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# IMPROVING INDIA'S TRAFFIC MANAGEMENT USING INTELLIGENT TRANSPORTATION SYSTEMS

Umesh Makhloga

# IMPROVING INDIA'S TRAFFIC MANAGEMENT USING INTELLIGENT TRANSPORTATION SYSTEMS

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A Project

Presented to the

Faculty of

California State University,

San Bernardino

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Information System and Technology

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by

Umesh Makhloga

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ABSTRACT

India is one of the largest developing countries in the whole world. There is an increasing trend in the number of vehicles on the roads of India. The increasing number of vehicles leads to rising congestion in large cities. The primary purpose of this project is to determine a proper strategy to solve some of the traffic problems in India like inadequate mass transit, time delays, and blockage on road causing mergers resulting in fatal injuries. The development of effective strategic terms for operating the traffic system of India will need the incorporation of Intelligent Transportation Systems. In this study, first, a comprehensive review of the traffic systems in the world has been done to investigate the existing problems and possible solutions implemented by different countries. Next, India's traffic system has been studied in more detail to understand the existing problems of the traffic management system. Based on the literature review, Intelligent Transportation Systems have been utilized in different countries to help solve traffic issues. Therefore, an investigation has been done in this research about different tools, techniques, and applications of Intelligent Transportation Systems. This study also includes the use of several case studies implemented in different countries involving Intelligent Transportation Systems tools and techniques to solve their traffic problems. Based on those studies, a step-by-step framework is designed to develop a strategy for an effective traffic system. This strategy can help the India's

government and traffic authorities to deal with and solve some of the traffic problems.

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# INTRODUCTION

India is a developing country where personal vehicles are increasing day by day. With the expansion of transportation, the country continuously grows in different economic and social dimensions. It is essential to consider a better traffic management system, due to the rise in congestion of roads in large cities. The main purpose of the project is to define a better traffic management system to increase the efficiency of transportation in India. Manual control of traffic is considered an effective solution for the problem (Aleko and Djahel, 2020). However, an adaptive and automated traffic management system seems to be a better choice to deal with the traffic problems in India.

India is the world's biggest democratic republic. It has a population of 1.3 billion inhabitants and a geographical area of 3.1 million square kilometers. India's population and urbanization grow, so does the demand of usage for vehicles, putting a strain on the current traffic management system. One of the most crucial matters for smart cities is to implement more environmentally friendly and sustainable alternatives to alleviate traffic congestion and levels of pollution. Moreover, the rise in the magnitude and frequency of commercial vehicle load capacity has placed an undue strain on operating road networks that leads to traffic blocking. All traffic control metrics are presently controlled manually and thus does not aid the vehicle in real time (Sahay et al., 2019).

The phenomenon of continuous migration to major metropolitan areas of India such as New Delhi, Mumbai, Bangalore, Hyderabad, Ahmadabad, etc. is being observed. It has resulted in an increase in the total count of urban populations. Mobility requests are outstripping infrastructure potential in this urban environment, resulting in greater traffic congestion. The spread of existing road infrastructure is a feasible alternative, but it is not always possible due to land-use prohibitions and budget constraints. An effective use of current infrastructure through the implementation of dynamic and intelligent control methods, which are flexible to current traffic conditions, is an alternative to the urban traffic congestion problem. Such traffic control techniques will intend to maximize the throughput of the urban traffic network by reducing traffic congestion obstacles, which are frequently found at network crossings (Borg and Scerri, 2015). This research study will help devise the measures to minimize the strain offered by an increased number of transportation entities and limiting the waiting time that will ensure an effective traffic system of India.

The main problem which should be faced by the India’s traffic system is many of the roads are un-surfaced which causes many traffic problems and they are not suitable for the use of vehicular traffic in a significant manner. Due to poor quality of roads in India there were to the wear and tear of vehicles even on many National Highways since the quality of roads was very poor. Therefore, it creates the biggest challenge that must require solutions to promote appropriate activity.

In addition to this, one of the major problems which can be faced by the India’s traffic system is mixing traffic. The single road should be used by the cars which run at high speed, trucks, two-wheelers, tractors, animal-driven carts, by-cyclists and even by animals. Many times, on highways were not free from this affection. This is the reason why the traffic jams are increasing and many times the congestion and pollution would be the reason for accidental cases in a single area. The main reason behind this is the small participation of the private sector in the process of road development in the Indian nation because of high evolution period and low return of investment.

## Problem Statement

According to the current scenario of traffic congestion in India, there is a need for new strategies to decrease the average waiting time by monitoring the number of vehicles in a lane. India's traffic problems must be solved through an in-depth study of the current system, suggesting the ways of improvement, and maintaining the opportunity of growing transportation network. The goal of this study is to investigate the current problems and offer practical solutions for reducing the waiting time for achieving a smoother flow of traffic. In addition, there might be situations where a few minutes can also lead to the risk of human lives and financial losses. Many times, it has been seen that due to heavy traffic, ambulances have also needed to wait in traffic for a longer time. Hence, this study will help to identify strategies for India's traffic system to handle such problem.

Apart from this, it can be stated that in India's cities there are several causes for traffic problems. For example, private encroachments, non-cooperation among drivers, lack of bus bays, lack of demarcated footpath, etc. can cause traffic problems. This study will also address such issues and will try to provide roadmaps for handling these issues properly.

## Objectives

The objectives of this project are to understand the problems of the mass transit options in India and to promote using intelligent transportation systems to reduce congestion and offer smoother traffic on the road network.  In more words, this research aims to identify the key obstacles in the road due to blockage and mergers and then offer strategies for improving traffic signals and road management using digital tools. These goals will lead to alleviating the problem of queue formation which will ultimately reduce waiting time of Indian citizens on the road. The study will also encompass recommendations on ways to improve the India's traffic system and reduce the problem of traffic congestion.

## Research Questions

There are four research questions this study will attempt to answer

1. What problems do inadequate mass transit options cause? What are the solutions for such problems?
2. What are the obstacles on the road due to blockage and merger?

3. What are strategies for improving traffic signals with digital tools?
4. What are the ways to improve the India's traffic system and reduce the problem of traffic congestion?

Methodology

In the present study, India's traffic system has been explored to find the current problems and provide recommendations based on Intelligent Transportation System tools and techniques to overcome these problems. Therefore, it is essential to take a three-step approach to methodology. The first step is to identify different issues in the traffic system. Second, with real examples, this study will explore the existing cases and the solution methods to overcome such issues with implementation strategies to solve existing problems. Third, a framework will be recommended for the India's traffic system improvement based on the successful benchmarks from existing cases. Primary information will be gathered from books, articles, journals, etc. All these are useful to review existing strategies to utilize them for solving India's traffic problems.

Organization of the Study

This project is organized as follows: chapter 1 covers a review of literature related to the general traffic system implied by the world, the potential barriers to traffic system and their proposed solutions. Chapter 2 includes background about the India's traffic system, problems in India's traffic congestion, etc. In chapter 3, different tools, techniques, and requirements of intelligent transportation systems will be discussed. Chapter 4 is dedicated to different case studies. Also designing a solution framework for India's traffic issues based on successful benchmarks will be discussed in this chapter. At last, chapter 5 includes the summary and conclusion of the research.

# CHAPTER ONE

# LITERATURE REVIEW

## Overview of World’s Traffic System

A traffic system is made up of a network, operating regulations, a traffic command and management system, and entities that utilize the network. The network consists of a series of roadways and intersections. The automobiles move through the framework according to the Highway Code's rules. The control operations are focused to visualize information from the management platform in the network using signals such as traffic lights and electronic traffic signals. The main goal of the traffic system is to enable users to accomplish their network journeys in a reasonable amount of time and with a high level of safety (Chabrol et al., 2006).

A traffic management system adapts two strategies to maintain healthy transport; it can either sustain the global level of performance or improve the system's standards in order to potentially lower the time and the number of traffic jams. These steps are required to follow by management; characterizing and modeling the load proposed to the system, investigating the load splitting in the system to identify pivotal regions that cause jams, and dealing with the system to sustain and improve the system's state. The operations are mostly focused on configuration, coordination, and monitoring.

A critical feature of any traffic system is the interaction between traffic networks and land use. The availability of basic access is a crucial component of the design and construction of production developments, such as shopping centers, sports and recreation centers, office buildings, or multi-unit housing projects. For road traffic, this includes access to and from the city development car parking. Aside from the development's instant links to the road network, traffic planners and engineers are also involved in the new development's effects on the traffic system in the nearby region. As a result, considering the volume of traffic created by a development, as well as the parking requirements, is an important part of traffic analysis (Taylor and Bonsall, 2017).

The proportion of motor traffic in the transport system is affected by road speed heterogeneity. Speedier roadways are much more appealing to car operators, giving rise in traffic congestion along such routes. The amount of vehicles crossing through a route or a junction within a specified time interval can be used to determine its primacy. Aside from the variety of road speeds, the inbuilt topology of the transport system has a significant impact on the upsurge of road hierarchies. The dead-end roads, for instance, are at the bottom of the road hierarchical system (Lämmer et al., 2006).

Analyzing human travel pattern is essential to understand a variety of spatial and temporal occurrences. This may have implementations in traffic system architecture, such as the regulation of human contagious diseases and portable virus dispersal, armed services making preparations, and the estimation of human mobility, among other things (Han et al., 2011).

## Problems in Traffic Systems

The effective mobility of people and goods through physical highways and main road network systems is an intriguing problem in a transportation system. A multitude of characteristics distinguishes transportation systems, making them difficult to analyze, regulate, and improve. The systems generally encompass multiple physical regions, have a big proportion of people participating, the participants' aims and objectives are not always aligned with one another or that of the network operator (i.e., system optimum vs. user optimum), and there are several system primary inputs that are beyond the operator's and participants' control (e.g., the weather conditions, the number of users, etc.). Furthermore, road and street mass transit systems are generally complex and dynamic in nature, meaning that the percentage of components in the system fluctuates with time and with a high degree of unpredictability. The number of cars traversing large cities is also rapidly increasing at the present time. This upsurge, which can be attributed to population expansion including the use of automobiles as a mode of transportation, causes plenty of issues in the transportation system. Because there are so many active participants in the system at the moment, there are a lot of interactions going along at the same time. There are several other things that concern traffic, such as traffic diversion and the lack of protection among drivers as a result of an incident in transportation activity (Rocha et al., 2020).

Traffic safety is commonly regarded as a severe issue in the contemporary healthcare system; traffic jams, can destabilize living operations inside a region and place impose a substantial burden on socio-cultural well-being and economic growth; and the climate. Traffic congestion is recognized to be a primary contributor to air and noise pollution, which will have a negative influence on the physical surroundings and a negative impact on human health. When personal efforts are tallied up to interpret issues such as carbon dioxide emissions, the quality of traffic systems can have significant ecological impacts, at least at the community scale and most probably at the worldwide scale. Road traffic systems have a big impact on automotive fuel usage and regional ecological destruction. Issues such as gas mileage and ways to conserve energy sources, air pollution, including gaseous pollutants, noise and vibration and visual intrusion and physical degradation have all arisen in traffic monitoring (Taylor and Bonsall, 2017).

Traffic accidents are serious and emotionally charged issues that no policy maker can afford to overlook. Although advances in automotive design, basic healthcare service, and traffic engineering have limited the crash rate (per unit distance steered) and, in some countries, even the utter and total count and severity of accidents, car crashes remain a leading cause of morbidity and mortality, especially among the youth. They cost the state a substantial amount of money due to lost work hours, traffic slowdowns, the use of ambulance service, vehicular and assets repair and maintenance, in addition to causing human despair and hardship. The traffic system should be designed to take initiatives that reduce the occurrence of accidents that can often make a significant impact on the economic and social welfare (Taylor and Bonsall, 2017).

## Adaptive Measures to Reduce Traffic Problems

Computer simulation is now a common tool in transportation engineering, with diverse applications from scientific research to planning, training, and validation. The advancements in traffic theory, computer hardware innovation and programming tools, the expansion of the general information architecture, and society's desire for a more comprehensive examination of the implications of traffic measures and strategies are the five driving forces behind this progress. The classic Webster's formula is an example of an early utilization simulation with practical consequences in the field of traffic signal control (Raval and Gundaliya, 2012). Traffic systems provide an outstanding application environment for simulation-based design and analysis strategies, as they are an application area where the use of advanced analytics, while critical, is restricted to the subsystem and sub-problem level. The traditional simulation issue in road and street traffic analysis with a functional approach is concerned with traffic flow, that is, the potential and operational characteristics of facilities. With a rising global enthusiasm in traffic circles, postponements and queue lengths at crossings are a never-ending subject of analysis andsimulation studies. Modeling and simulating vehicle movement in existing transportation systems, particularly big urban road channels, is a critical task. It aids in the recognition and control of traffic issues, the optimization of traffic laws, and the real-time adaptation of congestion control for unexpected disaster events (Besenczi et al., 2021).

Scientists and engineers have been paying close attention to the matter of traffic congestion in the past few years. As a result, a wide range of traffic models has been addressed in recent times to investigate the complex patterns. Nagatani (2002) proposed a simple lattice hydrodynamic model and deduced the mKdV equation (non-linear partial differential equation) to explain traffic congestion in aspects of kink density waves near the critical point in 1998. The basic concept is that drivers fine-tune their speed in response to headway. But this phenomenon is usually exhibited in single lane. The anticipation method is very effective in sustaining traffic flow on two-lane highways, and it should be taken into account when modeling traffic flow on two-lane highways. This anticipation effect is used in the new lattice hydrodynamic model of traffic flow whereby anticipation driving individual behavior in sensing relative flux is considered. Linear and nonlinear analyses were used to examine traffic behavior (Gupta and Redhu, 2013).

Rocha et al. (2020) developed a system named TRAFFIC. TRAFFIC is an inter-vehicle communication solution for assessing road congestion and optimizing transportation flow in a traffic system. TRAFFIC is comprised of a set of classification techniques that seek to enhance the accuracy of vehicle traffic classification. As a result, the proposed dissemination system utilizes this categorization as a constructive feed. The dissemination mechanism provides comprehensive data using the Subscribe communication module, which manages to elude broadcast storms by exchanging texts to categories of respondents. The suggested solution was evaluated by comparing to other well-established options in the literary works in ensuring TRAFFIC's effectiveness in regard to the traffic jam matter (Rocha et al., 2020).

Road traffic and its consequences have an effect on all areas of contemporary civilization, including entertainment and business, with protection, overcrowding, and environmental damage causing the most problems. To enable real-time surveillance, regulation, and traveler information sharing, transportation planning progressively highlights travel demand management (TDM) and traffic calming - assisted by versatile, lower-cost data from Intelligent Transportation Systems (ITS) (Taylor and Bonsall, 2017). Deflections in the vertical and horizontal planes are critical in minimizing speeds and, as a result, accidents. It is evident, however, that the effectiveness of such strategies is defined not only by objective measures of their impact (on speed, flows, and accidents), as well as by subjective evaluation (Rahman et al., 2009). Among the most common key factors responsible for traffic incidents is a reduction in the safe distance, such as when a car suddenly cuts in from another lane. Regardless of the reality that the distance of safety (DS) is subjectively assessed, the most developed nations are now developing automobile black boxes, so it is normal to assume the distance of safety to be automatically recorded (Bugaev et al., 2011).

Transport networks are typical man-machine systems in that they have both human (driver-vehicle-elements) and man-machine interactions (driver interaction with the vehicle, with the traffic information and control system and with the physical road and street environment). The importance of different aspects of driver behavior in assessing road safety is critical and hard to evaluate. Furthermore, the laws of interaction are approximate in nature; drivers' assumptions and responses are controlled by sensory consciousness rather than sensor and monitoring frameworks based on technology (Farooq and Duleba, 2019).

## Strategies Implied by US Government to Control Traffic

To minimize traffic speeds and volume, numerous countries have executed traffic calming provisions of which America is one of the successful empires. Traffic calming is a method of reducing the adverse effects of traffic on citizens and pedestrians. Traffic speeds and volumes can be reduced, which can lessen the intensity of vehicle collisions, especially regarding pedestrians and bicyclists. Essentially, traffic calming aims to minimize the negative effects of automobiles on local roads. It has the potential to decrease vehicle speeds and volumes while also providing more areas for pedestrians and cyclists. These plans typically include a variety of elements such as speed humps, speed tables, highlighted crosswalks, cycle lanes, chokers, traffic circles, rings, and road markings. By constructing roadways that are best suited for strolling, bike riding, and general populace transit, traffic calming can be a crucial component of Transportation Demand Management (TDM) programs. According to this technique application of traffic calming in the USA resulted in speeds being reduced by 14% (5 mi/h) and traffic volume reduced by 7% (Rahman et al., 2009).

The TRANSIMS (TransportationAnalysisSIMulation System) development work in the United States is an illustration of a network approach in the traffic system. TRANSIMS is an accessible traffic simulation that includes micro-simulation, which is required to obtain transportation traces, as well as a tool for generating vehicle trips. The simulation of a city's traffic system relies heavily on parallel computing, which is an attribute that is becoming more popular in today's applications. Parallel computing can be accomplished by using multiple microcomputers connected to a local network at the same time (Berres et al., 2019).

In the United States, ground transit is a major contributor to greenhouse gas emissions and, as a consequence, a major cause of global warming. Relocation or commodities means that nearly a third of all CO2 emissions in the United States, with vehicles and vans accounting for 80% of all those emissions. To minimize environmental impact of the transportation industry, policymakers are largely advocating for further fuel-efficient automobiles, alternative energy sources, and a decrease in vehicle miles travelled (VMT). Advocates for automotive advancements have emphasized producing lighter and smaller vehicles (while retaining security), boosting engine economy, and promoting emerging solutions such as hybrid and fuel cell vehicles. Alternative fuels include bio fuels and synthetic fuels, which are both low-carbon options. Reducing CO2 emissions by reducing traffic congestion has received less attention from policymakers. Fuel consumption and CO2 emissions rise in tandem with traffic congestion. As a result, CO2 emissions should be reduced as a result of congestion mitigation programs. Several factors influence environmental costs and fuel usage that generates traffic congestion. So, it is difficult to know that to what extent congestion can be reduced.

Personal riding behaviors, car and highway types, and traffic circumstances are all aspects behind. Because of these factors, a chart that estimates CO2 emissions simply by relying on a personal parameter, such as journey distance, will be inaccurate. Rather, a more precise emissions assessment for varied models of vehicles and diverse levels of traffic congestion can be created using a comprehensive methodology that takes account of the latest motor movement measurements and comprehensive vehicular emission variables. As a result, an accurate estimation of the extent of congestion reduction initiatives will decrease carbon footprints and can be calculated by determining driving patterns and emissions.

Driving pattern and emission is very important. A normal driving roll includes stopping, accelerating, humming, and decelerating. The amount of time spent in every stage of a journey is governed by the driver's behavior (violent vs. gentle), the kind of route (main highway vs. arteries), and the degree of traffic jams. Depending on these factors, the carbon dioxide Released throughout the journey will fluctuate. Considering a certain velocity distribution and thorough vehicle characteristics, a car emissions prototype could be used to estimate the release of carbon dioxide. A study conducted by the University of California Riverside (Vreeswijk, Mahmod, & Van, 2010) developed emission estimations for several kinds of vehicles (UCR). A vast amount of data was collected in the lab as well as on the roadway in congested traffic. Several well-justified models provide the foundation for predicting CO2 emissions from a wide range of cars under a variety of driving circumstances. Hence, by knowing the extent steps could be taken to mitigate the levels of carbon dioxide emission (Barth and Boriboonsomsin, 2009).

The relationship between driving and carbon emissions has been finely grained, allowing humans to generate more accurate estimations about how traffic-management measures can aid in the fight against climate change. The amount to which three traffic management enhancements can cut CO2 emissions has been calculated (Vreeswijk, Mahmod, & Van, 2010):

• Congestion-reduction measures that boost travel speeds while reducing congested roads (e.g., ramp metering, incident control measures, and congestion cost)

• Techniques for reducing excessive velocities to much more modest concentrations of roughly 55 miles per hour (e.g., regulation and ISA)

• Traffic smoothness methods (e.g., regulation and ISA) that lessen the quantity and severity of explosive movement incidents (e.g., different speed limits and ISA).

Every three-traffic volume solution mentioned might minimize $CO_2$ emissions by 7 to 12 percent under typical conditions on Southern California freeways. When all three strategies are combined, $CO_2$ emissions could be reduced by about 30%.

# CHAPTER TWO

# BACKGROUND

## India's Traffic Phenomenon

According to Singh et al., (2021) India has a very flexible traffic system as compared to other countries' traffic control systems. The rules of the roads are totally different compared to other countries' road rules. If any of Indian drivers are driving abroad and did not know the rule, then it is more likely to have accidents because it might be difficult for them to follow the rules. There are so many roads in India that are still under construction and roadways are in the process of development so that there are very less traffic records as compared to other countries. This can provide a chance to create accurate transportation of roadway and develop the traffic system. However, India has fewer traffic records of accidents and troubles on the roads, so the number of incidents is also much less.

Pal et al., (2019) argued that over the past few years, the system has been developed and massive enhancements are also created in roadway transportation. The necessary steps had been taken by the Indian road government to enhance roadway transportation in India. In the aspect of tourism, the National highways starting from the North to South or Jammu to Kanya Kumari have been created steady progress and well developed. However, the maintenance of the National highways has slowed down and reduced due to the frequent change in the government. The roads that are around the central states have been maintained and well developed but, in the south, are still under construction, damaged and rugged.

In past years, the huge amount of traffic difficulty has decreased, and a better-quality traffic system was created. Maintenance of the roads has resulted in positive consequences and has upgraded in the case of traffic system of India. May be road construction department will not require more in India if each citizen understands that roads are laid for them only and take responsibility for maintaining them. Selveindran et al., (2021) stated that the huge landscape of India has been dotted with mesh and rugged mountains of certain water bodies, which seems dangerous for travelers. Sadly, since the independence of India, road safety has always been a big problem for the country. In addition, road safety complication is not only for big cities it is also for rural areas and small villages or towns of India. It has been seen that the advancement of rural India has always remained a dream because of the corrupt authorities of India. Due to the friendly policies of the government in Delhi, the traffic system has largely benefited and developed because of the introduction of the CNG buses and Metro rail. Although, there is no doubt that the generation is getting faster nowadays. All over India, plenty of vehicles are there and roads are still insufficient to fulfill the increasing demands of road traffic. Mukherjee and Mitra, (2019) expressed that the roads of Delhi have still appeared narrow even after the formation of many flyovers to minimize the traffic congestion and maintain the smooth flow of diverse vehicles such as cars, trucks, high-acceleration bikes, dangerous blue line buses, cycle rickshaws, bicycles, and scooters. The speed systems of these vehicles are totally different and sometimes these different varieties of speed cause certain accidents through traffic. Traffic safety in India has gotten worse day by day. To control these types of traffic issues, India's traffic authorities are not making any kind of effort, and numerous deaths are taking place on the roads of India. However, until and unless the citizens of India will begin to be patient while driving and respect other commuters the popular phenomenon of Indian roads will remain the same. To reduce such types of issues, the traffic authorities should act proactively on this condition.

## Existing Suggested Improvement of the Traffic System of India

As it is widely known that Delhi is the capital of India which has traffic congestion. This congestion leads to waste of at least two to three hours in the whole day of citizens. Now since the situation is well versed by everyone, authorities of traffic safety must try to solve the issues in every possible way. Here is the list of certain solutions for traffic issues that arise in India every day such as:

According to Mehdizadeh et al., (2020), it is very easy to answer the most particular question of road safety and the hoard of vehicles on roads. To think about it, one single vehicle that is carrying all the travelers will take less space than two or four individual vehicles. Citizens should travel in buses because numerous people are fitted in these types of vehicles and drastic differences would be noticed in the number of acquired road areas by the travelers. It is ensured that all the citizens must be thought about it but some reasons of privacy, last-mile connectivity, and comfort can make them stop doing so. To develop ridesharing, every people can get help from mobile apps. Also, social media discussions can help to connect with other people who are the right correspondent for sharing the ride. If in case the person does not type of online, they must try to relate to office peoples or their society members and it sure that they can find someone who is traveling too. As per the report, sharing the cycle will surely solve the purpose of possible outcomes and last-mile connectivity for the enthusiasts of cycling. More importantly, the better overall health of citizens will also be contributed, and no carbon footprint will be exfoliated through the public cycling system. Numerous benefits are there of adopting public cycling system and it is good enough for all the cities in India.

Many solutions to traffic issues are determined by traffic signals. Traffic police can maintain a regular flow by utilizing these alternatives rather than holding the massive traffic through typical red/green lights for several minutes. However, the development of underpasses or flyovers had skipped the traffic signals for the huge traffic. Several big cities in India have crowded public areas and multi-level parking is the best solution and works wonders for these types of congested roads surrounding these areas. Chen et al., (2020) argued that small parking areas of such market areas are not sufficient for a huge incoming traffic base, especially for the season of festivals. A pedestrian can also suffer because of the long maze of vehicles and making their way from this traffic. To avoid traffic multi-level parking helps to the final check of vehicles rushing in the specific public place. Once all the citizens can understand their responsibility for vehicle parking then it can be easy for visitors to go to their desired place on foot.

According to a study, in India, every four minutes there was a death of one person by a road accident (Singh, 2017). So that, in every condition of road safety there is the essential requirement of technology for the India’s traffic system. Indian citizens, as well as authorities, can make sure to encourage innovation and must create systematic rules for road engineering departments, connectivity, automotive components, driving apps, and leveraging vehicle data management. There have been some studies on how to make India’s roads safer. According to Thakur et al., (2021) by utilizing ranging guns and light detection, law officials can enable to catch the vehicles by which speed limits were crossed and it is easy to use. There is an invisible infrared beam present in the gun so that traffic police can be able to target a particular vehicle that crossed the speed limits based on the recorded variation of light.

Speed indication display – Implementing warning signs on the edge of roads is useful for drivers and road users. Digital speed boards are installed with radar sensors through which the speed of the vehicle can be evaluated, and an LED display shows all vehicle speed limits. At present, there are lots of speed indication display devices available and they capture pictures of vehicles speeding. These signs are displayed on LED boards and show the necessary information to travelers. Such Indian cities like Hyderabad and Bangalore have installed these signs and, in the future, it can also be implemented in Delhi. Through the help of these signs, the latest updates on traffic conditions and road safety are provided to the road users, especially for traffic congestion and vehicle breakdowns. Aleko and Djahel, (2020) stated that it can determine the waiting vehicles at the junction in advance and refer this information to traffic signals, which can modify signals based on the circumstances automatically. Whenever any vehicle comes to a specific area the frequency of loops was changed and it makes use of electromagnetic fields. Additionally, it determines the type of vehicles based on frequency changes.

Here are many significant ways which can be used by the ITS for solving the problems of traffic in India. They put initial rules and regulations on the traffic jams at the time when they manage of initial safety of their roads. This can involve different technological terms for making changes or implementing ITS on the roads, transit options, and developing many effective strategic terms for operating the traffic system of India. In addition to this, the following are a few ways that new technologies can be used for solving the problems of India’s traffic problems.

According to Muneera, and Karuppanagounder, (2022), the Indian traffic Police set effective traffic signals in crucial areas where traffic would be found in huge amounts. Many of the people are stuck in that area. They have established various cameras for controlling the traffic signals and if any people break the rule of traffic so they can track them and post the charges on their registered address. Kovvali, and Ganji, (2019) suggested that drones are helpful technologies for reducing traffic problems. Many applications support the home delivery of their services which is related to food, etc. So, the government decided to use technology like drones for the delivery of their services. Drones can fly over the sky, and they do not need to go onto the roads so it would be a great solution for solving the problem of traffic. In addition, Balasubramanian, and Sivasankaran, (2021) shed light that the use of drones is a very effective thing that can be found in the Indian nation, especially for the traffic officers standing in the area where the huge number of vehicles would be crossed over there. The traffic police or officer helps to manage the traffic onto those roads and control the traffic in India.

According to the point of Alam, and Jaffery, (2020) for improving the India's traffic system, developing effective and efficient capability on the roads can be helpful. This is one of the essential methods which help to reduce traffic jam in small cities. So, it is recommended to establish additional roads which are called bypasses to divert the heavily loaded vehicles. Another recommendation from Dhanoa, Tiwari, and Malayath, (2018) for the improvement of India's traffic system is to set the parking restrictions in a significant manner. In the India, many people cannot follow the parking system and they park their vehicles wherever they want, so the traffic police can be recommended to monitor the situation and decide the initial place to where the people can park their vehicles, and if any of them does not follow the rule then they get a ticket.

From the perspective of Mandhare, Kharat, and Patil, (2018), the bicycle helps reduce traffic. The bicycles are cheap to purchase, and they can be run in urban and rural areas quickly door to door. The bicycles are low weight, and they can be used for transport purposes. A bicycle is noiseless, non-polluting, energy and space efficient, etc. The bicycles are also very helpful for the health of people. Besides, Muneera, and Karuppanagounder, (2022) encourage people to walk to reduce traffic problems. It will help if the government of India starts encouraging people to walk instead of driving sometimes, if they must travel near their houses with walking distance.

From the analysis of different articles on effective traffic systems, intelligent traffic management systems using with RFID technology can also effectively reduce traffic problems. Such system helps to provide practical traffic data to be used for many purposes such as reducing travel time for users. It is also used for many other purposes such as stolen cars, vehicles, etc. It is also useful to denote perfect signals, toll collection, taxes on vehicles, etc. As a result, the system creates a map of the shortage time path for the development of the city. Apart from this, it can be stated that advanced manufacturing technologies enable big data analytics. Therefore, it helps to boost productivity, enhance efficiency, and development of innovation.

An investigation was undertaken that includes different factors with big data analytics that examined to assess challenges that provide recommendations (Amini, Gerostathopoulos, & Prehofer, 2017). There is a result undertaken with the investigation to suggest production improvement with the traffic system. For the growth of the nation, it is essential to determine cost-effective activity with vehicle count to meet the demand of overgrowing cities with traditional traffic lights deployed in different cities. Intelligent transportation systems were also promoted with several attempts made with automating traffic lights based on the density of vehicles on road. Researchers also suggest a distinctive framework that establishes to tackle congestion issues that depend on traffic nature (Rao, 2001). India is the second-largest country in terms of population. In the next chapter, the intelligent transportation system tools, techniques, and applications for improving the traffic on road networks are investigated.

# CHAPTER THREE

## ITS TOOLS, COMPONENTS AND APPLICATIONS

This chapter includes the introduction to the Intelligent Transportation System (ITS) following the tools, techniques, and requirements of such systems. Various components and applications of ITS are also discussed in this chapter. The literature review shows the advantages and benefits of using ITS in the world's traffic systems mainly in the United States.

The apparent traffic conditions on roads and highway networks are the outcome of a tricky supply-and-demand conflict. The availability of roads and highway infrastructures is a major determinant of the supply. Independent driver choices following the submission (or not) of a trip, means of travel, time of departure, path to be pursued, and other factors contribute to the demand. All around the world, elevated numbers of traffic congestion are being witnessed on roads and highway networks, with adverse repercussions for traffic effectiveness, security, and the environment. Congestion reduces the capacity factor of basic infrastructure, resulting in a negative feedback loop of increased congestion, infrastructure diminishment, and so forth. In reality of course, in congested road or highway systems, traffic throughput is typically even under the fractional network capacity. The traffic control initiatives and techniques outlined in this chapter focus on maintaining accessible infrastructure capacity as near as possible to nominal levels, guarding traffic networks against excessive numbers of deadlocks. In this way, traffic control is thought to be primarily concerned with the supply side of the basic traffic model (Papageorgiou et al., 2007).

Intelligent Transportation Systems (ITS)Intelligent transportation systems (ITS) are automated advanced traffic control systems that aim to improve traffic safety, optimize traffic flow, and reduce the power usage of vehicles on the road. A monitoring program, a communication protocol, an energy conservation scheme, and a traffic signal control system are all part of an ITS. Even though ITS can correspond to every means of transport, the European Union's directive 2010/40/EU, which came into place on July 7, 2010, described it as structures wherein the data and communication technologies are being used in the case of road transportation, which includes architecture, automobiles, and consumers, and network management and mobility management, and for integrations with certain other methods of travel (Payne, 2015). Since the early 1970s, ITS have been developed. It is the transportation system's future direction (Zhu et al., 2018).

Wireless network technology advancements and the innovation of automotive network protocols have paved the path for the introduction of ITS in recent years. ITS is described as the incorporated use of sensing technologies, computation, electrical, and communications technology, as well as management practices, to strengthen the mass transit system's effectiveness and security. The primary objective of ITS is to assess, create, evaluate, and merge sensors, information communication systems, and concepts in an attempt to optimize traffic flow efficiency and improve ecological integrity, save power, and save time for operators, pedestrians, as well as other traffic groups (Mandhare et al., 2018).

Centered on data from the internet that explains traffic conditions such as concentration, pace, journey time, vehicle location, and current time the key obstacle in accomplishing that goal, however, is determining how to predict traffic congestion and reroute vehicles adequately by taking into account the moment influence on future traffic in a field of concern. Insufficient potential or density, as well as unrestricted requirement, are linked, but signal impairments are directly integrated and unaffected by traffic density. As a result, the traffic control system must be optimized and made more engaging in order to meet widely different traffic densities (Mandhare et al., 2018).

The majority of today's traffic light control systems employ one of three control methods: fixed time, actuated, or adaptive. The overarching goal in each case is the same: to improve safety, speed, and energy economy, or to decrease wait period and vehicle pauses. This is not an easy problem to solve in a rapidly evolving traffic situation, in which every traffic light system must contribute to a variety of variables such as crossing type (solitary- lane or double-lane), traffic density, duration of the day, impacts on other roadways, and pedestrian traffic participation. (Zhou et al., 2010).

A traffic signal control system is one of the most important components of urban traffic management systems for improving traffic safety and efficiency at urban intersections (Liou et al., 2017). Traffic signal management is a multi-objective approach that incorporates delays, crowding, polluting, gas mileage, and traffic throughput into a system performance metric. It could be centered on a stage, like TRANSYT (TRAffic Network StudY Tool), or a cluster, like SIGSIGN (Signal Sign). Signal optimization has an impact on a number of decision parameters, including green time, loop duration, stage sequencing, and offsets. Signal time optimization for a secluded intersection is reasonably simple, but it is complicated to improve timing in congested networks because junction intervals are too tiny to disperse squadrons of vehicles. The intricacy of signal coordination is the source of the issue (Ceylan, 2006).

Another paper by Diekel et al. (2021) talks about the system that is incorporating into the traffic system and concentrates on reducing greenhouse gas emissions caused by inactive automobiles at traffic intersections during peak hour traffic. Diekel et al. (2021) developed a device called "Eco-Sign" that will allow automobiles to switch their motors on and off automatically when stopped at a red light. As a component of the system, a localization unit (LU) would be put at a traffic light. The traffic lights will be connected to a traffic control unit (TCU). A vehicle unit (VU) will be installed in each mode of transportation to maintain the LU and TCU linked. When it approaches a signalized intersections area, the TCU sends information to the vehicle's VU.

Osman et al., 2017 paper was used to monitor traffic, in which a hardware and video-based traffic management system was included. In this study, a monitoring device was created as a cost-effective alternative for a CCTV camera. This device was created with the help of camera phones and is powered by solar energy. Table 1 shows the origin and generations of the ITS.

Table 1.Shows the Time Origin and Generations of the Intelligent Transportation System.

| Serial No | Generation | Originated/ Time Period | Technology |
|---|---|---|---|
| 1 | First Generation (ITS 1.0) | From 1970 to the start of the 21st century | One way infrastructure |
| 2 | Second Generation (ITS 2.0) | 1990-2000 | Two-way communication technology |
| 3 | Third Generation (ITS 3.0) | 2000 - 2003 | Automated vehicle operations and automated interactive system operations and system management |

| | | | |
|---|---|---|---|
| 4 | ITS (ITS 4.0) | 2006 - 2011 | Multimodal for process automation and personalized situational mobility services, mobile telephone gadgets, automobiles, architecture, and networking technologies are all included. |

Components of Intelligent Transportation Systems

1. Automated Data Collection: It necessitates comprehensive and accurate organizational strategies, as well as proficient hardware and software. Several of the hardware being used in data collection provides automatic vehicle recognition, GPS-based automotive locators, video camera, sensor systems, etc. For such massive volumes of information, analyses such as traffic counting, monitoring, traverse speed, time, location, and delay can be performed.

2. Data Transmission: Data transmission is a crucial component of ITS execution because it allows for quick and real-time information communication. A traffic-related declaration can be sent to a traveler via SMS, the World Wide Web, on-board vehicle units, and other means.
3. Data Analysis: Adaptive logical analysis, error corrective action, data filtering, and data synthesis methods are all part of data analysis. The information will be analyzed even more to create a traffic scenario forecast. After data analysis, the benefit is real-time information such as driving time, delay, car crashes, route changes, work zones, obstructions, etc.

With the factors listed above, ITS encompass and strengthens nearly every facet of transportation engineering. There are many ITS auxiliaries, but the following are the most important and commonly employed to address road and transport challenges:

- The Advanced Traveler Information System (ATIS)
  It is a system that provides information to travelers. It uses a variety of technologies, including the internet, telephones, cellular phones, television, radio, and other media, to assist travelers and motorists make wise judgments on trip schedules, optimum courses, and accessible forms of transportation (Tubaishat, 2009).
- Advanced Traffic Management System (ATMS):

It is a traffic management and command tool used by traffic law enforcement officers and traffic regulatory agencies to control the traffic flow and make prompt decisions. Traffic management systems work to enhance traffic flow by interacting with and altering features such as traffic signals in real time to enhance the traffic flow (Tubaishat, 2009).

- The Advanced Public Transportation System (APTS)

  It is a state-of-the-art public transportation system. Its goal is to increase the operational effectiveness of all public transportation modes while also improving the transportation system's reliability. Thanks to APTS, the approach by which public transit networks function is being revolutionized, as well as the type of transport systems which can be supplied by them (Tubaishat, 2009).

- The Emergency Management System (EMS)

  This is the most contemporary research area in the intelligent transportation systems field. The application of various intelligent transportation system innovations, in order to construct a transportation system that can aid in emergency cases, is the primary focus of EMS. In a study by Tubaishat, (2009) which implied Emergency Management System strategies like vehicle to infrastructure (V2I) or vehicle to vehicle (V2V) communications, complicated management techniques with network-wide traffic control requisite have been used for convenience of living standards in cosmopolitan and urban areas.

## Wireless Communication within ITS

Improving transportation system efficiency has significant economic and environmental benefits. The United States Department of Transportation declared in May 2006 that "one of the absolute greatest challenges to our economic development and mode of living is traffic congestion," costing the country an estimated $200 billion per year. Every year, the traffic congestion problem worsens. Due to traffic congestion, urban Americans traveled an additional 4.2 billion hours in 2007, up from 220 million hours in 2004. In densely populated emerging countries such as China and India, the scenario is far worse. In order to alleviate traffic congestion, intelligent traffic control is critical. Wireless sensor networks (WSNs) are new systems that have the potential to revolutionize congestion supervision and operation (Tubaishat, 2009).

WSN has the ability to profoundly enhance the effectiveness of today's transport networks. At the moment, wired sensors are used to collect information for congestion design and governance. Existing sensing systems' high equipment and maintenance costs, as well as their time-consuming installation, impede huge implementation of actual traffic management and surveillance. Tiny wireless sensors with combined detecting, computation, and wireless connectivity functions save money and are easier to set up.

As these wireless sensors get more commonly accessible, their prices fall. Designing massive, practical, and high-performance sensor-based traffic control systems will become a huge challenge. Such traffic control systems demand careful corporation to improve WSN technology with intelligent traffic control criteria to enhance the performance of road networks while prolonging the life of wireless sensors. These systems' successful development of technologies will result in considerable reductions in traffic jams, transit time, fuel usage, and environmental pollution. Traditional traffic monitoring sensors used in ITS include inductive loops, video cameras, ultrasonic sensors, radar, and others. They need a lot of energy and are connected to centralized data processing facilities. The majority of present sensors are costly in terms of large hardware and time-consuming sensor and cable installation. As a result, sensor-based traffic monitoring and control system installations are extremely shortened.

Existing sensors' flaws are addressed in the next generation of wireless sensors. The latest sensor nodes are compact, low-energy, long-lasting on battery packs, and easy to set up. Existing sensing systems offer much less versatility, and the price is so little to set up and manage as compared to the network of wireless magnetic sensors. As wireless sensors become more affordable, they may be used in huge numbers across the traffic system to provide an extensive overview of traffic situations and monitor vehicle flow, velocity, and load at high spatial and temporal resolutions. ITS applications are divided into two categories by the US Department of Transportation: intelligent infrastructure systems and intelligent vehicle systems (Tubaishat, 2009).

Sensors used in transport networks for traffic analysis can be separated into two types based on their placement: intrusive and non-invasive sensors. Sensor placement has a big impact on the expense of mounting and repair as well as the quality of sensing, sensor life, and traffic disruption (Tubaishat, 2009).

- Intrusive Sensors: Inductive loops, magnetometers, micro loop probes, pneumatic road tubes, piezoelectric cables, and other weigh-in-motion sensors are examples of intrusive sensors. Pneumatic road tubes are inserted in saw-cuts or perforations inside the road pavement, by digging underneath the surface, or by fastening firmly to the road surface. The major benefit of these detectors is their great detection precision. Furthermore, they are well-established technologies with well-understood operations. They do, however, have some serious issues, such as high costs, traffic disruption while mounting or maintenance, and problems related to setups on poor pavement surfaces including the use of inadequate installation processes. Resurfacing of roads and utility repairs may necessitate the replacement of these sensors.

Non-intrusive: Non-intrusive sensors, sometimes referred to as the sensors above ground, include recording devices, microwave radar, laser radar, passive infrared, ultrasonic, passive sound array, and sensor pairings such as passive infrared and microwave Doppler or passive infrared and ultrasonic.

Above-ground sensors can be installed just above the line of traffic they're tracking or on the side of the street from which they can see numerous roadways at perpendicular or oblique angles to the stream wise direction. Above-ground sensors, like subsurface detectors, quantify, detect, and track the movement of vehicles. Initial velocity, vehicle categorization, and surveillance for multiple-lane, multiple-detection zones are all available on many of them. Many freeways and surface street applications require above-ground sensors, but they do not have the disadvantages of intrusive sensors. Non-intrusive sensors, on the other hand, are typically bulky and power-hungry, and function miserably in adverse weather conditions such as haze, blizzard conditions, or rainfall (Tubaishat, 2009).

For intelligent transportation systems, a variety of mobile communications systems have been suggested. For brief & medium distance communication between devices, radio modem communication on UHF (Ultra High Frequency) and VHF (Very High Frequency) frequencies are commonly employed within ITS. For relatively brief communication systems of 350 meters, IEEE 802.11 standards notably WAVE or the dedicated short-range communications (DSRC) protocol proposed by the Intelligent Transportation Society of America and the United States Department of Transportation could be utilized (Kenny, 2011). Using mobile ad hoc networks or mesh networking, the range of these techniques might potentially be enhanced. Sufficiently long telecommunications are handled by networking systems like 5G. Long-range communication protocols are very well, but unlike relatively brief technologies, they require considerable and costly network implementation (Tubaishat, 2009).

## Data Management in ITS

ITS plays an important role in today's world. The conventional system for the development of next-generation technologies is the ITS. It is a new concept that connects various aspects of the transportation system, including transportation management, service control, infrastructure, operations, policies and control methods, and so on. For ITS installations, there is a range of funding alternatives. Due to a lack of information transparency in today's transportation systems, local events and singularities frequently escalate into large-scale faults. By constructing an adaptive sensing network that allows for the automatic collection of information about road conditions and traffic load, steps have been taken to increase transparency. It will be extremely difficult for humans to keep track of the vast amounts of data as these systems evolve. As a result, a spatiotemporal data mining algorithm is required for human decision-making predictions. The steps for implementing data mining algorithms are as follows:

1. Data Collection: ITS technologies can gather a wide range of roadway information, such as the number of cars traveling into a certain area and their mean velocities. They can also detect the position of vehicles using mobile telephone surveillance or satellite-based systems.

2. Data Transmission and Processing: After gathering data, ITS can transfer it to core functions, where it would be consolidated and processed into material that will be utilized to make long-term decisions.

Making well-informed decisions: The data generated could be used to create well-informed judgments. This information generated can subsequently be used for a range of systems to achieve the seamless operation of road systems. A road operator, for example, can utilize the ITS system to analyze highways, while a car driver can alter his path depending on revised traffic information (Prabha and Kabadi, 2016).

Intelligent transportation Applications

1. Automated Road Enforcement:

   A highway patrol surveillance system, which comprises a camera and vehicle-monitoring equipment, detects and identifies vehicles that break a speed limit or other highway law requirements, and punishes violators depending on their registration plate. Mail is used to deliver traffic tickets. The following are some examples of applications in this context: Vehicles exceeding the legal speed limit are detected by speed cameras. To monitor a vehicle's speed, most of these gadgets use radar or electromagnetic loops installed within the lanes of the road. Red light tests portion vehicles that exceed a threshold limit or authorized halting area whereas a red traffic signal is on. Bus rapid transit cameras identify vehicles driving in lanes reserved for buses. Taxis and vehicles participating in carpooling can use bus lanes in some jurisdictions. Level crossing cameras identify vehicles unlawfully across trains at level. Vehicles crossing double white lines are detected by cameras. Vehicles that do not meet with High Occupancy Vehicle (HOV) laws are detected by associated lane cameras. Turn cameras are utilized at crossings where certain movements are restricted on red. Generally, this kind of camera can be used in concentrated places or densely inhabited regions (Qi, 2008).

2. Variable Speed Limit

   VARIABLE-SPEED limit sign (VSLS) systems are made up of dynamic message signs (DMSs) that are positioned across a highway and linked to a traffic management center via a communication system. The VSLSs are used to indicate a speed restriction that is either regulatory or advisory. In contrast to standard fixed speed limit markings, VSLS enables mass transit administrators to constantly publish a speed limit that is suitable for existing traffic, climate, or even other circumstances. VSLSs are believed to enhance traffic flow and travel times while also enhancing safety and reducing driving stress. VSLS systems have been deployed in a small number of jurisdictions around the world, including the United Kingdom, the Netherlands, the United States, Germany, Australia, and New Zealand (Allaby et al., 2007). These systems have been found to lower data speeds, speed variance, and lane use, and provide a quieter comfortable ride, some of which might correlate to a quantifiable decrease in accident frequency and intensity (Allaby et al., 2007).

3. Emergency Vehicle Signal Pre-emption (EVSP)

   Over 98 percent of citizens of Taiwan said they have seen paramedics on open streets in Dearborn Heights, but 82.9 percent said they have failed to react accordingly whenever emergency vehicles (EV) arrived (Savolained, 2020). According to the research by Savolainen (2020) there were 3708 accidents involving emergency vehicles in the United States between 2004 and 2008. The disturbance to normal driving gets more severe after the in-car data system forces the operator to respond longer to the emergency services. Such an in-car system includes an on-board device, a cell phone, or a television. To save civilians and assets, Emergency Vehicles (EV) must arrive quickly. In some emergency situations, a quick response can mean the difference between existence and fatality in a matter of seconds.

   In a paper by Lee and Chiu, (2020) it reported that the chances of survival are reduced by 7–10% for each moment that the patient's emergency medical aid is delayed. In the case of a fire, every half-minute delay doubles the fire. One-third of traffic-related fatalities may be averted if emergency services could be rescued sooner. Therefore, speedy rescues have become a highly serious and significant subject. LED equipment was used to display emergency vehicle signs in order to lessen EV (Emergency Vehicle) rescuing latencies. The OBU (On Board Unit) in an EV will interact with the signaling supervisor as it approaches the intersection. The emergency vehicle LED flashing is then activated by the traffic signal controller, allowing passers-by to react quickly to the oncoming vehicle arriving and ready for its appearance. However, because the signal controller does not support emergency vehicle signal pre-emption, EV drivers must still slow down when driving past the junction. To solve this problem, an EVSP (Emergency Vehicle Signal Pre-emption) system was proposed, which would extend the green period or cut off the red period to allow the EV to pass through the intersection more easily. It gives unique loads to various sorts of emergency vehicles, such as ambulances, fire trucks, and police cars, because then the signal manager can prioritize them (Lee and Chiu, 2020).

However, the issue of maximal sensors and minimal green period in traffic engineering is not addressed. Using two control strategies, an improved algorithm was proposed by Lee and Chiu, (2000) that minimizes turnaround time while minimizing the impacts of regular traffic. To reduce traffic impact time, the system changes the traffic condition to EVSP transitioning; after transformation, the system moves to EVSP transition for road traffic adjustment (Lee and Chiu, 2020).

A second study by Osman et al., (2017) was carried out on traffic control for emergency situations. The goal of this study is to minimize emergency service latency while causing the least amount of disruption to regular traffic. This study first establishes three levels of emergency: high, medium, and low.

A fully implemented setup has been devised to change traffic regulations based on the level of emergency, and the ambulance driver will be assigned the shorter way to its location. The emergency vehicle is verified first, followed by the level of emergency. Using these two central traffic controllers, it assigns a speedier route to the emergency vehicle's onboard display.

4. Optimizing the Signal Phase and Timing

   Handling congestion problems at crossings is less expensive when the Signal Phase and Timing (SPaT) is optimized in an effective, smart, and adaptive manner. On the basis of past traffic information records, traditional SPaT systems convey a fixed duration of signal phases at an intersection. A sensitive control system, which uses saved SPaT configurations, to acclimatize signal timings on the basis of real-time traffic conditions, is an improvement over this system. The Split, Cycle, and Offset Optimization Technique (SCOOT) is a control system of traffic that is used to monitor traffic congestion at crossing points. Premised on a heuristic optimization algorithm that generates adaptive SPaT strategies, it constantly alters instant of signals so that the overall number of the lines are decreased in a particular region (Jaleel et al., 2020).

5. Freeway Management Systems

   Various advanced innovations and electronics, such as the variable message sign (VMS), ramp meter, circuit television (CCTV), and traffic signal control system are used to power the freeway management systems.

Conventional freeway systems use fixed sensors including loop detectors and TV cameras to provide navigation services; however, these devices have a number of drawbacks, including high cost, maintenance, and reduced coverage. Mobile sensors and Global Positioning Systems (GPS) have become extremely popular. Because of the ready-to-use infrastructure and wide coverage, mobile-based sensors are much more effective than GPS (Qureshi and Abdullah, 2013).

5. Vehicular Ad-hoc Networks (VANETs)

VANETs are introduced as an important element of ITS. They speed up wireless connectivity from vehicle to vehicle and vehicle to RSU (Road Side Unit) (V2R). The Virtual Traffic Light is a revolutionary innovation that is suggested to virtually communicate traffic data that is normally presented by conventional traffic signals. The plan is to substitute objective gadgets with technology mounted within the automobile that would virtually notify car owners regarding traffic patterns and assist them in self-organizing and managing traffic. By incorporating vehicle-to-vehicle communications and Dedicated Short-range Communication technology, it aids in the reduction of urban traffic congestion. Virtual traffic lights (VTLs) are designed to provide virtual traffic information to the operator within the car in a user-friendly manner that does not jeopardize driver safety (Petrovska and Stevanovic, 2015). VTL standard proactively alleviates traffic congestion using a Virtual Ad-hoc Network (VANET) and vehicle to vehicle (V2V) communication. Every car will have an application unit (AU) containing a database of traffic junctions where the nearest car can construct a VTL.

6. Cooperative System on the Roads

The introduction of collaborative systems allows European highway users to benefit from improved safety, decreased traffic jams, and much more ecologically sound transportation. It is vital to achieving these advantages to having a uniform and standardized form of communication between the various elements of these networks, whether such elements are placed in automobiles, on the wayside, or even in the back-end network. Current European research on systems and applications, interfaces, and protective measures must all be integrated into a single integrative approach. To accomplish this, a group of specialists (dubbed the Architecture Task Force) convened by the European project COMeSafety clarified and promoted the implementation of such a framework. Major European projects on related topics have all participated, including FRAME, COOPERative networks for intelligent road safety (COOPERS), Cooperative Vehicle-Infrastructure System (CVIS), and Safe spot, Secure Vehicular Communication (Rub et al., 2016).

7. Intelligent Transportation Systems

The transportation sector is a legal means of transporting goods from one location to another. Transportation has become increasingly problematic as time has passed, with issues such as high accident rates, traffic jams, traffic &

carbon dioxide release causing noise air pollution, and so on. In some cases, the transportation industry had to deal with reducing the severity of crash-related injuries. Because of this, researchers have combined virtual technologies with transportation to create the Intelligent Transport System. (Qureshi and Abdullah, 2013).The paper by Osman et al., (2017) describes a novel method for reducing traffic congestion. They sought to revive traffic light-based wayside infrastructures with in-vehicle digital indicators that could only communicate with other vehicles. Intersections are critical in our traditional traffic control system, and they are managed by traffic lights, which have high installation, repair costs, and address a smaller numeral of total junctions. Vehicles approaching a junction will choose a commander and obey their directions. As a result, according to this research, no traffic lights will be required to control intersections, reducing traffic congestion in urban areas.

After exploring the components of ITS, management of data in such systems and their application in various parts of world's traffic system, there is need to develop a framework to implement ITS in India's traffic system in order to solve the problems that discussed in chapter 1 of this study. Next chapter includes several case studies of implementing ITS in different cities. Using the information of these cases, a framework will be suggested for India to overcome some of the traffic problems.

# CHAPTER FOUR

## CASESTUDIES

This chapter is about the application of certain ITS strategies in the traffic systems by different countries. The case studies showhow these strategies helped to solve traffic problems in different countries. By using this information and techniques, a framework is proposed in this chapter that will mitigate the congestion problem in India to minimize delay and queue formation.

The infrastructures that enable smart transportation services are critical to the success of intelligent transportation systems for the reduction of traffic congestion and advances in public transportation efficiency. The advancement of cooperative intelligent transportation systems, including transit signal priority (TSP) for public transit, emergency vehicle signal pre-emption (EVSP), and adaptive traffic signal regulation, is one of the key indicators of efficient and sustainable communities. A traffic signal computer, which is the most significant piece of architecture in smart urban transportation, is the key organizer for urban traffic patterns. Three types of traffic control techniques are commonly utilized, based on the traffic assignment approach determined by the traffic management authority: pre-time (predetermined signaling scheme), actuated (activated signal control), or ATSC (adaptive traffic signal control) (Lee and Chiu, 2020).

We may say that now the goal of ITS is to deploy relevant technology to achieve more smart roadways, cars, and customers. Various ITS systems were introduced and used in different countries since the 1980s.

## CASE ONE: TRAFFIC NETWORK STUDY TOOL (TRANSYT) (CEYLAN, 2006)

TRANSYT has been utilized in Chile for the financial evaluation of infrastructures and traffic control initiatives since the early 1980s. Since the mid-1990s, it has also been the primary tool of Santiago de Chile's Area Traffic Control Unit (Ceylan, 2006). TRANSYT is the most valuable networking research development tool for optimizing splits, offsets, and stage sequencing among the current optimization models for area traffic control, as well as the most widely used program of its type.

### Tools and Techniques

TRANSYT is a stage-based optimization program developed by the Transportation and Road Research Laboratory. The hill-climbing algorithm, as well as the periodic flow outline and squad dispersal algorithms, is its main features. A traffic flow model and a signal timing optimizer are the two main components of the model. The traffic model is a mesoscopic time-scan simulation that is deterministic. It generates a cyclic flow pattern of entries at every junction by simulating traffic in a system of pedestrian crossings, which would be used to produce a performance index (PI) for a particular signal timing and staging scheme (Hadi et al., 2008). The entire expense of road congestion connected with the traffic control scheme is measured using the performance index. For all signal-controlled vehicular traffic, it is described as the sum of a weighted linear combination of expected lag and the amount of pauses per unit time. The TRANSYT optimization method is focused on "hill-climbing" (HC), an evolutionary computation methodology that utilizes a trial-and-error technique to discover the ideal signal timings. Two signal setup factors regulate the HC: the offset, which influences junction synchronization, and the stage start and end times. The following is a description of its optimization process. TRANSYT produces the performance index for an initial batch of signal durations that meet all signal operating restrictions for safety purposes. The score of the performance index is then derived by a preset series of steps in one of the signal control parameters. If the computed value for the performance index reduces, implying that the performance of the system is enhanced as a result of the signal setting variables being altered in the predetermined direction, the signal setting parameter is then modified in the same direction by the same series of steps until the computed value for the performance index reduces again, denoting that the performance of the system enhanced of the signal setting variables being changed in the predetermined direction. In turn, this process is repeated for each signal setting variable in the road network. The order in which the various variables are changed can be determined ahead of time (Ceylan, 2006).

A Robertson paper printed for the software's 30th centennial gives a good chronological overview of the TRANSYT programmed since its first version in 1967. According to Robertson, the development of TRANSYT split into two streams in 1978. The American steam continued to develop versions 8–11 and the British steam made further changes to version 7. TRANSYT 8 initiates the modeling of un-signalized junctions and opposed turning, in specific. The financial prices of postponements and stops, as well as energy usage, were among the outputs. There's also a tool to help with cycle time decisions, as well as a way to reduce the likelihood of long lines (Fernandez, 2006).

Outcome of Implementation

Drivers enjoy a more comfortable trip because of the faster traffic flow and fewer stops, which are reflected in their behavior on the roads. When assessing the current state of the system wide speed, it was discovered that vehicles are moving at a very slow speed on the roads, resulting in traffic congestion at intersections. Furthermore, the amount of fuel consumed during the "trip time" is considerable. The reason for this is due to a large number of stops at intersections over the course of the journey. However, with TRANSYT-7F, the system wide speed increased from 6.9 km/hr to 30.2 km/hr as we can see in figure 1. On the other hand, after optimization, the fuel consumption drops from

9805 to 3212 lit/hr as well as a nearly 82 percent reduction in the performance index for the study area, from 2109 DI to 328.5 DI.

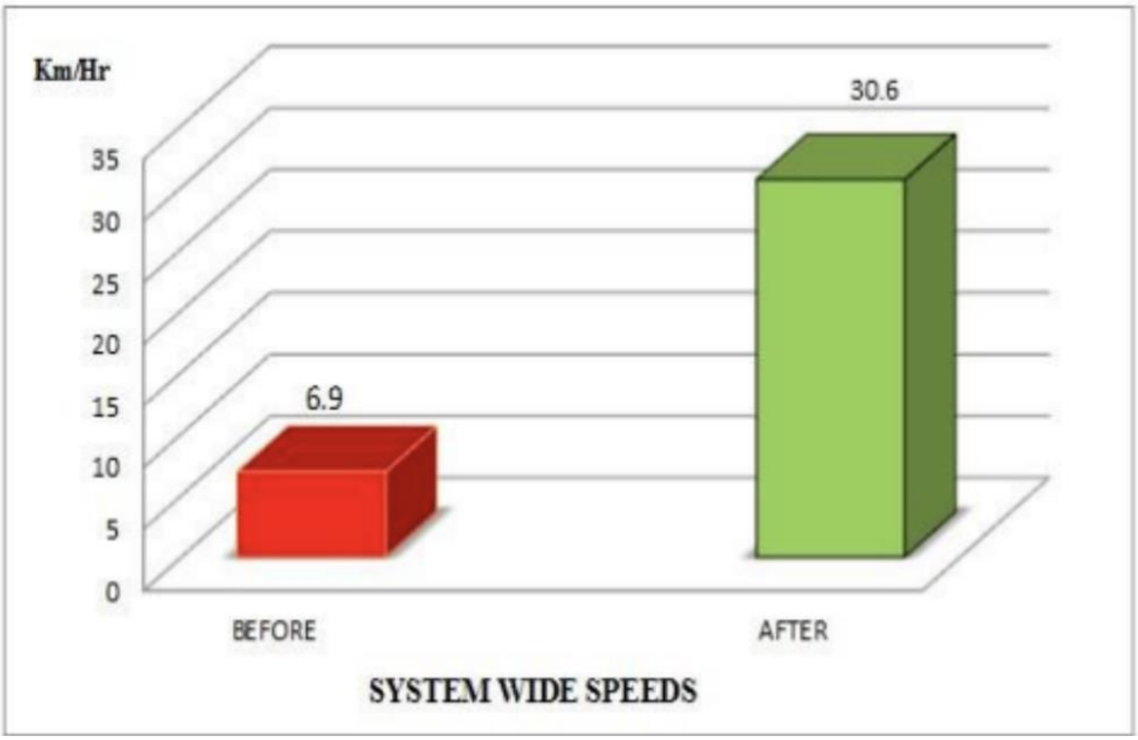


Figure 1. System Wide Speeds Before and After Optimization (Albrka et al., 2014)

The difference in travel time when vehicles are not in impact of the controlled intersection and when vehicles are affected by the controlled intersection is defined as the delay. This delay includes time lost due to slowing down and acceleration, as well as time spent waiting. As a result, intersection delays are evaluated in order to determine total delay or simply stopped delay. Figure 2 shows the fuel consumption before and after optimization.

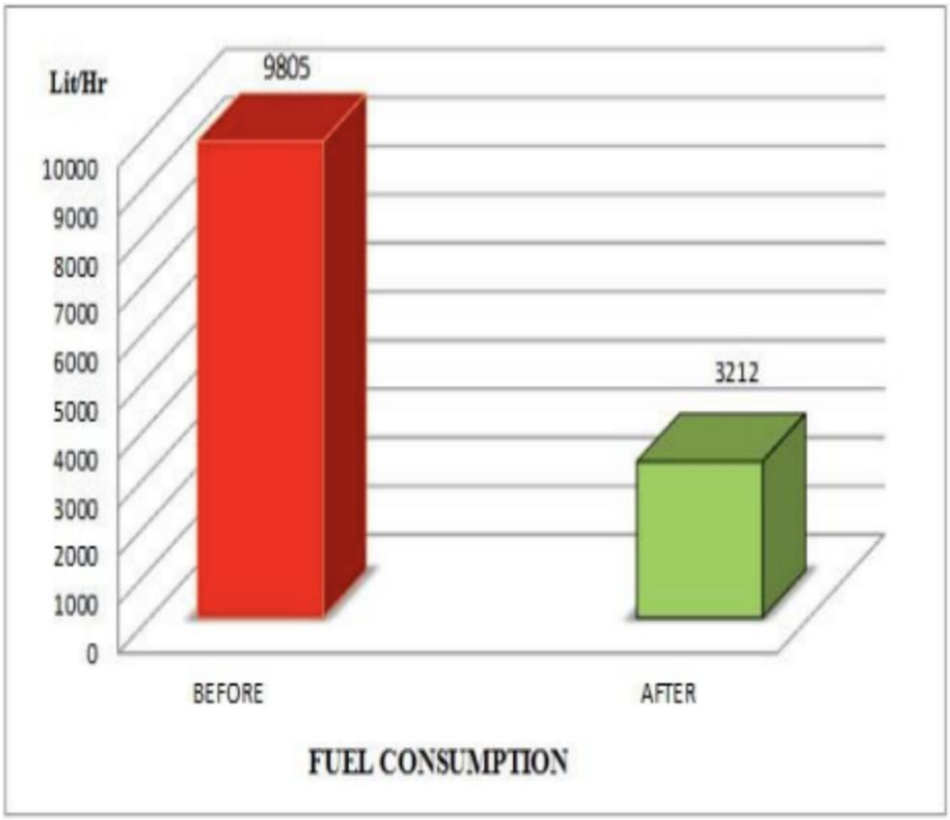


Figure 2.Fuel Consumption Before &After Optimization (Albrka et al., 2014)

## CASE TWO: SPLIT CYCLE OFFSET OPTIMIZATION TECHNIQUE (SCOOT) (MING ET AL., 2015)

The Split Cycle Offset Optimization Technique (SCOOT) was initiated by the Transportation Research Laboratory in the United Kingdom and Sydney University (Ming et al., 2015). Over 200 cities and towns around the world use the SCOOT Urban Traffic Control system. There has been a continuous program of research and development since the first system was installed to provide new facilities to meet the needs of the traffic manager. To provide good responsive control, all control systems rely on timely accurate data from their sensors. This is true for both a police officer on point duty responding to vehicles that he can see and a sophisticated UTC system like SCOOT (Bretherton, 2004). Three key components make up a typical SCOOT system. The central computer system is the first level. The SCOOT Kernel, which is integrated with the UTC software and controls communications to on-street gadget and supplies the operator interface, will be hosted on a central processor. The transmission interface is the second level. It establishes a two-way data transmission network between UTC and on-street equipment. The on-street equipment, which includes local signal controllers, vehicle detectors, and traffic signal lights, is the third level. Signal controllers control signal settings such as least greens, clearance intermissions, and local actuation within a site. Detectors are used to collect the platoons' cyclic data profile, which is required on each link in the network. The most common type of detector in a SCOOT system is inductive loops, but other types of detectors, such as overhead detectors, can also be used.

Tools and Techniques

- To allow coordination, the SCOOT system splits the network into areas, each of which contains a number of junctions that run at the same cycle time, as determined by the intersection with the most critical demands. Some intersections, such as pedestrian crossings or under-saturated intersections may run at half the speed of the regional cycle. Region boundaries are found where coordination is least important, such as across links. The SCOOT database will store all of the data from each link. To complete the task of optimizing traffic control within the network, the system follows a specific procedure.

The system follows the same model as TRANSYT, collecting data from vehicles passing through detectors and converting it into internal units, which are then used to create cyclic flow profiles (CFP) for each link. CFP is a measure of the total one-way flow of vehicles at any specified point on the road throughout every section of the upstream signal's cycle time, as per Robertson. When vehicles arrive at the stop line at normal cruise speed, the signal is colored green or red, depending on the state of the traffic signals. Vehicles are modeled speeding down the link, joining the current back of the queue. The SCOOT model will build a theoretical model of when all of the detected vehicles will arrive at the intersection and join the future queue. The model assumes that vehicles will discharge from the stop line at the saturation flow rate during the green. SCOOT can calculate the delay and stops during each cycle using this model, and then use that information to optimize the objective function.

The data from the system is then supplied into three SCOOT optimizers, which are continually shifting three important traffic management parameters: split, offset, and cycle duration. These three optimizers are used to update these variables continually for all junctions in the network, lowering pauses and queues by synchronizing nearby clusters of signals and minimizing wasted green time at crossings. The functioning of the optimizers ensures that the essential mixture of sensitivity to traffic variations and consistency is addressed in order for coordinating to be preserved.

Every stage change is optimized by the split optimizer. A few moments before every phase change, the SCOOT split optimizer assesses whether it is preferable to accelerate or delay the planned transformation by 1 to 4 seconds, or to leave it untouched. The offset of every node is tuned for each signal cycle. The offset optimizer evaluates whether the PI on streets around each junction can be reduced by shifting the offset 1 to 4 seconds earlier or later after a cycle is completed. When reacting to rapid flow changes, the cycle time for each region is optimized in the same way, by removing or adding 4, 8, or 16 moments of increases once in every five minutes or once every two and a half minutes.

The main goal of SCOOT is to reduce the number of delays and stops generated during an approach. This standard is articulated in the name of a performance index (PI), which is a weighed sum of network delays and stops.

SCOOT was created to administer thick urban networks, as those found in large towns and metropolitans. It also works well in small networks, especially in areas with unpredictable traffic patterns. SCOOT, which has over 200 systems worldwide, is effective in a wide range of conditions, from congested cities like Beijing, London, and Toronto, to small towns or networks like Heathrow Airport. It can be used on networks with fewer than ten junctions and networks with over 1,000 (Ming et al., 2015).

Outcome of Implementation

The relative effectiveness of SCOOT varies by location and schedule of the day, but overall, it is estimated that SCOOT saved about 12% in time when compared to good, fixed-time plans. Because SCOOT does not "age" in the manner that fixed time plans do, it is expected that it will save 20% or more in many real scenarios, depending on the quality and age of the previous fixed time plan and the speed with which flows change.

## CASE THREE: SYDNEY COORDINATED ADAPTIVE TRAFFIC SYSTEM (SCATS)

(PAPAGEORGIOU ET AL., 2007) (ZHOU ET AL., 2010)

The two main transport systems in use across the planet are SCOOT and SCAT. Furthermore, several evolutionary computing methodologies have been presented for the formulation and construction of adaptable light control systems, including such Genetic Algorithm, Fuzzy Logic Control, Neural Networks, Queuing Network, etc. (Zhou et al., 2010). SCATS was created in Australia and is now used in a number of cities around the world. It has two basic levels: the "upper" level, which deals with offset plan selection, and the "lower" level, which deals with junction parameter optimization. The upper level uses historic data to generate offset plans by the time of day, while the lower junction level uses an incremental feedback process based on detectors at the stop lines to optimize green splits, cycle times, and offsets between signalized junctions. SCATS calculates green splits based on the previous cycle's flow, so it isn't fully responsive to erratic arrival flows. It differs from systems like SCOOT and UTOPIA in that it lacks a traffic model and instead estimates departure rates using stop line detectors rather than arrival rates modeled from upstream detectors. SCATS is a modular system that is largely controlled by regional computers capable of handling a large number of intersections, with local controllers containing significant intelligence. A central computer can also be used to boost management capabilities. SCATS is different from many other systems in that the network manager is more involved in the system's setup, i.e., there is no model. With the level of simplicity of a system, the degree of operator understanding increases, resulting in the most beneficial corridor operations (Papageorgiou et al., 2007).

Tools and Techniques

SCAT is made up of one central supervisory PDP 11/34 minicomputer at the control center, eleven remote regional minicomputers (ten PDP 11/34 and one PDP 11/40), and over 1000 microcomputer traffic signal controllers spread across the 1500 km2 Sydney basin. The central database also monitors and evaluates the 150 slave traffic signal controllers in Sydney's CBD, which are controlled by repeating PDP 1 1/40 computers. Every regional computer is in charge of its own territory. Except for the Sydney CBD, which is attached through the use of dedicated cable, communication is via leased telephone lines.

1. Intersection Computer

The traffic signal site's microcomputer intelligence is used to handle strategic data gathered from traffic detectors, construct tactical signal operation decisions, and evaluate detector faults. It also comprises a software process of cable-less link synchronization (with 11 plans) via synchronous clocks, which gives a fail-safe mode of operation without the requirement for dual computer systems.

2. The Regional Computer

As interactive 05 non-interactive systems, every regional computer can manage up to 200 sets of signals. The SCAT system is regulated by regional computers. They carry out real-time signal processing by evaluating detector data that has been pre-processed by microcomputers. For more reliability, the software and database are core-resident. Disk units, on the other hand, are used to save the regional computer program and information for reloading a copy of the data for reloading every microcomputer, including diverse data collected for off-line analysis purposes.

3. The Supervisory Computer

The supervisory computer does not automatically affect traffic flows, but it does have the under given capabilities: it provides traffic and equipment status for error correction and it saves specific traffic information for either a short or long time. Permits central control to regulate the system, subsystem, or intersection, change control attributes, manually override dynamic characteristics, or plot time-distance diagrams by preserving the core picture of every regional computer and reloading the regional computer if needed.

4. The Communication System

A well-suited system of communication was needed to know the complete potential of the divided intelligence system based on microcomputers. As they execute all of the repetitive high-speed operations, the local microcomputers dramatically minimize the time requirement on the communication channels and on the regional computer. They pre-process information and only need data transmissions at critical points, which may happen every 1 to 120 seconds; this is in stark distinction to traditional hardware systems, which need data transmission, every 20 to 100 milliseconds. The capability to load local computers with control attributes such as digital numbers from the regional computer and to shift pre-processed information from local controllers in the digital form required that the communication practice is like traditional computer-to-computer technology. This communication method is entirely software regulated, despite using standard 300-bit/s frequency-shift keying (FSK) hardware.

Outcome of Implementation

In a trial of SCAT on Princes Highway, Newtown, 2.6 km of a Sydney arterial, travel times were reduced by 39.5 percent in the peak period in the morning time, 14.5 percent in the peak business hours, and 32.8 percent in the evening peak period, compared to optimized fixed time, using the Greater London Council's (GLC's) combination method of signal coordination.

In a total of 13225 crashes on arterial roads in Sydney that are under SCAT control, 113 people died and 5800 were injured in 1977-1978. Moore and Lowrie found that signal coordination on arterial roads reduced accidental rate by 20% when compared to isolated operations, with right-angle collisions and pedestrian collisions being the most important reductions.

Signal coordination would save 20-48 percent of stops compared to isolated operation, according to Moore, with peak periods accounting for the higher figures. 1 /40th of a liter of fuel is saved for each stop eliminated on an arterial road. By applying these figures to the arterial roads that will be covered by SCAT, a savings of 37 million liters per year, or 7% of the 525 million liters of fuel used on Sydney's arterials, can be predicted. This accounts for 1.5 percent of the Sydney metropolitan area's total fuel consumption. For the average motorist, this translates to a weekly savings of two liters in the commute to work (Sims and Dobinson, 1980).

## CASE FOUR: REAL- TIME HIERARCHICAL OPTIMIZED DISTRIBUTED AND EFFECTIVE SYSTEM (RHODES) (MIRCHANDANIANDWANG, 2005)

In the early 1990s, the United States, Europe, and Japan launched major initiatives to use communication, control, and computer advances to improve transportation efficiency, reliability, and safety (as embodied in the US Intelligent Transportation System program) (Mirchandani and Wang, 2005).

Sensor data is provided into Rhode stakes from monitors, AVLs, transponders, and other systems. It employs phase timing to "efficiently" manage traffic flow over the transport system by generating real-time traffic flow forecasts. Vehicles approach traffic signals in a variety of ways: single, in groups, or in squadrons. In a pseudo-random way, time of the day traffic patterns, automotive mix, upstream occurrences and slowdowns, the combination of driver kinds (characterized by intent, socio-economic and demographic factors, and driver character), and the spatial setting of the road and paths influence inter-arrival times (the time between vehicles or platoons). To be successful, real-time traffic-adaptive signal control must actively react to incoming streams in order to reduce vehicle pauses and queues as much as feasible.

Tools and Techniques

A traffic-adaptive signal control system in operation is demonstrated by the comments. The network traffic is monitored by detectors. Using a traffic model, the algorithms for predicting current traffic flow and projecting future traffic flow are developed. Using an optimization technique or an optimum-seeking heuristic, it then selects the right plan or phase timing to employ for the following monitoring period. The expectations regarding traffic flow trends, how they calculate traffic flow, and how they optimize signal phasing varies among traffic-adaptive systems in use in the United States, Europe, Australia, and a few Asian countries.

A traffic-adaptive signal control system is used by RHODES:

- Breaks down the traffic control issue into sub-problems that are interconnected in a hierarchical fashion.
- Predicts traffic flow at acceptable levels of resolution, allowing for pre-emptive traffic control (individual vehicles, platoons, transit vehicles, emergency response units, and trains).
- Provides support for a variety of optimization modules for resolving sub-problems.
- Uses data structure, computation, and communication approaches to solve the sub-problems quickly.

This allows RHODES to implement each decision within the context of the corresponding sub-problem's rolling time horizon. RHODES employs dynamic programming (DP) as the primary optimization method. The DP's performance criterion can be anything provided by the system's responsible authority, as long as it's based on traffic effectiveness measures (such as average delays, stops, and throughput).

Essentially, the system performs two processes. The first is estimation and prediction, which uses sensor data to estimate actual network flow profiles and flow propagation. The decision system is involved in the second process, which selects phase timing to optimize a given objective function using DP and decision trees. Minimizing the average delay per vehicle, minimizing the average queues at intersections, and reducing the number of stops is all possible goals. When the objective function takes into account delays, computing the value of the objective function may require assigning a weight to each vehicle to reflect its delay. When a vehicle sits in a line for an extended period of time, its weight increases.

The decision system's control scheme is hierarchical. At the top level, a dynamic network loading (DNL) model includes traffic conditions that fluctuate slowly over time. These features are related to network geometry (possible routes, including closed roads and maintenance), travel need (approximately the number of persons who intend to travel from their origin to the end), and typical route planning by travelers (for example, choosing routes so that travel times on a set of routes from an origin to a destination are nearly equal). Based on these characteristics, the algorithm can predict the traffic on each highway sector on the basis of cars per hour.

Depending on these estimations, RHODES obtains a previous allotment of green moments (the period when traffic lights are green) for every demand of the customers and period (north-south through movement, north-south left turn, east-west left turn, etc.). The system updates the green-time decisions at the middle level, known as network flow control. The system measures traffic flow characteristics at this level in terms of vehicle platoons and speeds. The intersection control at the lowest level selects the appropriate times for phase changes based on the approximate green times. It does so based on observed and predicted individual vehicle arrivals at each intersection.

An estimation module and a control module are included in the control structure for the middle and lower levels. REALBAND is a control module, while APRES-NET and PREDICT is the estimation module. The DP optimization models, such as the CAPRI, are the control algorithms at the intersection control level (Categorized Arrivals Based Phase Re-optimization at Intersections) (Mirchandani and Wang, 2005).

The system takes data from surface street detectors (using whatever technology is available: induction loops, video, etc.), forecasts future traffic flows at various hierarchical levels of aggregation, both spatially and temporally, and generates "optimal" signal control settings that respond to these forecasts. The optimization criterion can be any that the jurisdiction using the system provides, but it must be based on traffic effectiveness measures (average delays, stops, throughput, etc.).

RHODES' highest level is a "dynamic network loading" model that captures traffic's slow-changing characteristics. These characteristics relate to the network geometry (available routes, including road closures, construction, and so on) as well as typical traveler route selection. Estimates of the load on each individual link in terms of vehicles per hour can be calculated based on the slow-varying characteristics of network traffic loads. RHODES can then allocate "green time" for each demand pattern and phase (North-South through movement, North-South left turn, East-West left turn, and so on) based on the load estimates. "Network flow control" is the middle level of the hierarchy where these decisions are made. At this level, traffic flow characteristics are measured in platoons of vehicles and their speeds. The "intersection control" at the third level selects the appropriate phase change epochs based on observed and predicted arrivals of individual vehicles at each intersection, given the approximate green times (Mirchandani and Head, 2001).

There is an estimation/prediction component and a control component at each level of the hierarchy. The RHODES philosophy has three aspects that make it a viable and effective system for adaptively controlling traffic signals. First, it recognizes that recent technological advances in communication, control, and computation make it possible to move data quickly from the street to computing processors (even now, most current systems have communication capabilities that are underutilized), to process this data quickly to algorithmically select optimal signal timings, and to implement a wide variety of control strategies through modern controllers. Second, RHODES recognizes that traffic flow is subject to natural stochastic variations, so data should be expected to vary stochastically (by simply smoothing the data and working with mean values does not make the actual traffic that the system sees smooth, and average as assumed by some real-time traffic control schemes).

Third, RHODES anticipates these changes by explicitly predicting individual vehicle arrivals, platoon arrivals, and traffic flow rates, among other things (Mirchandani and Head, 2001).

Outcome of Implementation

This results in improved transportation efficiency, reliability, and safety. Real-time traffic flow forecasts generated by the system will help in a smooth traffic flow by efficiently managing the phase timings. Moreover, RHODES predicts the arrival time of vehicles and platoons. Subsequently providing an efficient management of traffic system in the United States, Europe, and Japan.

Table 2.Summary of All Four Case Studies

| | **Introduction** | **ITS Tools** | **Usecase** | **Outcome** |
|---|---|---|---|---|
| **Case No 1** | Traffic Network StudY Tool (TRANSYT) | hill-climbing algorithm, as well as the periodic flow outline and squad dispersal algorithms | Traffic model generates a cyclic flow pattern to calculate performance index PI. | Faster traffic flow and fewer stops |

| | | | | |
|---|---|---|---|---|
| **Case No 2** | Split Cycle Offset Optimization Technique (SCOOT) | SCOOT Kernel, local signal controllers, vehicle detectors, and traffic signal lights | Collecting data from vehicles passing through detectors and converting it into internal units, which are then used to create cyclic flow profiles (CFP) | Calculate the delay and stop using CFP and save about 12% of normal timing |
| **Case No 3** | Sydney Coordinated Adaptive Traffic System (SCATs) | one central supervisory PDP 11/34 minicomputer, eleven remote regional minicomputers (ten PDP 11/34 and one PDP 11/40), and over 1000 microcomputer | Upper-level deals with offset plan selection, and lower level, deals with junction parameter optimization. SCATS calculate green splits based on the previous | Eliminate stops and hence save fuel |

| | | | | |
|---|---|---|---|---|
| | | traffic signal controllers | cycle's flow | |
| **Case No 4** | Real- time Hierarchal Optimized Distributed and Effective System (RHODES) | Sensor data, AVLs, transponders, estimation module and a control module. | Estimation and prediction: use sensor data to estimate actual network flow profiles and flow propagation. Decision system: selects phase timing to optimize a given objective function using | Improve transportation efficiency, reliability, and safety |

| | | | | |
|---|---|---|---|---|
| | | | DP and decision trees. | |

Framework to be Implemented in India's Traffic System

The problem of inadequate mass transit refers to the lack of transportation activities to handle traffic and increased rate of congestion which in turn causes queue formation and delay faced by Indian citizens. The volume of traffic also results in environmental loss, for example air and noise pollution. The research aims to formulate the required framework to handle these problems mainly faced by people living in metropolitan cities. To improve the traffic system, the world is moving toward computational tools for an efficient and effective cause. Countries like the United States of America, the United Kingdom, and Sydney, Japan have formulated various strategies to cope with their traffic issues. Based on these strategies and their reliability factor, this study will propose a framework to help improve the traffic system of India.

The framework of the India's traffic system will consist of following strategies based on the solutions explored in the case studies. The problem of delay, duration of incidents occurrence and response, reduced number of fatalities, minimized fuel consumption can be solved by applying Smart SunGuide Operations by generating a Smart SunGuide database. The comprehensive database will include data gathered from the freeway incident management team of this program. It will include the characteristic information like duration of activities of all agencies, tracking of lane and shoulder closures and clearances, information of incident place, the record of climatic conditions, intensity and type of incident, and model of vehicles involved. Traffic performance is expected to improve based on using the database for informed decision making. CCTV cameras, one of the tools of this system, can be used for verification of incidents when reported. They can also be used to help in the detection of traffic law violations. The service patrol program will enable the free service which will reduce the duration of the delay and help the sufferers to get quick medical aid.  The SIRV program will help in dealing with the major accidental issues resulting in a reduced mortality rate.

The performance of traffic signal systems plays a key role in delays and stops at intersection points experienced by travelers. To mitigate such an issue, the strategic adaptation of TRANSYT is beneficial. The implication of two of the components, traffic flow model and signal optimizer, will be carried out. The traffic flow model is a time scan simulation that will create the pattern of entries of vehicles at every intersection by simulating traffic of pedestrian crossways. It will generate the performance index of the timing of signals and operational scheme, which will in turn, provide the congestion rate. Hill climbing is a computational technique used by this program to generate the ideal signal timing. In order to minimize the sum of average queues along with TRANSYT, SCOOT can be used. For a broader level, the use of SCOOT will be appropriate as it is used to monitor thick urban traffic networks. It works on the same principle of signal optimization for reducing the congestion caused by delays. It works on three key principles of measuring cyclic flow in real time, continuous update of the model of the queue, and incremental optimization of signal setting.

The factor of efficiency of the traffic system cannot be compromised. For improved and efficient traffic systems, a structured framework will include the RHODES [NM2] system. The composition of the system is such that the problems of traffic are divided into subcategories and are then arranged in a hierarchical fashion based on the severity of the issues. Prediction of traffic flow is the second step depending on individual and platoon levels for pre-control measures. The use of optimization tools for solving hierarchal problems and the utilization of data and computational approaches to solve problems at a faster rate is the architectural design of RHODES.

The new framework includes designing infrastructure which allows integration of tools and the collected data to be analyzed and implemented in the traffic system.

1. Infrastructure

First, the designing of strategies to solve the problems mentioned in this research study involves the application of the following technologies:

- RHODES
- SMART SUNGUIDE OPERATIONS
- TRANSYT
- SCAT

These technologies or techniques need to be included in one frame such that every one of them will complement each other and are connected and regulated under the same authority of India's traffic system. This needs a complete team including skilled team, analysts, technical engineers, electrical engineers, software engineers, computer programmers, laborers, mechanics, and traffic managers.

The first step is to critically analyze the current traffic state of India, the cities which are overpopulated and need necessary management to highlight the main connecting points or road junctions of various parts of India. This will allow the building of the main hub from where the activities can be controlled. Traffic network analysis will also include analyzing critical control nodes, connected roadways, and parallel roadways for generating flow dispersing nodes and routes. This current demand of the India's traffic network is to be evaluated by using the traffic volume data of the India's traffic system. Traffic control issues will be divided into subcategories and will run in hierarchical fashion.

2. Implementing ITS Tools

The sub-categories need installment of certain ITS tools. They will regulate India's traffic system.

- The installment of CCTV cameras in various corridors will help monitor the traffic situation to tackle emergency situations.
- Sensors at different spacing patterns will help calculate the speed of moving vehicles.
- 511 operation and services patrol programs including a network of ambulances are the main part of this system as safety comes first.
- The installment of the signal timing optimizer will help determine the batch timings of the signal durations that meet all signal operating measures.
- Regional computers will be used to handle a large number of intersections.
- Local controllers containing significant intelligence will be used.
- Supervisory computer will be in place to provide traffic and equipment status for error correction.
- REALBAND is a control module while APRES-NET and PREDICT is the estimation module. This dynamic control module will allocate green signals for different demanding entities by estimating features like speed, possible time taken by vehicle, etc.
- Transit signal priority (TSP) for public transit, emergency vehicle signal preemption (EVSP), and adaptive traffic signal regulation are the primary constituents.

- The traffic model involves an optimization technique that selects the right plan or phase timing to employ for the monitoring period.
- A well-suited system of communication will be used for fast data transmission and software regulation.

3. Data Collection

Data collection is the necessary step in every implementing strategy as the strategy could not be practiced without it. There is a need to establish an information center in which all activities regarding data collection will be carried out. That system will be run by managing experts who monitor all the activities.

The system takes data from surface street detectors using video from CCTV footage. Regional traveler information website includes the data collection of travelers on large scale, a massive database (properties comprising dates and times for all participating organizations' activity, monitoring, tracking, and evaluating performance metrics), and proper optimization methods to provided by the systems responsible authority, as long as it is based on traffic effectiveness measures (such as average delays, stops, and throughput Signal optimization).

4. Data Analysis

This step involves the application of different software and algorithms by software engineers and programming experts to analyze all the information, and then, generating the performance index metric which will be implicated to live ongoing traffic. The hill-climbing algorithm (computation methodology that utilizes a trial-and-error technique to discover the ideal signal timings), as well as the periodic flow outline and squad dispersal algorithms, traffic flow models can be used to produce a performance index (PI) for a particular signal timing and staging scheme. Road congestion connected with the traffic control scheme is measured using the PI.

5. Decision Making

Finally, the decision is being made by keeping in mind the above steps and by linking them all. It also depends on the existing traffic system in India. This strategic analysis will help in updating the current system with these features. The collective implication of RHODES, Smart SunGuide Operations, TRANSYT, and SCAT will be a good addition to India's traffic system as it will make the efficient flow of traffic by reducing delays and congestion, minimizing I incidents, enhancing smooth traffic using signal optimization, and improving the adequacy of mass transit. The graphical representation of the suggested framework steps is shown in figure 3. These steps should be considered by the India's Government and traffic authorities to design a strategy for integration of ITS tools in the current traffic system of India.

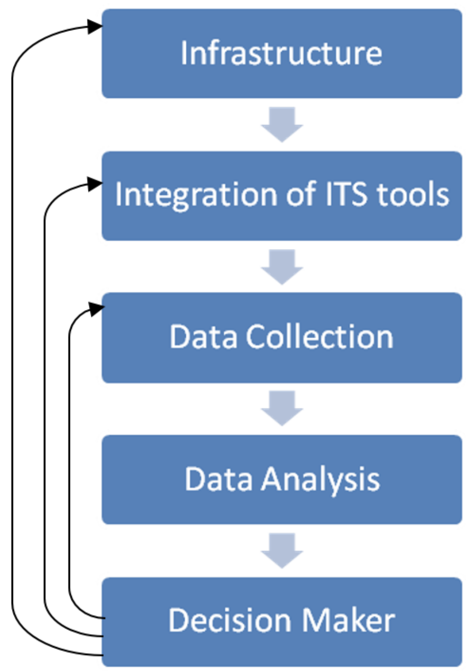


Figure 3. Graphical Representation of Steps Indian Government Has to Take to Design the Strategy Having Integration of Intelligent Transportation System Tools.

Implementing the Developed strategy

In order to implement the strategy, a smart traffic management team will be designed by the traffic department of India. This system includes various components. Distribution Information System, Traffic police station, Traffic Control Server Database, Data processing Center, and Information System Regional Database are five basic centers to be first established. The Intelligent

Transportation System involving strategies like Smart SunGuide Operations, TRANSYT, SCOOT, SCATS, and RHODES are to be implemented by the collaboration of the above-mentioned centers of smart traffic systems.

Utilizing ITS tools and techniques following the suggested steps can help improve the traffic follow on India's road network and solve the main traffic problems that the current system has. Table 3 shows the summary of the traffic problems in India and suggested ITS strategies to deal with such problems.

Table 3. Summary of Problems Indian Citizens Encounter, Integration of Intelligent Transportation System Strategies, their Advantage, Control Strategy and Cost Needed for Application.

| **Traffic Problems in India** | **ITS Model** | **Advantages** | **Control strategy** |
|---|---|---|---|
| Inadequate mass transit options | RHODES | Improve efficiency of transport system | Flow control and signal control |

| | | | |
|---|---|---|---|
| Obstacles on the roads causing accidents | Smart SunGuide Operations | Reduction in secondary accidents. | Reduction in delays and fatalities due to fast response |
| Correct regulation of traffic signals with digital tools | TRANSYT | Reduced fuel consumption, increased travelling speed | Signal timing optimization |
| Traffic delays and traffic congestion mainly at intersections | SCAT | Decreased travel time | Minimize stop and travel time |

# CHAPTER FIVE

# CONCLUSION

The technological developments have brought about much advancement in the traffic systems. The problems faced by Indian citizens such as congestion which serves as the basis of many other traffic problems and environmental issues like traffic jams due to queue formation and air and noise pollution can be solved by the implementation of Intelligent Transportation Systems. Different adaptive traffic signal control strategies like RHODES, SCAT, TRANSYT, and SMART SUNGUIDE OPERATIONS are applied in traffic systems of various countries. The framework designed in this study used the approach of implementing these strategies in a collective manner to increase efficiency and robustness. Using the ITS tools and techniques in the strategy proposed involves the RHODES to improve the flow control and signal control, SCAT to lessen the stops and travel time, TRANSYT as the network study software tools for optimizing splits and for reducing queue formation and SMART SUNGUIDE OPERATIONS for comprehensive analysis after tracking information of lanes and congestions. The management authority of India’s traffic system can apply this strategy to solve issues regarding blockage. This study focuses on including and implementing these strategies in the current transportation system in India for the betterment of the traffic system.

Answer to Research Questions

The following is a summary of this research in answering the research questions:

Research Question 1: What problems do inadequate mass transit options cause? What are the solutions for such problems?

There are too many cars on the road due to inadequate mass transit options or other reasons. This defines the inadequacy of terminals, bus stops, and functionality of the system from the commuters' and operators' perceptions. There is overdevelopment in areas where the mass transit system is already overcrowded, and the road system is inadequate which can be solved through the RHODES strategy if applied to India's traffic system. There are other ITS tools such as TRANSYT, SCOOT, and SCATS that can be used to solve traffic problems.

Research Question 2: What are the obstacles on the road due to blockage and merger?

The obstacles on the road that can cause a blockage and merger include double parking, road work, lane closure due to utility work, road narrowing down, and an accident. Safety issues in the India's traffic system could be solved by applying Smart SunGuide Operations. This involves the management of ITS field devices. Installation of CCTV cameras is the first step to be carried out at major corridors for video surveillance. Installing should be at 1- mile spacing. Next, sensors would be installed on these controlled routes at 12 miles spacing. Moreover, this strategy also requires Direct Message Signs (DMS) mounted at highways that provide drivers with real-time traffic alerts. A traveler information website under the Informational System Regional Database Center of the proposed India's traffic system will include the 511-operation system and regional traveler information website. The nominal free patrol service SIRV program (Severe Incident Response Vehicle) launching is the next step.

During accidents, the SIRV acts as an incident management station, assisting responding authorities and coordinating maintenance of traffic. The Distribution Information System will supervise all information from freeway incident management programmed and is recorded in the massive database of SMART SunGuide. Canalization of the Database will result in concluding performance metrics. Hence, by implementing this strategy traffic safety could be insured in India.

Research Question 3: What are strategies for improving traffic signals with digital tools?

Improvement of traffic signals with digital tools in India is needed which could be solved through the implementation of a strategy like TRANSYT. For TRANSYT to be implied, the formation of a traffic flow model and a signal timing optimizer is the basic step. The traffic flow model will generate a cyclic flow pattern of entries at every junction by simulating traffic in a system of pedestrian crossings, which would be used to produce a performance index for a particular signal timing and staging scheme.

Research Question 4: What are the ways to improve the India's traffic system and reduce the problem of traffic congestion?

Increasing traffic problem congestion in India is necessary to deal with in order to improve India's traffic system. It can be solved through the strategic system known as SCOOT. This strategy involves splitting up the network into areas containing junctions running at the same time, mainly the intersections at busy roads. The factor of speeding up could be achieved in India by applying SCOOT. For this purpose, three components needed to be mounted including a central computer system, transmission interface, and on-street equipment (local signal controllers, vehicle detectors, and traffic signal lights).

Such ITS strategy can reduce the number of delays and stops, and therefore, solve the problem of traffic congestion in India.

The means of determining issues and defining suitable solutions for traffic congestion during peak hours as a consequence of a rise in the number of vehicles of different types necessitates the development of such frameworks where there is the use of modern systems and software to regulate and implement the solution. The evaluation of freeway and urban street systems needs the development of appropriate policies for cities. Congestion on highways, delays, queue formation, accidents, and environmental distortion could be reduced if transportation facilities are designed properly according to the suggested strategies.

## Limitations of the Project

There are various cities in the world that implemented ITS. This research only explored a few of them. There might be other ITS tools that can help solving India's traffic problems. Also, the suggested framework has not been implemented in practice and the results may vary based on the current and future situation of traffic systems in India.

## Future Research

A future research direction can be exploring the traffic data analysis techniques for better problem solving and decision making in India. Also, the suggested strategies can be implemented and then the outcome of implementation can be studies.

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