real world problems. To detect the regression stint with accuracy achievement.
[8]	2021	Model having an efficient controller system and having maximum throughput.	Reinforcement Learning, RL Agent.	Generic IoT Devices	To use a topology for real time networks and for the usage of networks having dense capacity or nodes.

[9]	2021	A smart system to generate IDGADS (Domain Detection System) and detect real time traffic early without wasting time.	Deep learning model, CNN Model	DNS Server, Cloud	System because of the used approaches like statistics, machine learning and probability.
[4]	2021	Progressive driver assistance automated systems and provides smart vehicle performance in traffic.	Artificial Intelligence, Object detection and Semantic Segmentation.	Sensors, actuators, IoT devices	Traffic safety and Environmental challenges that can also be affected by subsequent stop signals.
[15]	2021	Regulate the strategies of traffic control, image processing plays an important role.	Image segmentation with the help of Faster Region Convolution Neural Network (Faster RCNN).	Image, Image segmentation devices.	Extracted images can be used for the further processing in the Intelligent Transportation System.
[76]	2022	To predict the vehicular traffic at several intersections of a four-lane system on the smart traffic light controllers.	Machine Learning and Deep Learning Models	IoT Devices	Predicted results can be used for the conversion of traffic lights from static to dynamic.

Taxonomy of Intelligent Traffic Monitoring and Control System

Traffic Monitoring and Control Systems can be classified into further categories and summary of the literature survey of taxonomy can be represented as of it. Figure 3 represents the taxonomy of traffic monitoring and control systems and Table 2 represents the summary of publications that adopt the taxonomy of Traffic Monitoring and Control Systems.

3.1. Congestion Control

Traffic congestion control is a major concern in urban areas. It is a problem which occurs due to a greater number of vehicles at the road and it occurs at the intersections and creates a blockage of roads. To overcome the problem related to congestion control a system is proposed prediction of traffic dynamically and a scheme used which mainly contain image processing techniques and having the self learning ability [14]. Liu et al. (2021) proposed faster RCNN (Region Convolution Neural Network) method is applied on the images that we get from a big

data environment and then split into multiple regions. Then different image extraction methods were used and then with the help of higher-level methods more detail can be extracted from the images [15].

VLC (Visible Light Communication) used in transportation systems for safety on roads. It provides a system which is based on dynamic collision and it can be further proposed for the priority vehicles. The proposed model helps to reduce the waiting time at intersections of traffic lights and reduce congestion based on the Bayesian model [21][25][26]. The proposed model illustrated the advancement in consistent state execution in conveyance and dynamic, and removal of congestion in critical impediment sections. The results of the experiment depend on real time data with high-devotion. The practical use of simulators can be exhibited by the proposed techniques [29]. The review introduces a structure with some schemes of Intelligent Transportation System which are recognized depending on the basis of abilities. Intelligent Transportation System is the significant device for distinguishing likely problems in the industry related to vehicles and this review has proposed answers for explicit problems. This can be seen that AI calculations are generally used to forecast the vehicles, traffic jams, route and congestion [33].

The proposed model for vehicles depends on the specialized attributes of the vehicle self-sorting out network. Disregard superfluous variables in the simulation cycle, and assess the general presentation of V2I unidirectional and single path moving vehicle self-putting together organization. In the metropolitan street traffic scene, the portable organization of the correspondence network between the vehicle and the framework (V2I), the vehicle, goes through the remote passageway in turn [35]. The proposed work, quick traffic video observation and checking framework are introduced alongside a unique traffic light control and accident identification system. Half and half middle channel have been used toward the start for manipulation of traffic recordings, and to remove the commotion. At first pre-handling the video pictures are finished with commotion evacuation through half and half middle channel and comparative analysis of approaches used in Adaptive Traffic Control System using machine learning [37].

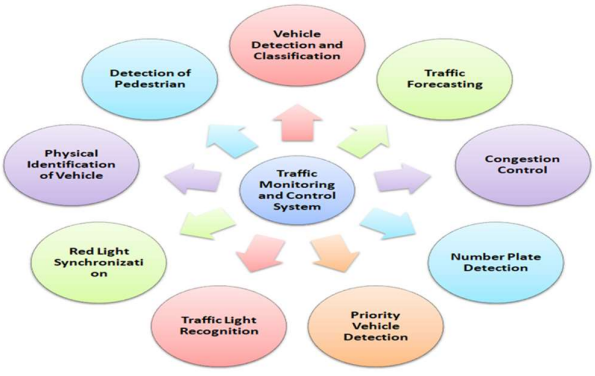

Figure 2 Taxonomy related to Intelligent Traffic Monitoring and Control System

3.2. Traffic Forecasting

Traffic forecasting is based on predictions and sensing of traffic based on past data. It is a process which is related to get an estimation of the number of vehicles or people using transportation in near future. The models based on Deep learning are helpful in Intelligent Traffic Sensing (ITS). Traffic prediction and sensing which includes travel time forecasting, anomaly prediction related to traffic can be done by deep learning methods. To meet the estimation demands of real-world traffic data with increasing multiplicity and complexity, a deep learning platform is used [13]. The traffic forecast can offer help in numerous viewpoints, for example, street directing, congestion control, and so on. To give a complete outline of the role of traffic prediction in Intelligent Transportation System frameworks [31] [40].

The major concerns in rush hour gridlock grouping are security and Quality of Service issues, new worries and spaces are recently arising like urban communities and minimal expense correspondence in WSN. The paper describes the attributes of the network traffic related to Internet of Things and recognizes it with the help of human traffic designs. An important outline related to traffic arrangement models was introduced for a continuous change to traffic grouping based on IoT [38] [76].

3.3. Vehicle Detection and Classification

Vehicle detection is based on the detection of the physical appearance of the vehicles and based on detection, vehicles classification can be done. The classification of vehicles means to categorize the vehicles into different classes such as priority vehicles, trucks, and cars. The system receives secure information with the help of sensors and the vehicular setting, such as, condition of street, vehicle and traffic conditions that can be in collaboration with the latest intelligent transportation structure to relieve a section of the problems that current and past design of transportation systems have been encountering. The application of objective and descriptive methods exhibits the original potential of assembling sensors with the Intelligent Transportation System [28]. The proposed algorithm for the intelligent traffic scheduling and object detection can be done with the help of reinforcement learning to monitor the real time data [30, 81].

The proposed system gives a suggestion of what ability of Machine Learning strategy to choose for an Intelligent Transportation System application, and the compilation can be distinguished from the already existing execution areas. After approval, the structure demonstrated sufficiently successful with a couple of little contrasts in characterization out of references, and just two huge contrasts between the system's suggestion and creators' decisions [39].

3.4. Number Plate Detection

Number Plate detection helps in traffic monitoring and control systems. The model segments the wide variety plate area from the image body. The region is extracted from the plate that contains the number; a brilliant decision-making approach is carried out to transform the low-decision picture into a high-decision photo. The advisable resolution approach is used with the CNN (Convolution Neural Network) to regenerate the pixel pleasantness of the entered photo. Bounding field approach is used to segment the image character by character. The recognition part is that the features are extracted and labeled using the CNN technique. The

main part of this study is the improvement of an intelligent system that can employ the CNN to get details about the number plates which are written in Bengali Languages and that have much less resolution [17].

For detection of number plates, edge detection and classification of morphology be there. CNN technique is used to extract the characteristics from segmented images. After all the processes character recognition, be implemented by the use of dataset "Plate Numbers" to train the model [19]. ANPR (Automatic Number Plate Recognition) algorithm proposed a model for recognition of number plates. Recognition of number plates based on the AI (Artificial Intelligence) capabilities and it uses the OCR approach. Camera data is used in implementation and helps in traffic flow. Real time implementation of Automatic Number Plate detection will be there with the help of CNN [20] [32].

3.5. Detection of Pedestrian

The Deep learning-based methods can be generally used to determine different problems related to traffic in the present-day Intelligent Transportation System. The paper explained the investigation related to different variations of Convolution Neural Network that are utilized to determine the problems, for example, monitoring of traffic sign and recognition of sign, traffic signal detection, traffic order and person on foot location, object recognition and confinement, highlight determination and streamlining in ITS [34].

The proposed algorithm based on R-CNN is more applicable for pedestrian detection. Tome et al. [42] described a system which is based on deep learning. It helps to advance the certainty of pedestrian detection. The future scope of the proposed model is to improve the performance and for better accuracy in real time data. The presented model contains so many poses and shapes in gnarled visual forms, so that it worked in a distorted area of vision [41] [43] [44].

3.6. Physical Identification of vehicle

Simulating the vehicles traffic Simulation of Urban Mobility tool [16] is used. This tool is used to decrease the waiting time by 50% than FIFO (First in First Out) strategy. Because in this identification of vehicles will be done by the image extraction process. The algorithm used for presentation of intelligent traffic light systems and image detection is used for this [16].

3.7. Red Light Synchronization

The Multi-agent Deep Deterministic Policy Gradient algorithm is designed to control traffic congestion. Wu et al. (2020) explained controller of traffic light is not an isolated process, as it can observe the real time data for traffic. It is mainly suitable for subsequent stoppage so as to help in synchronization of traffic lights [18]. G-LED (Green LED) changing light is produced and it can be implemented with the help of a simulator [78]. Real time traffic light condition's ability is compared with the developed system [22].

3.8. Traffic Light Recognition

Annabel et al. (2021) [14] to improve the traffic control the recognition of traffic lights is necessary. So that it decreases the amount of time a vehicle gets fixed in a signal. It helps in allocating the signal without involvement of humans and would help in traffic regulation. G-LED is based on the probability of crossing a signal and intersections and helps in efficiency

of flow of traffic in a real time environment [22, 82]. Table 2 contains the summary of papers review based on red light synchronization and recognition.

The proposed model sets the timing of green light on the basis of density of traffic. The result shows a 23% improved model than the current scenario. It is in collaboration with the real time CCTV data to train the model. MC-DCNN (Multi-Channel Deep Convolution Neural Networks) helped to design a model that controls the length of the red signal that is RLR (Red Light Runner). Regression process and classification based on multi steps are used to predict the passing at intersections of red light and the problem is solved using Reinforcement learning [23-27]. Li et al. (2019) proposed model helps to satisfy the people's travel time demand and control the flow of traffic or congestion on intersections [36].

Table 2 Review of papers based on red light synchronization and recognition

Paper	Objectives	Future Scope
(Wu et al., 2020) [18]	To control the traffic congestion an algorithm is designed and implemented in real time data.	Proposed algorithm can be used for the synchronization of traffic lights to remove stoppage and wastage of time and fuel on subsequent signals.
(Annabel et al.,2021) [14]	To decrease the time for which the vehicle remains in traffic.	Proposed model based on AI and can be helped in solving the problem related to fuel consumption, environment and health issues.
(Hussain et al.,2020) [22]	To reduce the flow efficiency of traffic and probability of crashes during green signal of lights.	In real time implementation it will be cost benefit and help in synchronization of traffic lights.
(Gandhi et al.,2020) [23]	To control the green signal on the basis of density of real time traffic.	For the synchronization of traffic lights, and adaptation of emergency vehicles.
(Kwon et al.,2020) [24]	To control the red-light runner time and increase the efficiency of intersections traffic.	Vehicle surveillance and verification of the real time data for safety at intersections and prevent economical loss.
(Zhengxing et al.,2020) [25]	To optimize the traffic light time, and prepare an optimized managerial model of traffic signals with real world data.	It can make intelligent traffic lights and help to control real time traffic and improve with intelligence.
(Wei et al.,2018) [26]	To control the traffic lights with the help of a reinforcement learning algorithm.	The validation of simulated models is done on the real-world data to get feedback.
(Meng et al.,2021) [27]	To control the traffic an image processing is used.	It can distinguish the existence of traffic reliably as the ongoing appearance of the vehicles.
(Li et al.,2019) [36]	To reduce the navigation time of all traffic by maintaining the traffic signals.	This can be handily stretched out to artificial intelligence methods, particularly unaided learning, to make a stronger framework for genuine and real time applications.

3.9. Priority Vehicle Detection

Image detection or classification model was implemented for Priority Vehicles. The SRS (Soft-Root-Sign) activation function takes low clarification time, has fast training speed, and better abstraction performance. On the basis of all activation functions PVIDNet (Priority Vehicles Detection Network) model is created which achieves better accuracy and good result for emergency vehicles [16]. Li et al. (2019) proposed model, in view of the vehicle's priority, targets giving an intelligent traffic signal framework which the High Priority Vehicles can send solicitation to after being stacked at intersections. According to the most elevated need of vehicles, the Model would turn traffic signals green for saving travel time of high priority vehicles to clear the Road Segment (RS) [36].

Table 3 Summary of Publications related to taxonomy of Traffic Monitoring and Control System

Taxonomy	Related Papers
Congestion Control	(Annabel et al.,2021) [14], (Liu et al.,2020) [15], (Fakirah et al.,2020) [21], (Zhengxing et al.,2020) [25], (Wei et al.,2018) [26], (Lee et al.,2020) [29], (Iyer et al.,2021) [33], (Zhang et al.,2020) [35], (Savithramma et al.,2022) [37]
Traffic Forecasting	(Zhu et al.,2020) [13], (Boukerche et al.,2020) [31], (Tahaei et al.,2020) [38], (Alqudah et al.,2020) [40], (Navarro-Espinoza et al., 2022) [76]
Vehicle Detection and Classification	(Guerrero et al.,2020) [28], (Li et al.,2021) [30], (Damaj et al.,2021) [39]
Number plate Detection	(Ahsan et al.,2021) [17], (Hossain et al.,2021) [19], (Mufti et al.,2021) [20], (Silva et al.,2021) [32]
Detection of Pedestrian	(Sirohi et al.,2020) [34], (Dong et al.,2016) [41], (Tome et al.,2016) [42], (Li et al.,2016) [43], (Zhang et al.,2018) [44]
Physical Identification of vehicle	(Calvarhlo et al.,2020) [16]
Red light Synchronization	(Wu et al., 2020) [18], (Hussain et al.,2020) [22], (Tomar et al.,2022) [78]
Traffic Light Recognition	(Annabel et al.,2021) [14], (Hussain et al.,2020) [22], (Gandhi et al.,2020) [23], (Kwon et al.,2020) [24], (Zhengxing et al.,2020) [25], (Wei et al.,2018) [26], (Meng et al.,2021) [27], (Li et al.,2019) [36]
Priority Vehicle Detection	(Calvarhlo et al.,2020) [16], (Li et al.,2019) [36]

Table 4 Details of Traffic Monitoring and Control System contributions analyzed over taxonomy

REFERENCE	Traffic Monitoring						Traffic Control		
	Traffic Forecasting	Vehicle Detection and	Number Plate Detection	Detection of Pedestrian	Physical Identification of	Priority Vehicle Detection	Congestion Control	Red Light Synchronization	Traffic Light Recognition
Mufti et al. [2]		✓	✓		✓				
Fan et al. [3]	✓								
Englund et al. [4]	✓	✓		✓	✓		✓		
Vlahogianni et al. [5]	✓			✓	✓		✓		
Angarita-Zapata et al. [6]	✓	✓		✓	✓		✓		
Lee et al. [7]	✓	✓		✓	✓		✓		✓
Balakiruthiga et al. [8]	✓	✓					✓		
Sirohi et al. [10]	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maha Vishnu et al. [11]		✓	✓	✓	✓		✓	✓	✓
Zhu et al. [12]	✓						✓		
Zhu et al. [13]	✓	✓			✓		✓		
Annabel et al. [14]		✓		✓	✓		✓	✓	✓
Liu et al. [15]		✓	✓	✓	✓		✓	✓	✓
Carvalho Barbosa et al. [16]		✓	✓	✓	✓	✓	✓	✓	✓
Ahsan et al. [17]				✓	✓				✓
Wu et al. [18]		✓		✓			✓	✓	✓

Ye et al. [19]	✓						✓	✓	✓
Fakirah et al. [21]		✓			✓		✓	✓	✓
Hussain et al. [22]		✓			✓		✓	✓	✓
Gandhi et al. [23]		✓			✓		✓	✓	✓
Kwon et al. [24]		✓	✓		✓		✓	✓	✓
Zhengxing et al. [25]		✓		✓			✓	✓	✓
Wei et al. [26]		✓		✓			✓	✓	✓
Meng et al. [27]	✓		✓	✓			✓		✓
Guerrero- Ibáñez et al. [28]	✓						✓	✓	✓
Lee et al. [29]	✓	✓		✓			✓		✓
Li et al. [30]	✓	✓			✓		✓	✓	✓
Boukerche et al. [31]	✓				✓		✓		✓
Silva et al. [32]		✓	✓	✓	✓		✓		✓
Iyer et al. [33]		✓		✓		✓	✓	✓	✓
Sirohi et al. [34]	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zhang et al. [35]	✓	✓			✓		✓		✓
Li et al. [36]				✓	✓	✓	✓		✓
Savithramma et al.[37]	✓	✓	✓	✓	✓		✓		✓
Tahaei et al. [38]		✓			✓		✓		✓
Damaj et al. [39]		✓	✓	✓	✓	✓	✓		✓
Alqudah et al. [40]	✓	✓			✓		✓		✓
Dong et al. [41]		✓		✓	✓		✓		✓

Tome et al. [42]		✓		✓	✓		✓		✓
Li et al. [43]		✓		✓	✓		✓		✓
Zhang et al. [44]		✓		✓	✓		✓		✓
Pan et al. [46]			✓				✓	✓	✓
Sasi et al. [47]			✓				✓	✓	✓
Li et al. [48]	✓		✓		✓		✓	✓	✓
Al-Shemarry et al.[49]	✓	✓	✓		✓		✓		✓
Dia et al. [50]		✓	✓		✓		✓		✓
Hegt et al. [51]		✓	✓		✓		✓		✓
Mannion et al. [54]	✓	✓			✓		✓	✓	✓
Wiering et al. [55]	✓						✓	✓	✓
Abdoos et al. [56]	✓						✓	✓	✓
Abdulhai et al. [57]	✓	✓					✓		✓
Frank et al. [60]	✓	✓			✓		✓	✓	✓
Kim et al. [61]							✓	✓	✓
Shen et al. [62]	✓	✓		✓	✓		✓	✓	✓
Jang et al. [63]	✓	✓		✓	✓		✓	✓	✓
Kuppusamy et al. [68]	✓	✓		✓	✓	✓	✓		✓
Abdelhamid et al. [69]	✓	✓		✓	✓		✓	✓	✓
Lange et al. [71]	✓	✓			✓		✓		✓
Chen et al. [75]	✓	✓	✓	✓	✓		✓	✓	✓

Navarro-Espinoza et al. [76]	✓	✓			✓		✓	✓	✓
Yuan et al. [77]	✓	✓	✓	✓	✓		✓	✓	✓
Tomar et al. [78]	✓	✓	✓	✓	✓		✓	✓	✓

Techniques used in Traffic Monitoring and Control System

The Traffic Monitoring and Control System utilizes various methods including Artificial intelligence, Image Processing, Machine Learning, Deep Learning, Neural Network, and Sensor-based Internet of Things. Each of these categories corresponds to distinct techniques, and detailed explanations for each one can be found below.

4.1 Machine Learning Preliminaries

In this section, there is the introduction of machine learning and its preliminaries. Then, there are some systems which can utilize the traffic data for forecasting, number plate detection, monitor and control traffic for real time data. In supervised learning manually labeled or classified data is used as a source for training the model. In unsupervised learning, there is a lack of labeled data or supervisor and with the help of numerous data devices data is being collected and that data is Big Data which is basically the challenge for today's machine learning model. In Semi-supervised learning the combination of classified and unclassified data that is used to train the system generated and further predictions. In Reinforcement Learning to produce the agent or an intelligent program decision making function is used [45]. SVM (Support Vector Machine) helps to predict the traffic, $\{(x_1, y_1), (x_2, y_2),\ldots\ldots(x_n, y_n)\ldots..\}$ here x_n be the input value of training datasets and y_n be the class label of x_n [12]. The support vector can be calculated by the following equation 1 as follows:

$$\max_{a_j} -\frac{1}{2}\sum_{i=1}^{l} y_i y_j x_i x_j\, K(x_i, x_j) + \sum_{i=1}^{l} a_j$$

$$s.t. \sum_{i=1}^{l} y_i\, a_i = 0 \qquad (1)$$

Machine learning can be used for the traffic forecasting and in the methodology two sorts of Traffic Forecasting issues with various occurrences of them. The primary sort compares to the expectation of traffic at an objective area, from one viewpoint, utilizing just past traffic information of this area, and afterward considering verifiable traffic information coming from the objective area. In the two cases, the input is improved with schedule information. The second sort of Traffic Forecasting issue is centered on anticipating traffic speed inside a metropolitan setting. Over and again, the forecasts are finished in a single objective area thinking about solely chronicled information of this spot; and then again, considering past traffic information of the true area along with other positions. Once more, the information in the two occurrences is supplemented with schedule information [6].

The technique of machine learning can be used for character abstraction is additionally utilized for Feature Recognition; it lessens handling extent and the less significant pixels are eliminated [46]. Support Vector Machine is utilized for character acknowledgment in [47, 48]. For the

complicated and challenging number plates, a further developed Support Vector Machine based algorithm is designed in [49]. The element vector is delivered by horizontal and vertical character projection. The projections have been quantized into four explicit levels [50]. The transformation in Hoteling is executed on each character to deliver the trademark vector. This change is very receptive to the division yield [51].

The problem related to congestion control can be solved and for this process traffic network reinforcement learning is used. Here intersections are considered as agents and that agent controls the traffic light. The intersection states can be represented as S = (V, P, D, M, L) at the time t. Where V is the matrix which represents velocity of vehicles at road, P is the matrix which represents the number of roads at intersections, D is the matrix which represents queue length, M represents number of pedestrians going from south to north and north to south and L represents traffic light phase. The action is selected by each operator and then a new state is received at time t+1. To make the decision on traffic lights several rewards have been calculated as the feedback of action [18] [20]. Figure 4 represents the text caption generations from the image with the help of neural networks. Neural network techniques are being effectively sought after in an assortment of extra applications from natural language interpretation to community separating.

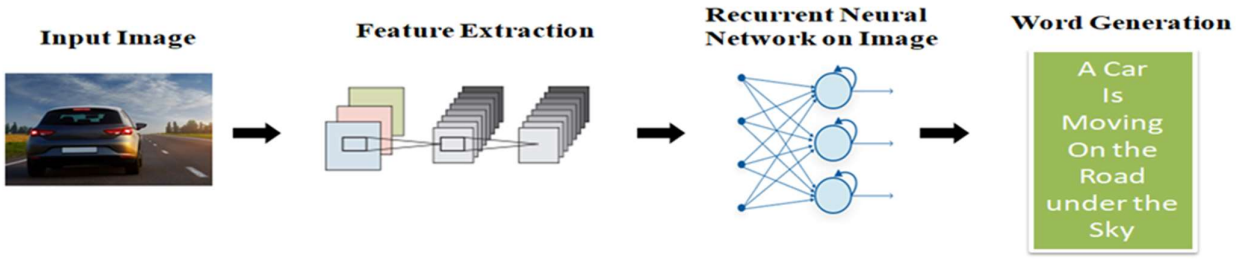

Figure 4 Generation of text caption from the input image with the help of neural networks

In reinforcement learning structure, the state will be taken by the agents, which is represented by the environment, as input. The environment normally incorporates the current traffic signal stage and traffic conditions [26]. Because of the inadequacy of managing dynamic multi-heading traffic in past strategies, more works attempt to utilize reinforcement learning calculations to take care of the traffic signal control issue [53, 54, 55]. Normally, these calculations take the traffic out and about as state. These techniques for the most part show better execution contrasted and traffic-responsive and fixed-time control strategies. Strategies planned the event as distinct qualities like the area of traffic and number of held up vehicles. In any case, the discrete state-activity pair esteem framework requires a large amount of storage capacity that holds these techniques back from being utilized in huge event space issues [55-59].

4.2 Image Processing

Image processing tasks include image correction, filtering, segmentation, object tracking, identification and modeling. In the technical tasks it is used for frame extraction, shooting, and video transmitting. The algorithm contains some steps that are to be followed in sequence. Fig. 5 represents the steps to be followed for image processing. Firstly, image acquisition is

performed and that is obtaining the image with resolution which contains elemental and structural information [64]. Then cropping of image is performed and algorithm for cropping of image that the handling steps are directed by the characterization of the pictures into different parts that are semantic. The algorithm helps to solve the semantic and visual data. Visual data is acquired from a visual consideration model, while semantic data identifies with the naturally assigned picture classification and to the identification of face and skin locales [65]. Some parameters are used to estimate the correlation from each channel of RGB and then converted into a GRAY image and the unwanted part is removed from the image [66].
The canny algorithm for edge detection is used for image filtering and gradient of image is calculated. But the problem of this algorithm is the fixed value of threshold and it uses the concept of gravitational field intensity and image gets dilated [67]. After that the dilated image with the help of feature-based image matching technique is matched with the reference image. Then on the basis that density is calculated and time will be allocated to traffic signals [27].
Time is allocated to traffic signals on the basis of traffic density and traffic density is calculated by the ratio of area covered by vehicles to total region [60]. Then calculation of the percentage of image matching will be there and if the percentage of image matching is more so we put signal green for less time else there is large time required for green signal. This can also explain how threshold algorithms, component adjustment and filter for median are used to recognize the traffic light signals [61].

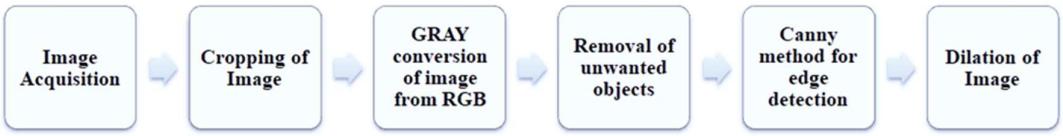

Figure 5 Steps of Image processing

The idea of edge-based picture extraction from a large information climate in traffic management. It is sensible that gatherings with more significant position can remove more data in traffic, and moderate mystery picture allocation related to picture classification plans are planned which can accomplish these characteristics. The classification of images is planned so that the gatherings can be partitioned into junior gatherings and senior gatherings which can further extend the operation in management of vehicles [15].

The color distribution of signal lights to regulate the values for each color based on the threshold. Then a model for color is processed and that proposed model is a gaussian model [62]. The procedure takes care of the issue related to color saturation and diminishes images up-sides since the low pixels picture is uncovered for a brief time frame. From the low openness image some region is selected, the situation with three, four and six bulb traffic signals in an ordinary picture are characterized using a help vector machine with a histogram of arranged slopes [63][52].

4.3 Internet of Things

The Internet of Things simplifies different dimensionalities such as business, home and applications related to industry. The aggregation of sensors and different objects decreases the number of human resources, their time for operation and data processing. The intelligent framework for remote cloud and smart server improves the processing of traffic signals and hence diminish the time of vehicles that are waiting, reduce pollution and control the congestion at intersections [68]. Nowadays sensor technologies have attracted a lot of attention. It supports traffic safety, control, and entertainment. Various sensors are additionally imported in vehicles by some manufacturers to cover the presentation and quality of the vehicles and provide higher knowledge which helps for operators to access the vehicles. Right now, the original counting of the sensors is about 80–120 in a vehicle, for every vehicle that becomes "more intelligent", the counting related to sensors reaches as numerous as 250 numbers of sensors for every vehicle [28].

The sensors for intelligent traffic monitoring and control systems can be classified based on their categories such as safety, diagnostic, traffic, assistance, environment, and users [69]. Table 5 represents the description and example of each sensor used for traffic monitoring and control system.

Table 5 Sensors Classification used in traffic monitoring

Sensor Category	Example	Description of Sensor
Traffic	Radar, Camera and ultrasonic sensors	To gather real time data for improvement of traffic management and monitor the condition of traffic in some zones.
Diagnostic	Temperature sensor, airbag sensor, pressure sensor, position sensor	To detect the defects in vehicles and their performance and provide the real time data.
Environment	Weather condition, temperature sensor, cameras, humidity sensors	To monitor the condition of the environment and give warnings or alerts to passengers and drivers for their trips.
Users	Electroencephalogram sensors, Cameras, Electrocardiogram sensor, heart rate sensors	To monitor the behavior and detect the abnormal health condition of drivers that can affect their driving.
Assistance	Rain sensors, humidity sensor, distance sensor, temperature sensor, fog prevention sensor	To gather the real time data this provides convenience and comfort.
Safety	Speed sensor, laser beam, radars, ultrasonic sensors, night vision sensors.	To recognize the real time safety events and accidental risks.

In Intelligent Transportation system sensors help to develop many applications that will contribute to solving the problem such as traffic congestion, commuting time, excessive CO2 emission that leads to pollution, parking problems and large number of accidents. In the scheme of Smart City where data or knowledge is shared between buildings, vehicles, and infrastructure to control the traffic congestions and provide safety on roads. This can be

implemented and possible with the support of Artificial Intelligence, Sensors and IoT (Internet of Things) only [4].

Sensor advances create and processing power builds, the utilization of independent robots, both ethereal and with helds will increase. The enemy's impact abilities will facilitate the lives with moment conveyance, directing, conveying, and observation [70]. To use the past traffic data to model a transportation system Graph neural network is used. Google map is collaborating with this and helps to improve the estimated time by 50% in formulation with Graph neural network [71].

4.4 Deep Learning

Deep Learning is a subfield of Artificial Intelligence and Machine Learning. This approach explores the Convolution Neural Network (CNN). The problem of this technique is that it requires a big or huge count of data to train the model and tries in detection of tiny objects [73]. The proposed model is a vehicle acknowledgment framework by embracing a CNN based on deep neural network feature extraction technique and Support Vector Machine classifier [74]. A model is proposed to order five particular gatherings of vehicles that include vehicles, vans, transports, trucks and farm vehicles dependent on AdaBoost calculation and the organizations related to convolution neural networks (CNNs) dependent on deep learning approach. The novel technique that can be utilized by CNN to extract the feature and SVM is used as the main classifier for the good arrangement [75]. Fig. 6 represents the steps required for the deep learning process. In the Q-learning q value can be used in given state to measure the quality of some actions followed by:

$$a_t = \arg\max Q(S_t, a) \qquad (2)$$

As per the equation (2) if action is performed then it gives the maximum of its q values [19].

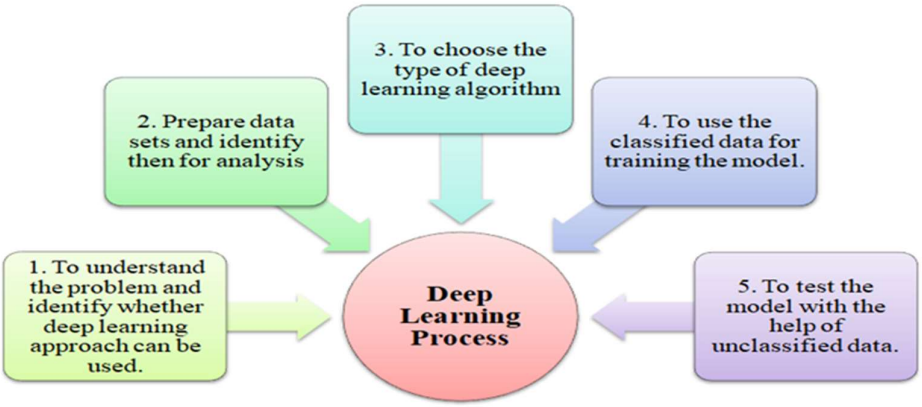

Figure 6 Steps of Deep Learning Process

Deep learning helps in detection of objects with the help of Recurrent Convolution Neural Network (R-CNN). This technique can help to find the area of interest [72]. The proposed model is used to develop the traffic light which contains three main parts; database, deep learning algorithm, and traffic light algorithm. Database is the set of images which are used to train the model. The algorithm related to deep learning consists of the model for training and

testing with the help of classification and identification of algorithms. Traffic light algorithm works with the help of priority of vehicles set in the algorithm and help in improvement of traffic signals [16].

Research Methodology

The existing review summary related to Traffic Monitoring and Control System. The basic approach used under the methodology is planning, conducting and documenting. The protocol has been followed and is represented by Figure 7. The steps that lead to literature review are explained below:

- Distinguished the need of literature review when contrasted with alternative techniques.
- Distinguished the questions related to research to clarify the literature review.
- Distinguished a group of identifiers which can be used for fetching databases and finding articles with help of query from the symposia/conference papers/papers published in workshops.
- To apply inclusion/exclusion on the fetched data of published articles to separate sensitive data of articles that helps to find the better sets of papers in that scope.
- Featured out the significant analysis from the actual survey to the future researchers that are also working in the area or field related to traffic monitoring and control systems.
- Recognized the future research area and gaps in related plan in the survey.

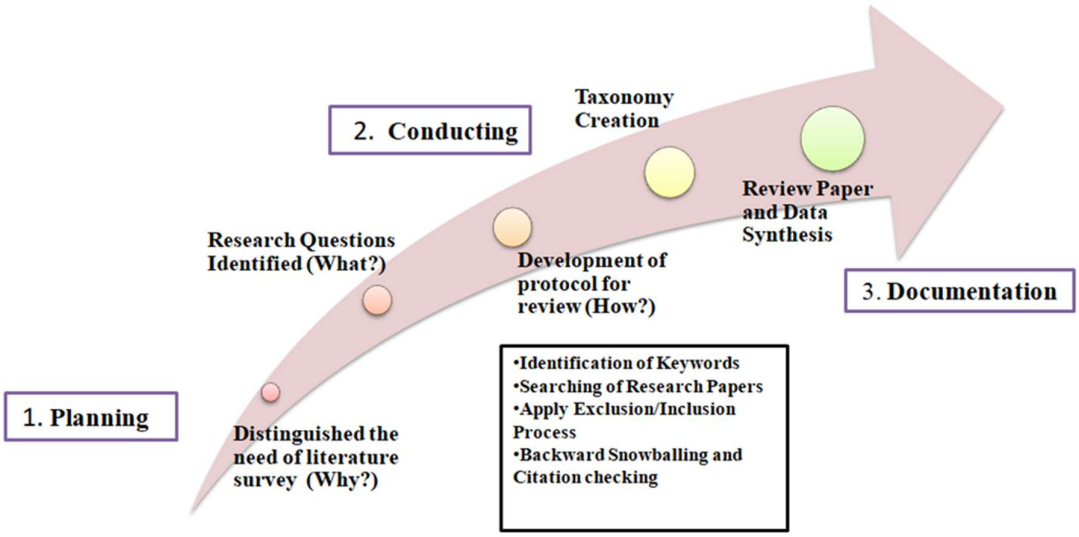

Figure 7 Process of Literature Review

5.1 Benefits of Literature Review

The consistently expanding plenty of exploration being distributed in the area of wise transportation framework and that is hard to monitor writing. The best answer for managing the circumstance is to perform a survey. The main point of a survey is to consolidate the singular investigations into a solitary extensive outline to dissect the intricate problems and

solve the inconsistencies which might occur, must keep an area in center. The survey can be a conventional fictional survey, or a more present-day Literature Review.

5.2 Research Questions

Intelligent traffic monitoring and control systems are used to control traffic congestion and improve the health problems which occur due to the long stay in traffic due to traffic congestion. It mainly creates problems related to back bones, breathing problems due to pollution. It helps to save the fuel and create environment pollution free. With the help of this monitoring of traffic will be there and because of that signals become dynamic at intersections and prevent congestion. It can also be helped to synchronize the traffic signals to improve the traffic monitoring and increase the efficiency of vehicles. The value of this literature survey is that it helps the researchers to provide the complete information in a collective way to help the future scope. Table 6 explains the questions related to research for different reasons that are directed towards literature review.

Table 6 Identified Research Questions

Identifier	Question related to Research	Objective
RQ_1	What are the different factors of intelligent traffic monitoring and control systems?	To create the taxonomy of it and their related problems.
RQ_2	What are the different techniques used to conquer the issue of congestion?	To compare the different techniques used to build models and draw conclusions from that.
RQ_3	What measure should be used to verify the strength of planned work?	To study the results that exists and then identify future enhancement of the work.
RQ_4	What are the areas where gaps exist that must be continued for future analysis achievements?	To propose guidance in an area for future research.

5.3 Search Strategy for Review

The target area of this review paper is the study of taxonomy and problems related to intelligent traffic monitoring and control systems. To achieve this, a large number of papers or articles published related to this field were collected from different sources. Initially, a broad level of pursuit of papers was accomplished on the different computerized databases related to research: IEEE Xplore, Google Scholar, Elsevier, ACM, Sensors and Springer. In addition to that a few more origins like workshops, proceedings of conferences, and symposia. The keywords were distinguished and separated into different four groups related to likeness. The first group of identifiers contained different adjectives utilized for a planned system in the area of research. The second group of identifiers included words identifying problems related to traffic monitoring and control. The third group of identifiers contained for "traffic monitoring and control". At last, the fourth group of identifiers contained the identifying with the platform or techniques used to handle the traffic related problems. Thus, these identifiers are remembered for this group to not lose on any significant experiences that can be strained from such research papers.

A combination of identifiers was worn to handle queries on the previously identified databases related to research. The groups of the identifiers are defined as:
Identifier_1_group = {intelligent, novel, strategy, priority, smart, dynamic}
Identifier_2_group = {synchronization, signals, congestion, pollution, health problem, economic}
Identifier_3_group = {traffic monitoring, traffic control, traffic light, traffic signals}
Identifier_4_group = {deep learning, machine learning, image processing, sensors, IoT}
On the basis of these groups, query (QE) has been formed:
QE = P OR Q AND R OR S
Where, P as Identifier_1_group, Q as Identifier_2_group, R as Identifier_3_group and S as Identifier_4_group.
The query that can be created with the help of the above query formula is "Intelligent or synchronized traffic monitoring in deep learning".

5.4 Criteria of Inclusion/ Exclusion

An inclusion/ exclusion process is practiced on the arrangement of papers related to research recovered because of search on the basis of keywords applied on the different databases referenced in the above segment. To get the scope of literature review this method is used to refine the sets of research papers. The criteria that can be applied as an inclusion/ exclusion for the extraction of papers as follow in Table 7.

Table 7 Criteria for Inclusion/ Exclusion

Basis of Inclusion/Exclusion	Inclusion	Exclusion
Source of Publication	Conferences, workshops and journals	Research reports and working papers
Type of Publication	Research articles, books, chapters, literature review.	News reports, letters
Language	English	Non-English
Time Frame	2011-2023	Before 2011
Review Types	Peer	Non-peer
Others	Quantitative results, high quality	Poor quality, duplicates and irrelevant content.

5.5 Selection of Article

The outcome set of distributions recovered later keyword-based search was enormous all together. As a result of all the applied processes for the research papers we got many articles for further study. After reading their abstracts, 153 articles were scrapped and the remaining papers were studied. But the content of 82 papers were fit in this literature survey and other 71 papers were found irrelevant to topic and research. After the literature survey the shortlisted papers were further divided into different categories such as traffic congestion, red light monitoring and synchronization, priority vehicles detection, and number plate detection.

Figure 8 and Figure 9 represent the studied research papers based on the publisher types and published years respectively. In this review nearly 57% papers were from the year 2020-22 and

almost 45% of papers were published by IEEE, MDPI published 20% of the papers, Springer published around 15% and tracked by Elsevier and ACM, and the remaining papers from the articles by Scopus and others.

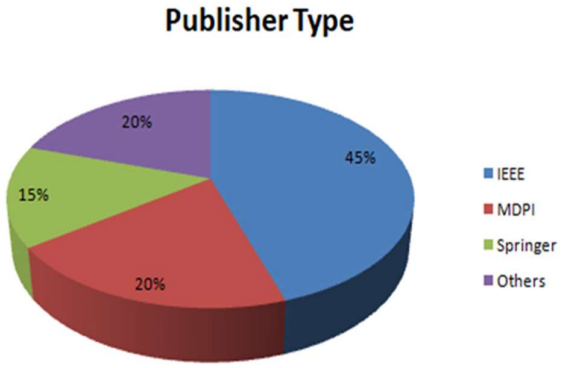

Figure 8 Partition of research papers based on the publisher types

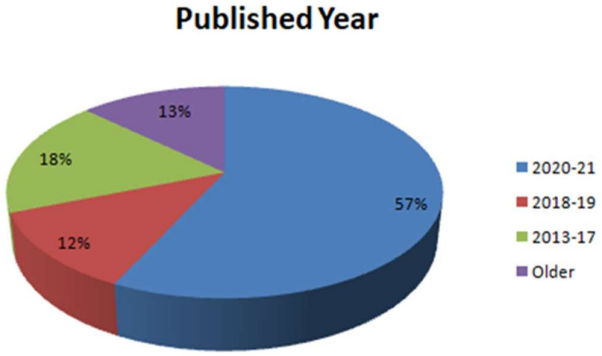

Figure 9 Partition of research papers based on the published years

Discussion

After studying a variety of papers related to traffic monitoring and control systems, it has been shown that if the framework contains congestion control, then there must be implementation on real time data and many problems related to congestion, health issues, pollution related problems and fuel efficiency. From the survey papers, it has been observed that problems related to traffic can be determined by constructing a framework or system with the expected amount of real time data of Intelligent Traffic Monitoring and Control System. For the quality-of-service Machine Learning has a critical role. In the techniques section role and importance of machine learning was explained and helped in recent development of Intelligent Transportation System applications which help in reduction of traffic congestion at intersections and helps in synchronization of traffic signals to reduce the usage of fuel consumption. Figure 10 contains the word clouds of traffic monitoring and control system. Figure 11 shows the knowledge map of Intelligent Traffic Monitoring and Control System. It contains the summary of the traffic management system that includes technologies used, parameters, applications and maturity of approach.

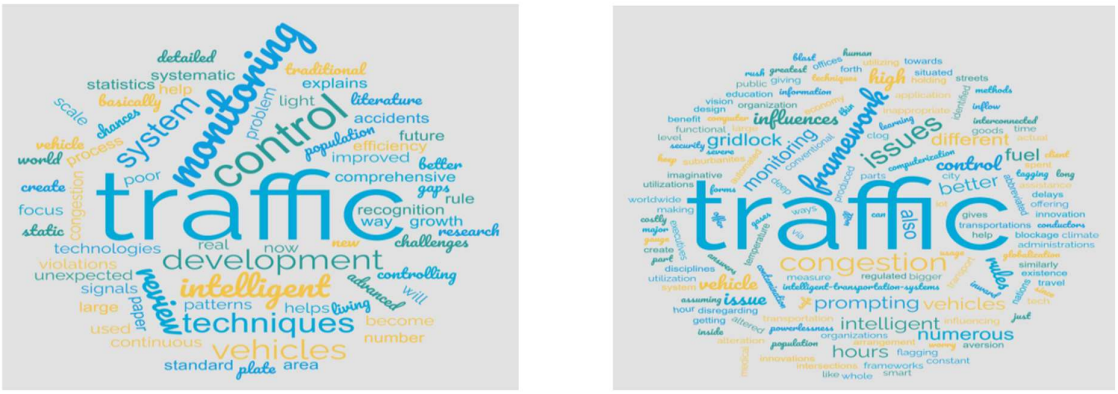

Figure 10 Word Clouds of Traffic Monitoring and Control System

Figure 11 Knowledge Map of Intelligent Traffic Monitoring and Control System

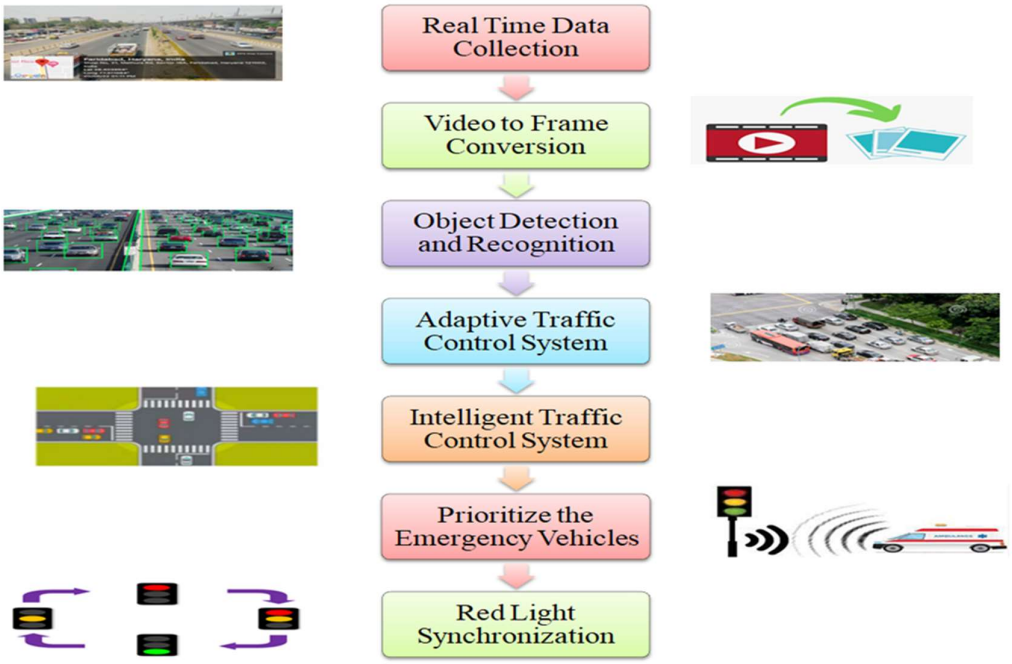

Figure 12 Proposed framework for Traffic Monitoring and Control System

Future Scope and Gap Analysis

The process of conducting the literature survey, the research question RQ_4 can be answered by identifying the gaps present in the research that can be used by the researchers to further improve the monitoring and control of traffic lights.

- Currently, there are no traffic decongestion initiatives such as synchronization among traffic lights in order to avoid multiple subsequent stops signals for the same vehicle in a short period of time in order to reduce Red-Light running and improve vehicle fuel efficiency.
- Traffic congestion also leads to death by getting stuck in emergency vehicles which aren't able to get right of way. Currently, there is no traffic monitoring and control to facilitate priority vehicles leading to a huge number of fatalities.
- In the present scenario, traffic control uses an adaptive traffic control system which avoids traffic congestion occurring as a result of the huge number of vehicles at several intersections.
- The rule violations related to traffic in today's day and age largely go unchecked in India because of manpower and resources constraints. There is no detection of the vehicles prohibiting the passage of way to emergency vehicles and providing e-challan. Additionally, the rules around number plates are not monitored and enforced effectively.

Conclusion

The paper focuses on the complete strategies related to traffic monitoring and control systems. There is a need to survey and study various research papers related to the Intelligent Transportation System. The current literature survey has been analyzed to answer all the research questions which were discussed at the starting of the paper. The research technique is used to achieve the literature review that also helps in some research decisions. This paper represents the taxonomy of intelligent traffic Monitoring and Control Systems which helps in getting knowledge related to congestion control problems; problems related to pollution, health related issues, fuel consumption, and time utilization. The existing survey examines the traffic strategies and taxonomy and hence finds the solution for the same. Some other factors that were also mentioned can be analyzed by researchers in future to propose some efficient model for that. The study also suggests that the problem related to Intelligent Traffic Monitoring and Control System is a result of primary aspects- 1) Traffic congestion at intersections, 2) Synchronization of traffic signals, 3) Analysis in real time data, and 4) Pathways provided to priority or emergency vehicles. These aspects are explained in detail in the taxonomy part.

In the process of the survey above discussed parameters, the strategies and techniques were classified. Techniques used for finding the solutions are discussed in paper. Furthermore, the survey paper is concluded by analysis of gaps area that will be used by researchers to continue the path of findings. The finding of the paper will help the researchers in this field.

In recent years, population growth worldwide has resulted in an increase in urbanization, which has contributed to a multifold increase in transportation usage, in turn leading to traffic congestion. Traffic monitoring is the biggest concern in many countries due to issues like overcrowding, globalization, and shortened or narrow roads. The goal of this research paper is to design and develop a novel framework for an Intelligent Transportation system using real time data to prevent traffic congestion and reduce traffic violations.

The proposed framework aims to solve three fundamental objectives: congestion control, traffic monitoring, and vehicle detection and classification for red light synchronization. These goals are based on the key problems hinged on the survey results, which include: 1) traffic congestion at intersections, 2) synchronization of traffic signals; 3) analysis of real-time data, and 4) pathways provided to priority or emergency vehicles. A systematic research methodology was followed, and numerous techniques such as machine learning, image processing, the Internet of Things, etc. were studied to land on streamlined processes to achieve the aforementioned objectives.

The key factor of this framework over the existing solutions lies in the usage of real time data as opposed to simulated or historical data, which helps to improve the efficacy and predictability of traffic control, leading to improved forecasting, reduced congestion, and prioritized vehicle flow. This process includes the following steps: 1) Real time data collection, 2) Conversion of videos to frames, 3) Object detection and recognition from the images such as two-wheelers, three-wheelers, four-wheelers, and emergency or priority vehicles, 4) Adaptive Traffic Control System, 5) Adaptive Traffic Control System using AI, 6) Prioritize the emergency or priority vehicles for the prevention of delay and 6) Vehicle recognition,

classification and number plate detection for the red light synchronization and traffic monitoring.

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