

# Intelligent Traffic Management Systems: A Review

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## Abstract

Traffic congestion has become a major problem nowadays. Traffic congestion especially occurs in metropolitan cities. Increased air pollution, noise pollution, accidents, delay in travel time etc are some of the problems that are faced by people living in these mega cities. Traffic jams have severely impacted the lives of citizens. The traditional traffic lights deployed in cities are not sufficient to meet the demands of an over-growing city since these traffic lights have specific pre-determined time intervals for changing from red phase to green phase. In this regard several attempts were made to automate the traffic lights based on the density of vehicles on the road. Some authors suggested the use of sensors to determine vehicle count while several others suggested the use of video cameras to capture moving vehicles and perform preprocessing on the videos to obtain vehicle count. This paper summarizes a review on the various methods that were used for the development of an intelligent traffic management system. A detailed comparison of all the methods is provided in this paper along with the pros and cons of every method.

**Keywords: Intelligent traffic system, traffic analysis, traffic signal control, traffic management, reduces traffic congestion, Smart city**

## I. INTRODUCTION

It is predicted that, in few decades most of the world population will live in the urban regions. This may lead to many socio-economic challenges. In recent years the cities world over have grown by leaps and bounds. Smart cities are essential for a sustainable urban development. It can remove many major problems faced by most of our cities for example traffic jams, thefts, environmental pollution, public transportation issues etc. [1].

One of the major problems faced by cities today is traffic congestion. Traffic jams causes a rise in the cost of transportation as well as it affects the routine lives of people. The problem of traffic congestion pervades everywhere, but mega cities are the ones that are most affected by it. The ever increasing nature of traffic makes it difficult to estimate the road traffic density in real time so as to make better traffic related decisions and manage the traffic more efficiently.

There are several reasons for this sudden surge in the traffic, in urban regions. The main reason can be attributed to rise in the population which in turn has caused rise in the number of vehicles on the road. Also there are several other reasons for congestion like insufficient capacity of roads, large red light delays, incomplete information regarding traffic, inefficient transport management, unrestrained demand etc. Insufficient capacity and unrestrained demand are interrelated but signal delays are hard coded and do not depend on the amount of traffic density. Therefore there is a need to optimize the traffic control system and make it more dynamic so as to accommodate the varying traffic density.

This paper provides a review of the various techniques that are used by different authors to automate and optimize the traffic flow. One of the methods makes use of VANET to design an intelligent traffic system [2] while another method makes use of infrared signal [3] to track vehicles and determine traffic rule violation by any vehicle. Another method makes use of state space equations to build a model of urban traffic network. In yet another system, fuzzy logic [5] is used to dynamically treat the problem of traffic and reduce travel time of vehicles at the intersection. In [6] a system is proposed using photoelectric sensors which are installed on one side of the road to monitor the vehicles passing through that road. The system also proposes to provide the traffic data to the central traffic department so that this data can be used by all the departments specially to integrate all the traffic data to take future course of action. In [7] an intelligent traffic management system using image processing technique is presented.

The rest of the paper is organized as follows. Section II gives a review of the existing work on developing an intelligent traffic management system. Section III provides a comparative study of all the existing methods used. Section IV describes The advantages and disadvantages of all the methods that are reviewed in this paper. Lastly section V gives a conclusion about all the methods.

## II. RELATED WORK

A smart city framework for intelligent traffic system using VANET was proposed in [2]. The proposed system consists of Intelligent Traffic Lights (ITLs) that are set up on crossroads of a city as shown in the following fig.1. The job of these ITLs is to gather the traffic information such as traffic density of passing vehicles, update the traffic statistics such as update congestion information and also report these traffic statistics to individual vehicles which are near these ITLs. In case an accident has occurred these ITLs will send collision related information to the vehicle so that the driver can select alternate route to avoid congestion near the site of accident. Every vehicle has its own GPS installed on-board. Every vehicle will transmit its exact location which is will be used to calculate the traffic density. The system architecture consists of three modules as shown in fig.2:

- 1) Warning Message Module: This module determines if any traffic accidents have occurred and warns the driver about the same. The information gathered by this module is sent to the next module i.e. Traffic density calculation Module.
- 2) Traffic Density Calculation Module: This module calculates the traffic density on each road.
- 3) Decision Making Module: The above two modules gather their information and send it to the Decision Making Module where appropriate decision is made to provide a congestion free path to vehicles

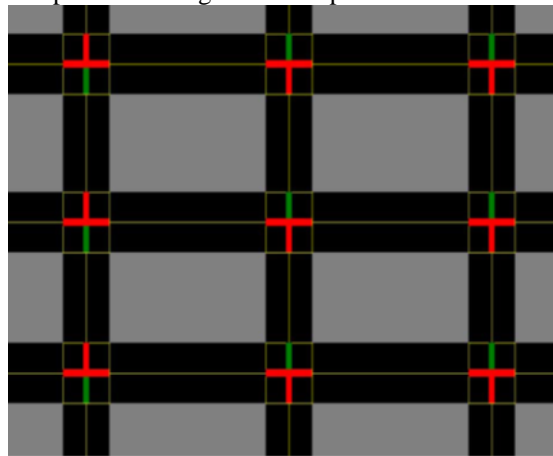


Fig. 1: Smart city framework consisting of ITLs [2]

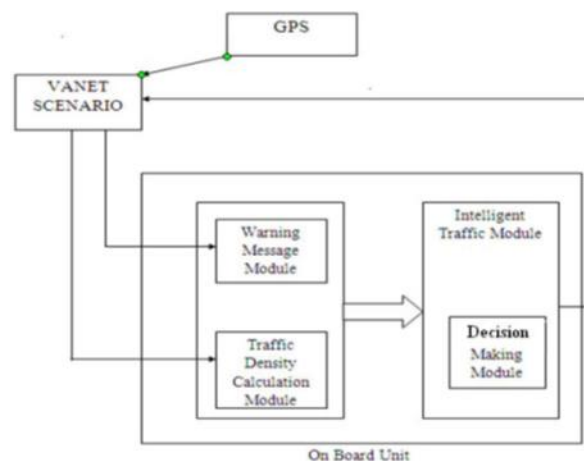


Fig. 2: System Architecture [2]

An infrared based intelligent traffic system was proposed in [3]. The block diagram of the proposed system is as shown in fig.3. The proposed system consists of three components:

- 1) Transmitter module: The transmitter module consists of a microcontroller which stores unique ID of every car. The microcontroller transmits a base pulse which turns on the driver and the data of every car is transmitted by the IR transmitter.
- 2) Receiver Module: IR Receiver in the receiver module receives the data transmitted by the IR transmitter. The receiver module also consists of a microcontroller which decodes the received data and helps store it in the EEPROM. The received data can then be displayed on the LCD display which is provided in the system. Also two switches are provided which help in the manual viewing of the data stored on EEPROM.
- 3) LCD display: LCD display can be used for viewing the unique ID number of every car.

The proposed system can work on one-ways, road dividers as well as four way terminals. One-way roads will have single receiver, road dividers will have two receivers whereas four way terminals will consist of eight receivers. Every vehicle has a unique ID and if a vehicle breaks the signal then its ID is tracked for penalty.

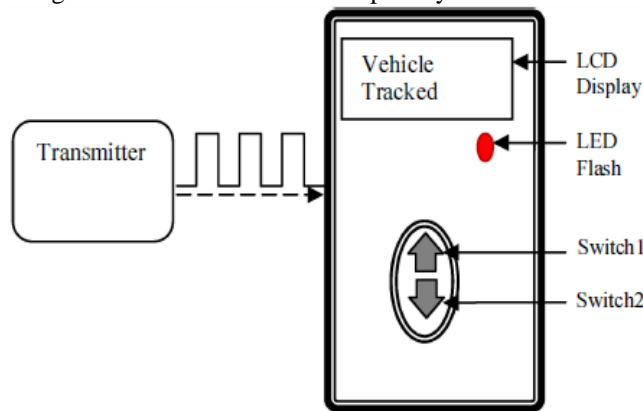


Fig. 3: Block diagram of intelligent system [3]

In [4] fuzzy logic is used to optimize the traffic light timing at a Diphasic's isolated intersection. Here two fuzzy logic controllers are used – one is to optimize the signal and other controller is used to extend the green phase of a road in an intersection. The proposed system consists of setting up a Simulation Time (ST) by the user and the following steps are performed in case the current time (t) is less than ST: The phase of the traffic light is changed to green and if the green time is minimum then the first controller displays the Optimum Green time to be set. When the Optimum Green Time set by the first controller is terminated then the second fuzzy controller shows the Extension Time (ET). In case the value of ET is not zero then the traffic light remains green for the ET specified by the second controller. When this ET is terminated the second fuzzy controller will again decide upon the new ET and set the time according to the new ET. This process continues until the ET becomes zero. The sensors used to collect input data are video cameras which are placed at incoming and outgoing lines. The controller then utilizes the information collected through these sensors to make optimal decisions and minimize the goal function.

In [5] an intelligent traffic controller based on fuzzy logic using FPGA is designed. The proposed system as shown in fig.4, takes in number of vehicles and average speed of traffic flow in each direction as the input parameters. The number of vehicles and average speed of traffic flow can be determined using sensors placed on the road. Average speed is calculated as follows [5]:

$$V_{avg} = \frac{n}{\sum_{i=1}^n V_i}$$

Here  $V_i$  is the speed of each car and n is the number of cars. The rules base defined by knowledge of expert man is then given as input to determine the time for which the green signal must be given. The input to decision making algorithm of Field Programmable Gate Array consists of output of the fuzzy control system and output of sensors which indicate the moving vehicles. The waiting time for every vehicle on every route is determined based on six linguistic variables i.e. Z1(very small time), Z2(small time), Z3(media time), Z4(large time), Z5(very large time) and Z6(long time).

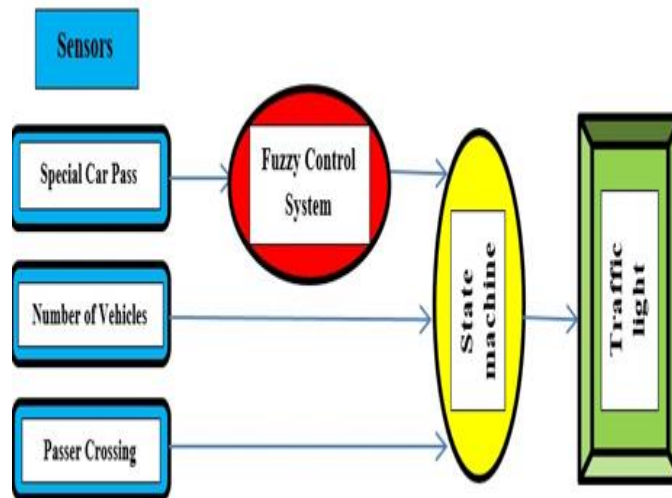


Fig. 4: Block diagram of proposed intelligent traffic management system [5]

In [6] an Intelligent cross road traffic management system is proposed using long range photoelectric sensors. The traffic management department chooses appropriate distance to install these sensors, so that they can monitor the moving cars. This data is then sent to the traffic control cabinet where software is installed which will calculate the relative weight of each road. Based on the relative weight calculated the system will allow the overcrowded road to have larger duration of signal. Also this system is designed in such a way that it can handle emergency situations (such as passing of ambulance, ministries and other VIPs) by opening complete paths for these vehicles to pass first. The emergency situations are handled by installing RFID tags on these vehicles (ambulance, ministry, VIP vehicle). This RFID tag is detected by the RFID reader located besides the sensor and the detected information is then sent to the traffic control cabinet wherein the decision is taken. In this way fluency of the traffic is guaranteed.

In [7] a vision based intelligent traffic management system is proposed. The proposed system uses image frames acquired through cameras installed on roads. The first step is to perform vehicle detection wherein dynamic background subtraction technique is used. In this algorithm the first frame of the video is considered as background. This background is then dynamically updated using the following formula specified by the author [7]:

$$bg_n = (gray * v) * (bg_{n-1} * (1-v))$$

In the above equation  $bg_n$  is the updated background,  $gray$  is the original video frame,  $v$  is the dynamic background constant and  $bg_{n-1}$  is the previous background image. The dynamic background constant can be adjusted within the range of 0 to 1 to increase or decrease the impact of previous frames on the updated background. Then by applying various morphological operations the clarity of the detected objects is increased. Vehicle counting is performed by drawing a rectangle around the object when it enters a pre-defined area of interest. When another object enters area of interest then another rectangle is drawn around the newly arrived object and the vehicle counter is incremented. Updation of vehicle count is done at regular intervals of time and this updated value forms the basis of signal controlling algorithm.

### III. COMPARATIVE STUDY OF ALL THE METHODS

All the methods that are reviewed in this paper have a common architecture as shown in table 1 which includes:

- 1) Choose an input method to acquire data.
- 2) Acquire traffic parameters (such as traffic flow rate, number of vehicles).
- 3) Determine traffic density.
- 4) Update traffic parameters in database.
- 5) Traffic Flow Control.

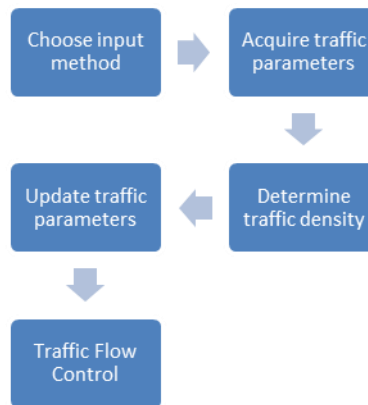


Fig. 5: Common architecture of system

### IV. ADVANTAGES AND DISADVANTAGES

All the methods that are reviewed in this paper use different techniques to determine the traffic density and change the traffic light based on different criteria. In [2] use of VANETs provide easy mobility of vehicles on the road by providing easy communication between vehicles and road side units but use of specific hardware on the vehicles proves to be a drawback of this system. Similarly infrared based system [3] is cost-effective and cheaper but the system is not flexible as receiver and transmitter have to be in direct line of sight of each other. Also large areas require multiple emitter panels to be installed which can add up to the overall cost of the system. Again in [4] complex systems become more complicated by the use of fuzzy systems. In [5] the proposed system reduces air pollution by reducing traffic, proves to be more flexible and provides highly accurate results. But the use of sensors increases the cost of the system. Also the system works on the basis of values that are stored in the database so every time the system needs to first connect to the database. Hence constant connectivity is required. In [6] the system makes the traffic information available to the administration department as well which can make use of this information for making other decisions as well. In [7] the algorithms used are easy and simple but the system does not handle the problems of occlusion (i.e. hiding of object under bridge or tree) and shadow overlapping. The various advantages and disadvantages of every method are shown in a tabulated manner in the table 2.

Table-1  
Comparison of Various Intelligent Traffic Management Techniques

Sr. No.	Input method used to acquire data	Based on	Traffic parameters acquired	Determine traffic density	Sensor used on vehicle?	Hardware required?
1.	Intelligent traffic lights (ITLs)	VANET	Accident data, Location of every vehicle	Total number of vehicles gives density information	Yes. GPS used	Yes. ITLs need to be installed. RSUs need to be installed.
2.	Infrared signal	Infrared	Unique ID of every car	Total number of vehicles given by unique ID gives density information	Yes. IR sensor used.	Yes. Transmitter unit, receiver unit and LCD display
3.	Video cameras	Fuzzy logic	Vehicle queue length, Length of vehicles, waiting time of vehicles,	Vehicle queue length gives density	No.	Yes. Video cameras.
4.	Sensors	Fuzzy logic	Number of vehicles, Average speed of traffic flow	Number of vehicles gives traffic density	Yes. No	Yes. An integrated circuit i.e. FPGA.
5.	Sensors and RFID tags	Photoelectric sensors	Weight of road, Probabilty distribution of expected cars at rush hours.	-	Yes. RFID on specific vehicles (ambulance etc.)	Yes. Sensors need to be installed on the sides of road.
6.	Video cameras	Image processing	Vehicle count by vehicle detection	Vehicle count in area of interest gives density	No	No

Table-2  
Advantages and disadvantages of various intelligent traffic management system

Sr. No.	Input method used to acquire data	Advantages	Disadvantages
1.	Intelligent traffic lights (ITLs)	VANETs allow easy communication between vehicles and between vehicles and RSUs. Provide accident information. Reduce trip time of drivers.	Installation of GPS on two-wheeler is difficult and costly as well. Also full map of the city and information about every ITL present must be kept which is a difficult task.
2.	Infrared signal	Microcontrollers used are cheap, so cost-effective. Batteries are used in transmitter and receiver so consume less power. Installation is easy.	Receiver and transmitter must be in direct line of sight of each other so reduces flexibility. High intensity lights cause interference with infrared.
3.	Video cameras	Optimized traffic control algorithm. Shows realities such as accidents. Takes into account different traffic conditions.	Use of fuzzy system is transparent only for simple systems. Fuzzy system proves to be more complicated for complex systems.
4.	Sensors	System has high speed and high precision. FPGA is economically affordable. Flexible system.	Complex system. Cost increases due to use of sensors. Constant connectivity to database is required.
5.	Sensors and RFID tags	Reduced waiting time at traffic. Human intervention is eliminated. System automatically switches to normal system when intelligent system not required. Guaranteed flow of traffic in emergency situation.	Deployment of photoelectric sensors. Cost of maintenance is high since deployed in rugged external conditions. Priority of every road must be set in advance. It is impossible to determine priority in advance.
6.	Video cameras	Incorporates fault detection capability. Algorithm used is simple and easy to implement.	Occlusion and shadow overlapping is not handled.

## V. CONCLUSION

This paper has provided a review of all the methods that have been used to develop an intelligent traffic management and control system. Traffic jams have become a serious issue. Hence an automated traffic management system is essential especially in mega cities where the number of vehicles has increased to a large extent. The methods that are reviewed in this paper mostly use sensors which provide an exact count of number of vehicles. But as discussed above these sensors have high cost of maintenance associated with them due to their deployment in external conditions as well as they are prone to other external conditions, lighting conditions etc. Use of video cameras proves to cost effective but the image processing techniques that will be used on the videos must be able to remove occlusion and shadow effects. Further research can be made in this area and implemented to develop a real time dynamic traffic management system.

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