INTELLIGENT TRANSPORTATION SYSTEMS AND ITS TOOLS AS A SOLUTION FOR URBAN TRAFFIC CONGESTION: A REVIEW

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Abstract : The dynamic development of urban areas poses increasingly more challenges for the provision of transport services for the population. The concentration of the economic potential and population in the metropolitan areas results in the occurrence of large transport needs, and when these needs are met at the same time, the phenomenon of congestion occurs. Traffic congestion has become a serious problem in many cities around the world and it is a challenge that is not easy to manage. Traffic congestion has increased dramatically also in India. Congestion and the associated slow urban mobility can have a huge adverse impact on both the quality of life and the economy. Traffic congestion has been increasing worldwide as a result of increased motorization, urbanization, population growth and changes in population density. Congestion reduces efficiency or transportation infrastructure and increases travel time, air pollution and fuel consumption. In order to over-come from such congested problem, Intelligent Transportation Systems (ITS) has been utilized to improve transportation systems in the worldwide platform. Intelligent Transportation System (ITS) provides solution to these problems with the help of new technologies. ITS is an integrated system that implements a broad range of communication, control, vehicle sensing and electronics technologies to solve and manage the traffic problems. The purpose of this work is to analysis the implementation of ITS impacts on congestion relief and to further help in improve the system according to Indian perspective. I wish depending on this work, researchers and scholars in the field of ITS can have a clearer view to set their attitude towards suitable future research studies and methodologies which in turn will contribute to the related accumulated knowledge in the field.

Index Terms **- Intelligent Transport System, Traffic Congestion, Traffic control, Traffic information systems.**

I. INTRODUCTION

Traffic congestion has increased dramatically in India. Congestion and the associated slow urban mobility can have a huge adverse impact on both the quality of life and the economy. A popular view is that urbanization leads to ever larger cities and increased rates of motorization. These two features eventually lead to a complete gridlock and congestion. However, economic growth also brings about better travel infrastructure, which facilitates uncongested mobility and increases the pace of urban mobility. Indian cities have experienced both these trends. The multi-purpose nature of urban transport also impacts urban mobility in India. Roads in cities are multi-purpose public goods, used by various classes of motorized and non-motorized vehicles to travel and park, as well as a wide variety of other users such as street-sellers, children playing and animals. Non-transportation uses of the roadway do slow down motorized vehicles. Most cities in India are experiencing multi-faceted problems as a result of rapid urbanization. Urban congestion is one such problem afflicting urban agglomerations in India and has multiple effects on urban economies. Urban congestion is broadly defined as excess demand for travel over its supply.

In fact, the reason why governments are forced to revisit their policies for urban mobility is because of growing demand for travel with limited supply of services. The presence of urban congestion prevents free movement of traffic. We can observe this attitude in the study of the transportation scenario, particularly in road transport. This fast going behavior sets the path to increase the usage of different types of vehicles including two-wheelers, four wheelers, and others. This scenario brings the issues of increased vehicle counts, high traffic, pollution, tragedies of accidents. ITS comes into place not for avoiding all of these types of issues, but it prevents the most of these problems by avoiding in prior. It provides different levels of technological support for dealing with road transportation issues. ITS is an integrated system that includes a wide range of communication, control, vehicle sensing, and electronic technologies.

As traffic congestion has economic, environmental, and safety impacts on society. Operational treatments on roads, such as ITS, provide benefits to these societal impacts. There are many existing solutions to analyse the traffic situations in the real road traffic, yet this thesis discusses the Indian traffic conditions by considering the various external factors which include the abnormal behaviors of the road user. The objective is to understand the ITS and its application in Indian perspective in term of traffic congestion and suggesting some smart solutions to analyse the Indian traffic conditions which in turn paves a way for generating input for more ITS applications like Advanced Traffic Management System (ATMS), Automatic Vehicle Location and Fleet Management System (AVL & FMS), Automatic Vehicle Detection System (AVDS), Advanced Traveler Information Systems (ATIS), Traffic Signal Control Systems (TSCS) and Automatic Fare Collection System (AFCS).ITS and its tools can provide long term benefits to individuals by helping to make surface transportation more affordable, more reliable, and more efficient ways when implemented properly.

II. LITERATURE REVIEW

In general, the concept of congestion may be related to a situation in which a good is used or consumed collectively by a larger number of buyers and this good cannot be provided in the form of separate units. The condition for congestion to occur is that a larger number of users or consumers of a given good will cause negative effects, mainly consisting in hindering others from having access to these resources. The situation described above is common in transport where congestion occurs on a large scale,

causes lots of nuisance, and its costs are high. Congestion occurs when traffic on the road is delayed due to the presence of other vehicles. Along with an increase in demand exceeding the capacity of an infrastructure facility, the costs of users grow and the quality of using the facility deteriorates. Transport congestion is defined as mutual obstruction of traffic by vehicles due to the existing interrelation between the speed of moving vehicles and the volume of flows in the conditions of depletion of the infrastructure capacity. In other words, congestion is associated with such a level of vehicle traffic that exceeds the capacity of a given road which results in a decrease in the speed of moving vehicles or total prevention of free movement. Congestion is a result of an imbalance of the travel demand and the transport system supply. The demand results from the concentration of travel in space and time. The supply is constrained by the historical shape of the infrastructure, the level of investment, transport management and operating practices.

Rodrique et al [1] states that congestion can be perceived as unavoidable consequences of scarce transport facilities such as road space, parking area, road signals and effective traffic management. They argue that urban congestion mainly concerns two domains of circulation, passengers and freight which share the same infrastructure. Thus, traffic congestion condition on road networks occurs as a result of excessive use of road infrastructure beyond capacity, and it is characterized by slower speeds, longer trip hours and increased vehicular queuing.

Downie [2] also opines that traffic congestion occurs when the volume of vehicular traffic is greater than the available road capacity, a point commonly referred to as saturation. He describes a number of specific circumstances which cause or aggravate congestion. Most of such circumstances are concerned with reduction in the capacity of road at a given point or over a certain length, or increase in the number of vehicles required for the movement of people and goods.

There are principally two factors causing traffic congestion, namely micro-level factors, including the high number of people on the roads at the same time, and the overflow of vehicles on the limited road space; and macro-level factors, such as land-use patterns, car ownership trends, and geographical economic development. Congestion is prompted at the micro-level, and steered at the macro-level [5]. Some of the factors causing traffic congestion are listed in Table 1 below:

Table 1: Factors Giving Rise to Traffic Congestion

Sr. No.	Factors Causing Traffic Congestion	Relevant Studies
1	Excessive No. of Vehicles	As stated in the Report on Study of Road Traffic Congestion in Hong Kong (2014), the excessive number of vehicles on the roads is one of the primary reasons why traffic congestion arises.
2	Population Growth	Raheem et al. [4] postulate that as the population of a country increases, the demand for road travel also grows. They however added that the growth in population has not been complemented by the construction of new roads, thus causing roads to be congested.
3	Inefficient Public Transport Services	The ineffectiveness of public transport to offer services efficiently gives rise to traffic congestion, which in turn has critical repercussions on the socio-economic activities of a country [5].
4	Inefficient Road Traffic Management	Road congestion can occur due to the narrow and poorly constructed roads and streets that are ineffective in handling various vehicle types. This results in the inability to effectively manage traffic, creating bottlenecks that last for extended periods [6].
5	Poor Roadway Condition	The uneven road network features, lack of lane discipline, and unsuitable bus-stop location prompt road congestion

III. Intelligent Transportation Systems (ITS) & Its Tools

Intelligent Transportation Systems (ITS) are advanced technologies that have been used in large cities in developing countries to reduce traffic congestion and then increase environmental quality. Congestion causing poor traffic performance has negative impacts on environmental quality. Intelligent transport systems are information and communication technologies or systems placed in transport infrastructure or in a vehicle. They provide for the transfer collection, processing and exchange of information between service providers of traffic and transport infrastructure users. Using intelligent transport system is the best way to solve or at least minimize traffic problems. Intelligent transport system includes all modes of transport and intersects the various components of each mode – vehicles, infrastructure, communications and operating systems. Different countries have developed strategies and techniques that are based on their geographic, cultural, socio-economic and environmental level to integrate the various components into interconnected systems [6]. Current traffic management systems are limited in their abilities to adapt based on real-time traffic conditions. For example, traditional timing systems for traffic signals are programmed based on historical traffic data and are unable to dynamically adjust timing due to irregular events like traffic accidents and construction. Some major cities have implemented a

synchronized traffic signal system with the goal of increasing traffic flows at major gridlock intersections. An intelligent traffic management system could help cities manage traffic flow more efficiently.

The backbone of any intelligent traffic management system is wireless connectivity throughout the city's infrastructure. Relevant technologies include 4G, 5G, low power wide area network (LPWAN), catering to the various end use applications that require different types of networks. Incumbents like Cisco and AT&T are providing cities with 4G and 5G services for traditional high bandwidth applications like traffic signal control, while start-ups like Sigfox and Activity have developed Low Power Wide Area Network (LPWAN) technologies to support the influx of low power sensors.

3.1 Advanced Traffic Management Systems

Advanced traffic management systems (ATMS) seek to reduce, or at least contain, traffic congestion in urban environments by improving the efficiency of utilization of existing infrastructures. These systems typically seek solutions to congestion problems occurring on urban freeways and surface streets through the deployment of state-of-the-art sensing, communications, and data-processing technologies. Problems considered include both congestion caused by regular traffic patterns (congestion management systems) and traffic problems caused by stalled vehicles or other unpredictable incidents (incident management systems).

ATMS is an integrated solution to manage highway traffic through real time information collection, processing, analysis and finally dissemination to the users, concerned agencies and stake holders. To ensure round the clock safety, it is of prime importance to provide real time and precise information to users about the road condition, traffic situations, incidents and weather conditions on the highway. It is also important to make interventions for smooth, safe and efficient traffic movement by providing rescue and relief to the users to avoid distress [7]. Custom-integrated Advanced Traffic Management System solutions is an efficient and cost- effective solution designed, engineered, built and integrated with a balance of customized components and commercially off-the-shelf-products for customer. A highway traffic management system (HTMS)/advanced traffic management system (ATMS) involves a set of intelligently integrated roadside equipment that are connected to ensure a safe and secure journey, including smooth traffic movement and timely reaction to untoward incidents.

Its purpose is to enable concessionaires, highway/road operators or government authorities to monitor complete highway by various sensors & technologies to take corrective actions that ultimately results in assurance of safe journey for road users, enhanced efficiency, productivity, mobility and better highway traffic management system.

ATMS typically attempt to take advantage of information that can be provided by roadside traffic sensors. These systems typically attempt to use available traffic information to develop optimal traffic control strategies addressing traffic needs at a single intersection, along an arterial or freeway, along a given corridor, or throughout a given area. Real-time solutions capable of automatically adjusting to changes in traffic conditions are often sought. These systems also frequently rely on variable message signs or other information dissemination technologies to provide relevant traffic information and travel recommendations to travelers.

3.2 Automatic Vehicle Location And Fleet Management System

Automatic vehicle location systems (sometimes referred to as automatic vehicle monitoring or automatic vehicle location and control systems) are computer-based vehicle tracking systems. These systems are used extensively both for military and civilian purposes, including transit and trucking fleets, police cars, and ambulances. Their use in transit applications continues to grow, driven by a number of expected benefits. Automatic vehicle location (AVL) systems operate by measuring actual real-time position of each vehicle, and relaying the information to a central location. Actual measurement and relay techniques vary, depending on the needs of the transit system and the technology (or technologies) chosen. Each AVL system employs one or more of the following location technologies: dead-reckoning, ground-based radio, signpost and odometer, or global positioning system (GPS).In prior years, the most common form of AVL chosen by transit agencies was the signpost and odometer system. Although some major bus systems are in the process of installing new signpost and odometer systems, most agencies are choosing GPS-based systems [8].

AVL systems designed for surveillance operations enable law enforcement to discreetly track and monitor vehicles. AVL systems can report vehicle information, such as location, speed, and stops, to investigators by obtaining data from global positioning system (GPS) satellites. AVL systems are field-deployable and most can be mounted to the undercarriage of a vehicle in a matter of seconds. There are two types of AVL systems: passive and active. Passive AVL systems, also known as data loggers, store location information and other relevant data to an onboard storage device for later retrieval.

3.3 Automatic Vehicle Detection System

Automatic vehicle detection and recognition has become, in the last years, an important subject of study. Many related applications that have been developed, such as self-guided vehicles, driver assistance systems, intelligent parking systems, measurement of traffic parameters and probably the two most important, related with surveillance problems for fighting crime and preventing terrorism, and accident prevention, continue to suggest that a vehicle recognition system is a good manner to help some different areas such as safety, intelligent transport systems and traffic management. Vehicle classification is a crucial stage in ITS. Most of the classification task is done by human, which has a bad performance in time complexity. However, an automatic system can provide a more accurate and lower cost solution. Classification model contains two parts: feature extraction and classifier selection. In their approach, measurement-based features (MBP) and the histogram of orientation gradients (HOG) features are used to classify the road vehicles into four categories: car, van, bus, and motorcycle [9].

Recently, vehicle recognition system is used to detect the vehicles or detect the traffic lanes or classify the type of vehicle class on highway roads like cars, motorbikes, vans, heavy goods vehicles (HGVs), buses and etc. The detection of moving object's regions of change in the same image sequence which captured at different intervals is one of interested fields in computer vision. An important large number of applications in diverse disciplines are employed the change detection in its work, such as video surveillance, medical diagnosis and treatment, remote sensing and underwater sensing.

3.4 Advanced Traveler Information Systems

There are many sub branches of ITS out of which one of the most widely used is Advanced Traveller Information System (ATIS). Traveler information systems provide travelers with information on one or more modes of transportation to facilitate

decision making before their trip as well as during the trip. Information can be provided to trip makers at home, work, transportation centers, wayside stops, or on-board vehicles. With links to automatic vehicle location, traveler information systems specifically for transit are beginning to provide real-time information, such as arrival times, departure times, an delays [10]. Travelers can access this information through a variety of media. As a traveller the biggest problem faced is the unavailability of the information. This problem can be solved using ATIS, which can provide the information regarding the basic facilities, bus routes, emergency Services etc. and these information proves to be very vital for an user who is new to that city. As Geographical Information System (GIS) is a powerful tool for storage, graphical representation and analysis of information of large data. These all features make it very useful for the development of ATIS.

As a key application category in ITS, Traveller Information Systems (also called "Passenger Information Systems"), use various technologies to track bus locations in real time along with other data that are useful in predicting bus arrival timings at each stop along the route. The information provided to travellers allows passengers to plan their travel time efficiently and reach the bus stop just before the bus arrives rather than waiting for a delayed bus passively. The systems will also allow public transportation systems to attract many passengers by encouraging them to use public transport system rather than private vehicles which results in less traffic and reduces pollution [11]. Real-time traffic data acquisition and the sharing of traffic information with passengers are the essential parts of an advance traveller information system. Real-time vehicle tracking can lead to more efficient operations and also enhanced sense of safety for transit operators. However, issues such as satellite coverage, cost and real-time requirements, make an efficient traveller information system solution challenging.

3.5 Traffic Signal Control Systems

A traffic signal is ensuring that traffic moves as smoothly and safely as possible. The existing scenarios in the major cities need to implement the flexible traffic signal sub-sequences to coordinate the traffic flow. Traffic light/signal controllers are undergone with continual improvement. The main objective of the traffic signal controller is to provide the sophisticated control and coordination on traffic. The co-ordination of traffic light control system is achieved by implementing microcontroller chips to make it a simple and low-cost system, which inbuilt with microprocessors like 8085, 8051 etc. [12]. These microcontrollers are controlling these traffic lights in a specific manner and auto changing at a specified range of time interval or density of the traffic.

Adaptive traffic control system is a management of the traffic system as actual traffic demand. ATCS count and analyzing the incoming data and give the real-time response at intersection geometrics and change the traffic lights as according to traffic demand. It is the majority of traffic signal controllers with various microprocessors inbuilt configurations. An intelligent traffic light monitoring system using an adaptive associative memory was designed. The research was motivated by the need to reduce the unnecessary long waiting times for vehicles at regular traffic lights in urban area with 'fixed cycle' protocol. To improve the traffic light configuration, the paper proposed monitoring system, which was able to determine three street cases (empty street case, normal street case and crowded street case) by using small associative memory. The experiments presented promising results when the proposed approach was applied by using a program to monitor one intersection in Penang Island in Malaysia. The program could determine all street cases with different weather conditions depending on the stream of images, which were extracted from the streets video cameras.

3.6 Automatic Fare Collection System

Automatic Fare Collection System (AFCS) systems calculate the fare that the users must pay depending on the time of service (time-based) or the points of entrance and exit of the system (distance-based). Improvement in transportation systems result into the good life style in which we achieve extraordinary freedom for movement, immense trade in manufactured goods and services, as well as higher rate of employment levels and social mobility. In fact, the economic condition of a nation has been closely related to efficient ways of transportation. Increasing number of vehicles on the road, result into number of problems such as congestion, accident rate, air pollution and many other. All economic activities for different tasks use different methods of transportation. For this reason, increasing transportation is an immediate impact on productivity of nation and the economy. Reducing the cost of transporting resource at production sites and transport completed goods to markets is one of the important key factors in economic competition. Electronic toll collection is a technology allows the AFCS at toll points. As it is studied by researchers and also applied in various expressways, bridges, and tunnels require such a process of electronic toll collection. ETC is capable of determining if the vehicle is registered or not, and then informing the management center about to process violations, debits, and participating accounts.

The most excellent advantage of this ETC system is that it is capable of eliminate congestion in toll plaza, especially during those seasons when traffic seems to be higher than normal. Design and development of a "RFID Based Automatic Toll Plaza" which is based on microcontroller, RFID technology and load cell to save the time at toll plaza and having cashless operation.

IV. INFRASTRUCTURE SOLUTIONS TO URBAN TRAFFIC CONGESTION

In the modern urban world, it would be difficult to locate a metropolitan city that does not have a traffic problem. Over a period of time, a whole series of words, related to traffic congestion, have gained currency to convey different degrees of the severity of the problem. Rush hour, traffic jam, crawling traffic, traffic snarl-up, motorway hold-up, town-centre bottleneck, bumper to bumper driving and gridlock are some of the terms that describe similar or different kinds of traffic scenario. Gridlock is the worst kind of traffic jam, where extraordinary long queues bring vehicle movement on an entire network to almost a complete stop for long periods of time. The worst gridlock reported in history is the Chinese traffic jam on Beijing-Zhangjiakou Highway. In Aug 2010, vehicles stood in a queue for eleven days. The queue ran for more than 100 km, with some drivers spending as much as five days at a stretch on the road. The larger the city, the more problematic city traffic seems to become. This is on account of the ever-rising number of motor vehicles on roads that outstrip the transportation infrastructure capacities of cities. Rising urbanization brings more people into metros; economic success generates more income for families and this catalysis the purchase of more cars.

Cities have tried out several kinds of antidotes to alleviate traffic congestion. Some of these fall in the realm of negative regulations, such as parking restrictions, high parking rates for longer parking, higher parking fee for larger cars and congestion pricing. Positive regulation includes reversible lanes to match asymmetric traffic demand, active traffic management through the

use of GPS and mobile traffic guidance. Others are developmental via the addition of fresh traffic and transportation infrastructure. Quite clearly, none of these have the strength to singly eliminate traffic woes. Even considered together, their efficacy has been limited or short-lived. This has led to transportation planning rising up the ladder as a priority strategy. This invariably comprises these days the promotion of mixed land use and transect inputs that get fully integrated with land use planning as critical components. These strategies allow a city to be organized in a manner that would effectively reduce the need to use vehicles. This is because the arrangement allows most activities to be carried out within short distances either on foot or by cycle.

Infrastructure solutions attempted by cities include road-widening, single or multi-layered flyovers and under passes, grid separators, new roads, signaling systems, signal synchronization, more parking lots and other intelligent traffic responses that use technology to offer solutions. Many transportation experts have been critical of infrastructure additions for personal transport. Road widening, for instance, has been criticized as it makes road crossing for a pedestrian difficult. Additional lanes to ease traffic have been compared to bulky men loosening their waist belt to accommodate accumulated obesity.

Since it is getting tellingly clear that any amount of traffic and transportation infrastructure additions would fail to provide very long-term solutions if citizens keep buying personal cars and commute in them on city roads. This has led to a universal agreement that cities must migrate from personalized vehicles to public transport systems. Many large cities have taken up the construction of metros; others have opted for a BRTS (Bus Rapid Transit System) on account of affordability and relative ease of construction of a dedicated lane for buses.

V. CONCLUSION

Traffic in India can be characterized by the heavy congestion, poor quality of roads and disorderly traffic. Intelligent Transportation Systems (ITS) are advanced technologies that have been used in large cities in developing countries to reduce traffic congestion problems. ITS techniques that were developed for the developed countries, doesn't hold here. ITS in the Indian scenario fails attributable to lack of freeways, non-uniformity of vehicle speed and the lanes made by the ITS techniques in the developed regions. Installation of fixed sensor techniques involve huge installation and maintenance cost. There is need for the techniques that take the characteristics of the Indian roads into account. Use of sensors like GPS, Microphone, Wi-Fi and camera in the smartphones can be used to predict the traffic conditions and arrival time of the vehicle at the destination. Installing the infrastructure on the Indian roads is restricted by the space. Since there are lot of challenges remain to be resolved for the fully deployment of ITS on Indian roads.

In developing countries implementation of Advanced Traffic Management Systems (ATMS) as a part of ITS are well known. ATMS is used to solve traffic congestion problem. ATMS will integrate the management of various roadway functions. Researches regarding the impact if ITS in increasing traffic performance and then enhance the quality of environment in large cities in developing countries are very limited. However, it can be summarized that to produce a good results of implementation of ITS tools in increasing traffic performance and enhancing the quality of environment, specific local geometric and traffic conditions such as limited road infrastructure, high population density, high number of vehicles, high traffic congestion should be concerned. Moreover, road user should change their traffic behavior and adhere to the traffic regulation in order to support government's efforts. Multiple ITS technologies are used by several systems serving rural, small and medium urban, and large urban locations. Each population category uses several different transit management technologies within their systems.

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