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Traffic Management System Using IoT Technology - A Comparative Review

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***Abstract*— With an ever-increasing population growth in cities around the world, continuous production of all kinds vehicles by manufacturers, and the number of vehicles on the roads will only continue to rise. This naturally leads to increased traffic congestion, especially in large metropolitan areas and even more so during peak rush hour time. This phenomenon constantly puts pressure on researchers, city officials, and urban planners to continue to improve traffic management systems in ways that are safer and economically more efficient. In order to address this evolving problem, a number of studies have been conducted that have resulted in some notable improvements such as designated lanes for emergency vehicles in urban areas. However, even with these lanes, often the ideal target-times for emergency vehicles to reach their destinations is hard to achieve. A new method which seeks to address this issue is called Intelligent Transportation System (ITS). This method can help solve the problem by integrating existing technology with the current infrastructure. In this paper, our goal is to compare different methods for managing traffics, namely Traffic Light Systems (TLS): Static and Dynamic TLS, Radio Frequency Identification (RFID), and Internet of Things (IoT). In the latter method, traffic data are quickly acquired and sent to Big Data for processing and mobile applications AKA User Interface (UI) to estimate traffic density in various areas in order to suggest alternative ways to alleviate traffic.**

***Index Terms*— Intelligent Traffic System (ITS), Internet of Thing (IoT), Smart Traffic Management System, Traffic Light System (TLS), Green Light Phase Time (GLPT), Global System for Mobile application (GSM), Base Station (BS), Wireless Sensor Network (WSN)**

I. Introduction

Traffic congestion in developed and urban cities across the globe, especially during rush hour, continues to be a major issue that plagues residents, commuters, local officials, and urban planners. The impact and consequences of traffic congestion are many, ranging from increased air pollution and fuel consumption to slower economic growth [1]. As the number of vehicles on roads increases, traffic congestion will only continue to present more barriers and obstacles for economic growth while having a negative impact on quality of life. As a result, people will naturally be inclined to relocate to areas where there is less traffic congestion, safer, and more efficient. This poses a serious challenge for urban planners to create an efficient traffic management system that can serve the needs of a large metropolitan area while at the same time remaining easily adaptable to the population growth.

Recent advances in wireless technologies especially in Radio Frequency Identification (RFID) has played a significant role in the field of traffic management. The technology behind RFID has been around for more than fifty years [2]. This technique allows for cost-efficient and user friendly solutions for large scale Automatic Vehicle Identification needs. By using RFID, the cost of expensive infrastructure can be reduced significantly. Radio Frequency Identification also has many other uses, but its use in traffic management systems has been one of its most successful applications. In addition, RFID is applied in various areas of traffic management, such as vehicle detection, identification, security, tracking, and parking management.

Traffic Management System (TMS) addresses issues of urban congestion. To start with, smaller systems have been put in various places in the city. As time goes on, new solutions, methods, and technologies are found and additional functions are installed within the existing system in order to enhance the system efficiency [3]. Doing a comparison between the improvements seen on the final system and the initial state (without any traffic management system) requires access to data which we do not have. As mentioned before, traffic lights can be taken into consideration for controlling traffic congestion. Traffic lights play a key role in traffic management and they serve two purposes: a) Decrease vehicle accidents, and b) Ease traffic congestion when coordinated properly in tandem. The first manually operated traffic light was invented by John Peake Knight in 1868 [4], and first automated traffic light was invented by Lester Farnsworth Wire [5] in 1912.

In the past, Fixed Cycle (Static) TLS was more popular than Dynamic TLS and was more widely used in traffic management systems [6]. Fixed Cycle TLS was inefficient because it leads to increased density of traffic and congestion, especially on roads that already had a high volume of traffic flow to begin with. This is especially seen in countries such as Malaysia where the use of Fixed Cycle TLS is widespread. A Dynamic TLS can help to greatly reduce this congestion by adapting traffic pattern based on the number of vehicles on the road at any given time.

Furthermore, beside the traditional traffic control systems, cutting-edge technologies in the area of wireless communication, control systems, image processing, and data mining have integrated with the current transportation and street infrastructures which implies the next level of smart and intelligent facilities known as Intelligent Transportation

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Systems (ITS). Recently, the advancement in the field of communication has also emerged new area known as Internet of Things (IoT) which has gained special interest both in academia and industry due to the diverse platform that can be connected together and communicate with each other under this paradigm.

II. Related Works

Intelligent Traffic Systems (ITS) has become one of the most important applications of Internet of Things (IoT) which is enabling the development of smart cities [6]. There are many studies where focus is to improve traffic management [7]. One technique that has been studied is called the Green Wave System in which an incoming emergency vehicle can enable the traffic light to change to green during the time that the vehicle is crossing the intersection. In addition, image processing [8] can be used for detection of the location of emergency vehicles. With this system, an emergency vehicle will receive all green signals along its route and will not be affected by any stops while on its way to its target destination. Another benefit of this system is that any stolen vehicle that passes through the intersection during this time can be easily detected. The main disadvantage of this system is related to showing an inaccurate information about emergency vehicle location in severe weather conditions. Because of wind, fog, rain, and snow the picture which taken by camera is distorted by noise and cause lots of mistakes for detecting the exact location and identification of vehicles. To address this drawback, RFID can help to allow for more appropriate synchronization.

Radio Frequency Identification (RFID) utilizes tags which acts as labels that are attached to the objects to be identified. Taken separately, RFID tags don't utilize any battery or other power source. Instead they receive the related information via an RFID reader [9]. Most of the time, RFID tags are invisible to human eyes because they are embedded inside the dashboard of cars or other vehicles during manufacturing process. In the scenarios involving emergency vehicles, the idea behind the RFID system is that an RFID tag is installed on an ambulance, and a reader is installed in the traffic system. The function of the reader is to read all the incoming data from the RFID tags and detect the ambulance as it approaches to a traffic signal system. Until now, there is little mention in various papers regarding the drawbacks of this system. For example, in a situation where there is no emergency and no needs for a rapid response, would the light remain the same color or turn green to allow passage of the ambulance through the intersection? The answer to this question is not clearly mentioned in some of the research papers I have read through. In the real world, however, ambulance or other emergency vehicles would not have any priority to pass through an intersection if there was no emergency that required an urgent and rapid response.

In one research paper, some methods are suggested to improve the accuracy of vehicle detection by utilizing a system called a Wireless Sensor Network (WSN) which involves the use of magnetic sensors [10]. Vehicle detection is one of the most important system functions that should be taken into consideration. Why is this function so essential? When vehicles are detected accurately, the data sent to the traffic management system is also accurate. This allows the system to more efficiently manage traffic volume, lane occupancy, and speed detection of vehicles. In this model the system utilizes the raw data to determine a threshold that allows for more accurate vehicle detection [11]. The most significant drawback of this system relates to a value called the Signal-to-Noise Ratio (S/N). If this parameter is too low, it can potentially result in adverse effects in the quality of vehicle detection such as increased sending of false alarms or increased rates of missed detection due to poor system performance.

M. Bathula *et al.* [12] mentioned that the combination of magnetic and infrared sensors can be used to improve vehicle detection and the overall efficiency of the detection system. The main issue they face with this process, however, relates to the trajectories of incoming vehicles, especially in work zones. M. Bugdol *et al.* [13] made use of magnetometer detectors for vehicle detection in intelligent transportation systems (ITS). As a vehicle approaches a magnetic detector, there is a partial distortion of the local magnetic field that is generated by the detector. Whenever the vehicle is in the middle and the last portion of the magnetic field generated by the detector, the total local magnetic field is distorted. Subsequently, the data that has been received from the detectors is then transmitted to a controller. The main function of this controller is to check and analyze the direction of incoming traffic and then to utilize this information to control the traffic light systems in multiple intersections simultaneously.

Another system [14] that has been suggested for alleviating traffic congestion is the use of mobile-based traffic measurement systems. This system allows for monitoring and managing traffic congestion on roads. This proposed system consists of seven layers, spanning from the individual smartphone to the top layer business model, and can ultimately allow for the determination of all the various aspects of traffic on roads. This will then allow the mobile application to received information regarding the congestion on those roads and then to calculate the time one might be delayed due to traffic, and to subsequently suggest viable alternative routes, approaches, and other improvements. Badura and Lieskovsky [15] proposed a new model for Intelligent Traffic System. Here, the cameras installed at the junctions, scan and monitor their domain area. The acquired data is immediately sent to topology independent data delivery system for general image analysis. The role of data delivery system is to provide the communication framework and ensure data transmission over mobile Ad-hoc network (MANET). They have experimentally demonstrated the effectiveness and real time data transmission for various scenarios

Salama *et al.* [16] suggested Photoelectric sensors for controlling traffic lights. One of the most crucial element is the exact spots for installation of sensors. This is mainly because the traffic management department wants to monitor vehicles' moving at specific time especially during rush hours. The acquired data are relayed to traffic control center where the sensors' readings are fed to an algorithm with an assigned relative weight to each road. After these calculations, the

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system will open the traffic direction for the road which is more crowded than the other side and gives extra time for alleviating the traffic congestion compared to other less congested road. This system can let human intervention in exceptional circumstances to control the traffic congestions. The details of Photoelectric sensors will be taken into consideration in methodology section.

III. Methodology

In order to implement proper Intelligent Transportation System (ITS), the system has three predefined categories for vehicles: normal vehicle, stolen vehicle, and emergency vehicle. These categories aren't constant and they can be changed as required. There are three levels of priority for systems namely low, high, and highest. We need these two important parameters (categories, and priority of vehicles) for updating the database dynamically with Short Message Services (SMS). Aside from categories and priority of vehicles, all the vehicle's information passing through the junctions can be stored in database as well. This technique provides a circumstance to use this current information for traffic monitoring in the next stages. In order to solve the problem of stolen vehicle's direction, readers can help us very well. They can be installed before each traffic light junction so that the direction of stolen car can be easily detected. But the main issues with these readers are related to rain or direct sunlight. The signals from readers in this situations will be distorted.

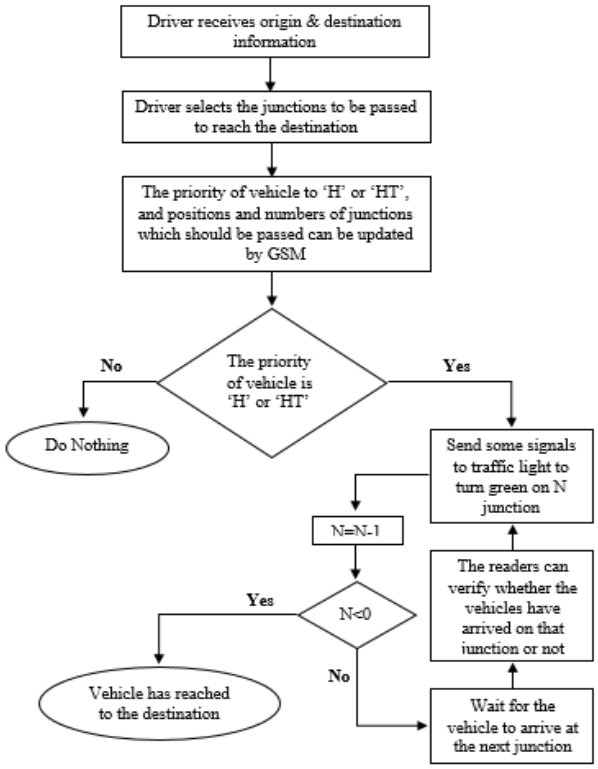
The implementation of ITS on the road consists of two major systems: software system and electronic system [17]. The software system consists of green light algorithms, control system, cloud server, and some applications for monitoring congestion of traffic for traffic officers. While, electronic systems consist of connection between traffic lights, sensors, and microprocessors as well. Detecting and collecting data for each road bound is the first step to control traffic congestion. In order to reach this goal, inductive loop detector can help us effectively. After transferring these data, which has been collected from chips or microprocessor to Base Station (BS) by the help of Wi-Fi, the first step is completed successfully. The second step is how to design a useful algorithm that can calculate Green Light Phase Time (GLPT) based on the data which has been received and stored in database [18]. The information related to GLPT of each road bound is transferred from BS to microprocessor. As a consequence, now the microprocessor has all of the needed information for altering GLPT of each road bound. Also traffic officers can take an advantage of this situation and see some changes related to GLPT on the traffic light monitoring applications. The detailed algorithm of this process is well explained in [1].

The following two flowcharts [19] give the fundamental algorithms of green wave and also the detection of stolen vehicles. In flow chart 1, the category "high" is shown with "H" and the "highest" is shown with "HT". If we want to organize the priorities, the category highest (HT) has higher priority than high (H). If two vehicles approach towards the traffic light junction at the same time from the opposite direction, the priority is assigned to the vehicle with the highest priority. Furthermore, if two vehicles have same priority, the priority is given to the vehicle which comes sooner.

In flowchart 1, the driver of vehicle will receive the destination information and selects the junctions to be passed in order to reach the destination. The function of Global System for Mobile Application (GSM) is to update the priority of vehicle to "H" or "HT" and also the position and number of junctions which should be passed during this phase.

Once the priority of vehicle is set to "H" or "HT", then the system will transfer some signals to change the color of traffic light to green on the *N*th junction and then decrease the number of *N* to *N*-1. Whenever the number of N is decreased, there are two options: (a) *N* is less than zero which it means the vehicle has reached its destination, and (b) *N* is equal to zero or greater than zero which it means the vehicle has to move to the next junction. We can verify whether the vehicle is arrived on a specific junction or not by the help of reader installed 200 meters before the junction. These data are sent to traffic light in order turn the color of traffic light system to green on the *N*th junction. This process will be continued many times until *N* is changed to less than zero which means that the vehicle has reached the destination.

Flowchart 2 shows a methodology for detection of stolen vehicle. First, the user will report via SMS the information pertaining stolen vehicle. After that the system will update its database and designate the priority of the stolen vehicle to 'T'. Now there are two scenarios: (a) vehicle is equipped with GPS. In this case, the exact location of the stolen vehicle can be traced. This information is transmitted to the Police Department. (b) the vehicle is not equipped with GPS, in which case the data from RFID reader can help significantly. Once RFID detects the stolen vehicle, it sends the location of junctions where the vehicle was traced.



Flowchart 1. Green Wave Systems

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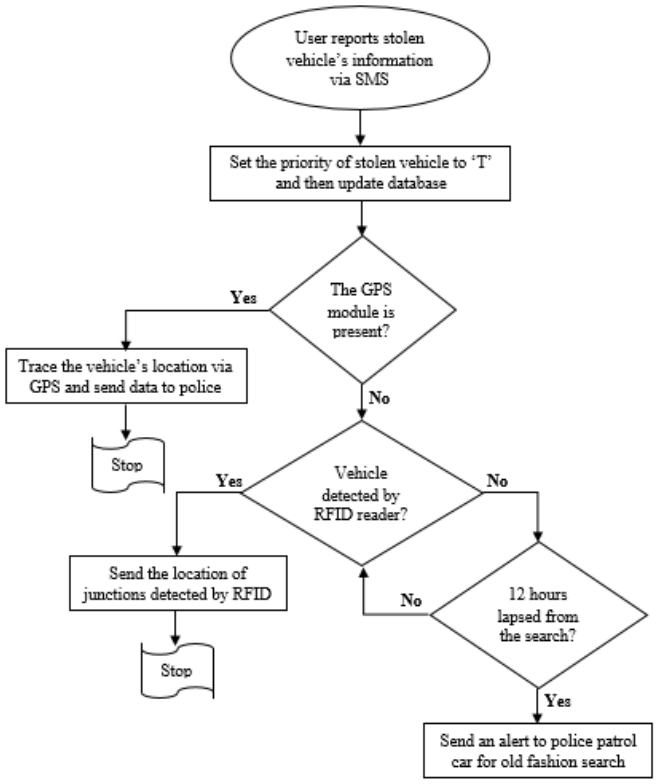

Flowchart 2. Stolen Vehicle Detection

TABLE 1
OBTAINING RAW DATA METHODS

Method	Description	Rating
Triangulation method	In developed countries as the number of cars increased significantly, some cars contain one or more mobile phones. This phone can transfer the information to mobile phone network. Barring any distortion of data, this method creates a circumstance to measure and analyze network data and produce traffic flow information.	Useful
Vehicle re-identification	In this technique, a set of detectors are required along the road. Here, a unique serial number of device in the vehicle is detected at one location which can be re-identified again down the road. This method is very useful in calculating travel times and speed of vehicle by comparison between real time that the vehicle is detected and time at which a specific vehicle is detected by the set of sensors.	Very useful
GPS based method	These vehicles must be equipped with GPS systems to detect the location and the velocity of the vehicle very accurately and be capable of two-way communications with a traffic data provider.	Useful
Smartphone-based monitoring	Most smart phones also have full GPS features and various sensors for tracking the traffic flow and speed.	Useful

B. Ghazal *et al.* [20], have attempted to reduce the traffic congestion through Infrared (IR) Sensors. Most of the traffic light systems were equipped with IR sensors and IR transmitters linked to IR receivers. As soon as vehicles approach the intersections, they get detected and based on the signal frequency or density, traffic volume is analyzed and the traffic lights change accordingly. Another useful technique for determining the traffic speed and traffic congestion is called Floating Car Data (FCD) or floating cellular data. This method depends on several elements such as collection of localization data, speed, direction of travel and time information which have been received from GPS in vehicles that are being driven [21]. As a result, the function of each vehicle with an active mobile phone is like a sensor for the road. It can identify traffic congestion, calculate travel times, and also generate traffic report for Police Department. One of the advantage of this technique is that FCD does not need any additional hardware/device. Each switched-on mobile phone becomes a traffic probe as anonymous source of information. FCD is divided into three sub-systems. The first sub-system, which is called probe system, contains the probe vehicle and a geo-location unit. The second one is web database, which gathers all the required traffic data and puts all the required data on the top of digital map. The third sub-system is web client which is designed as a User Interface (UI) for accessing easily the traffic information [16].

In order to gather raw data, one of the four methods listed in Table 1 are used. The geo-location data is very useful, because it is used to estimate the probe velocity of vehicles. As mentioned before, FCD does not need any additional hardware and all is required is a smart phone. This smart phone can be connected to a probe vehicle in order to calculate the velocity and heading of a vehicle and also for measuring the probe vehicle positions. Finally, all these data are transmitted to a server via wireless network using a very simple HTTP request. On the server side, all these data will be tagged with acquired time

Kanungo *et al.* [23] has suggested another technique to minimize vehicular congestions via video processing which obtains data from cameras with feedback mechanism. This is an essential element in decision making process whenever the traffic congestion is significantly high. If it is a four-way junction, the system has a video camera on each side, or four cameras at the junction above the red light. The captured videos from each camera are transmitted to server where through an algorithm for image processing the traffic congestion in each side of the road are calculated and the traffic lights are switched correctly. The methodology of video processing consists of hardware and software components. The function of camera is to create a connection between the actual traffic scene and server. The received feedback then enables the system to control the requirement of this process as needed. The software toolbox [24] consists of image processing, analysis, visualization, and algorithm, using MATLAB, and C++ compilers.

One such development is proposed by Salama A.S *et al.* [16] involves the use of photoelectric sensors. In this system, the sensors detect changes in the weight of the road as a way to measure the amount of traffic. This data is used in an algorithm utilized at a nearby traffic control center to control traffic lights

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based on this information. By altering the frequency at which traffic lights change, the system can allow for the opening of traffic congestion on roads that have a higher relative weight based on the readings of the photoelectric sensors. The added benefit of this system is its flexibility, as it can also be utilized in unique situations that require minimal to no congestion, such as the passing of emergency vehicles. This can be accomplished through the use of radio-frequency identification (RFID) technology. Overall, this system allows for the maintenance of fluid traffic flow in general while being able to adapt to specific situations that occur on certain roads monitored by the system. As an added benefit, the proposed system can be programmed in such a way that requires minimal human involvement, or for more human involvement for optimized control in certain situations that demand it.

TABLE 2. VARIOUS METHODS FOR TRAFFIC LIGHT CONTROLLER

Method	Description	Pros and cons
Traffic Management System (TMS)	This technique is a top-down management perspective that integrates with technology in order to improve the traffic flow and safety. In this situation the task is divided into smaller systems put in various place. Real time traffic data is gathered from cameras and speed detectors are transmitted into Transportation Management Center (TMC) for improving traffic flow.	**Pros: 1.** Increased road user satisfaction for saving precious time of commuters. **2.** Reduce possibilities of traffic jams. **Cons: 1.** Excessive delay may be caused due to TMS malfunction and downtime. **2.** Unnecessary delays result in significant fuel waste and higher motorist time.
Green wave system	In this technique whenever the vehicle is crossing the intersections, an incoming emergency vehicle enables the traffic light to change to green. Image processing can be used for detecting the location of emergency vehicles more accurately. As a result, an emergency vehicle will receive all green signals along its route and will not be affected by any stops while on its way to its target destination	**Pros: 1**. Can allow emergency vehicle to pass through intersections safely and rapidly. **2.** Useful for detecting the stolen vehicles that pass through intersections. **Cons: 1.** Weak performance in severe weather conditions. **2.** If it does not work correctly, it can cause a heavy traffic jam
RFID tags	This technique overcomes the severe weather problem in Green Wave System as Radio Frequency is not affected by the weather. RFID uses tags assembled in the dashboard of the ambulance and RFID readers are installed at the 200 meters from junctions. The RFID reader will read all the data from tags in order to detect the ambulance as it approaches traffic light systems.	**Pros: 1.** The RFID tags can store a lot of information, and follow instructions **2.** It is not affected by severe weather conditions. **3.** These RFID tags are usually smaller than thumb tack and they can be embedded into dashboards. **Cons: 1**. Active RFID can be expensive because of power sources such as battery. **2.** RFID may be easily intercepted, even if it is Encrypted.
Wireless Sensor Network (WSN)	This technique utilizes a set of magnetic sensors to improve the accuracy of vehicle detection. As a vehicle approaches a magnetic detector, there is a partial distortion of the local magnetic field that is generated by the detector. Whenever the vehicle is in the middle and the last portion of the magnetic field generated by the detector, the total local magnetic field is distorted. After that these data can be transmitted to a controller.	**Pros: 1.** WSN can be applied in large scale and in various fields as it avoids wiring. **2.** It performs well at high speed and is flexible to go through a centralized monitor. **Cons: 1.** If Signal-to-Noise Ratio (S/N) is too low, it can potentially cause adverse effects in sending false alarm. **2.** Easy for hackers to hack the system because the propagation of waves cannot be controlled.
Global System for Mobile Communication (GSM)	In this technique, embedded controller is used to produce data pattern as an input for microcontroller. The C program language, then is converted in HEX code and transfer into receiver of microcontroller. Then transmitter of microcontroller will send these data to GSM. The GSM can active messaging service with the 3G connection of SIM alert a specialist with message.	**Pros: 1.** Very useful in saving time because it can send a message to medical doctors about patient's situation before arrival of the ambulance. **2.** It can show video display by using 3G connection in ambulance. As a result, the doctor can analyze the condition of patient and recommend some first aid steps. **Cons:** Concerns about losing control of their network and the data. Also, losing battery of mobile can disconnect the connection.
Infrared Sensor (IR)	Most of the traffic light systems have IR sensors which consists of IR transmitter and receiver. Whenever the vehicle passes between sensors, the IR sensors can be activated. The collected information can be analyzed to change the traffic light to green.	**Pros:** Reportedly stolen vehicles or vehicles of criminal suspects can be tracked, and the time and direction of travel can be traced. **Cons: 1.** Initial setup cost is high **2.** An emergency cannot be automated and normally requires human intervention.

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TABLE 3. COMPARISON OF THE PERFORMANCE OF TRAFFIC LIGHT CONTROLLER
Low = L, Medium = M, High = H

	Safety	Trustability	Efficiency	Overall Rating
Fixed Cycle TLS	**M** Sometimes in rush hours the police should control the traffic congestion	**H** This is the most basic TLS with the least chance of failure.	**L** It leads to increased traffic density at peak hours, or unnecessary delay behind red light when there is no traffic at all.	**Widely used**. Its use is diminishing in smart cities.
Dynamic Cycle TLS	**H** A reasonably safe and a proven technology.	**H** A reasonably safe and a proven technology.	**H** The vehicle's driver can pass the road when there is no traffic density.	**Very useful** It can adapt traffic pattern based on the number of vehicles on the road at any given time**.**
Green Wave System	**M** Sensors are continuously and in real-time are tested for added safety and reliability.	**M** If the sensors cannot work very accurately, it will cause traffic density	**L** In severe weather conditions, it cannot detect the emergency vehicle accurately	**Not very useful** It can be useful in areas where winter and sever weather condition is not an issue.
RFID tags and readers	**M** Store lots of info and instruction for sending to server	**L** It cannot be affected by weather conditions	**M** Not cost efficient because of power source requirement.	**Useful** Can keep track of stolen & emergency vehicle.
Wireless Sensor Network (WSN)	**L** Easy to hack the system because still there is little security in WIFI systems.	**M** By the help of magnetic sensors, emergency vehicle are detected more reliably.	**M** If Signal-to-Noise Ratio (S/N) is too low, it can potentially cause adverse effects in sending false alarm	**Useful** WIFI and AI are promising technologies for real-time detections now and with increasing reliability.
Global System for Mobile Communication (GSM)	**H** The EMS assistants can send their assessment of the patient to the medical team before arriving to hospital	**M** Dead battery or loss of mobile network is of prime concern.	**H** Communication about the condition of the patient can be enhanced via video call	**Very useful** Saving time because it can send a message to specialist doctor about patient's situation before arrival of ambulance
Infrared sensors (IR)	**M** It can send high resolution images to traffic light control center to decide safely for duration of green light.	**L** It's a little difficult for large areas and more complex to gather all traffic data from IR sensors.	**L** The initial setup is too much expensive and sometimes emergency cannot be automated.	**Useful** It can detect stolen vehicles while they are passing between IR sensors.

IV. CONCLUSION

In this paper, several intelligent traffic management systems were reviewed. These included utilization of RFID readers and tags, Green Wave Systems, smart phones and wireless communication with Big Data center. Applications, pros and cons of each method were discussed and summarized briefly in Tables 1 and 2. The technique of IoT has been used in order to gather data which related to traffic congestion more quickly and more accurately. Furthermore, mobile application was discussed as a "User Interface" to detect traffic congestion in different places and provide users with alternate routes. The goal of these techniques are to provide the drivers of vehicles to know more information about traffic and road conditions. Moreover, the priority for emergency vehicles can be assigned through Intelligent Traffic Systems.

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